The BRIDGE

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Editorial

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An Engineering Response to Terrorism

Engineers have a major role to play in preventing or reducing the ravages of terrorism. Ultimately, of course, terrorism must be addressed at its roots: poverty, hunger, political oppression, and economic injustice. But it is unlikely we will ever eliminate it. There will always be new grievances, new hatreds, new causes that will prompt acts of terror and attract people willing to immolate themselves in the commission of those acts. Thus, defensive measures are imperative to thwart terrorism and mitigate its effects.

Engineers can also help put terrorism in perspective, for it is far more destabilizing when perception magnifies the phenomenon's lethality. To avoid overreaction, terrorism needs to be viewed in the context of other threats to our lives, such as natural hazards and accidents in the home, on the highways, in the air, and at sea. For instance, the disasters of TWA Flight 800 and of Swiss Air Flight 111 were not acts of terrorism, but grievous technical mishaps. Terrorism is a risk, but other hazards thus far have killed many more.

Putting in perspective certain acts of terrorism does not diminish the importance of addressing the engineering challenges they pose. Certainly, it does not mean discounting the potential loss of life from chemical or biological attack on a large city's water supply or from a terrorist's nuclear bomb. Mass destruction in urban areas, where so much of the world's population is concentrated, represents a far greater risk than acts of terrorism on a smaller scale, no matter how tragic those may be. Yet, we pay much more attention to the latter.

There are two key areas where technology can aid in the defense against terroristic acts. The first relates to detection of threats. We need to think about surrounding potential targets with networks of sensors. Such systems would provide an immediate signal before a water-supply system is contaminated or a toxic cloud is allowed to diffuse into a subway or building. Developing effective and cheap sensors of all kinds is a major challenge. The ability to reliably sense threats enhances not only the defenses against terrorism, but also basic technological prowess, with potential spin-offs to industry, the service sector, and national defense. A key part of the challenge is to develop policies that encourage the private sector to invest in the development and production of these new technologies.

The second relates to the design of structures. It is time for engineers and architects to get together to devise new structural forms that offer a higher degree of protection not only against terrorist attack, but also against other hazards. There is much to be learned from what happened in Nairobi and Dar es Salaam, in Oklahoma City, and at the World Trade Center. Similarly, retrofitting of existing structures needs to be studied systematically, as it can reduce, at modest or virtually no cost, the potential for damage. What is today an episodic, artisan-like approach can be made much more effective by policies that consolidate the market for retrofitting innovations. Retrofitting as well as new designs have been very effective against fires and earthquakes. There is no reason to believe that the same sorts of improvements cannot help us deal with the threat of terrorism in office buildings, production plants, power grids, pipelines, and harbors.

Engineering has a unique role to play in advocating appropriate policies of this kind, in demystifying terrorism, and in encouraging the public to assess intelligently the issues of cost versus risk. To reiterate, none of these actions will eliminate terrorism. They will, however, help reduce the chance of mass slaughter, help protect important elements of our infrastructure, and—it is hoped—enhance our defenses against destabilizing events.

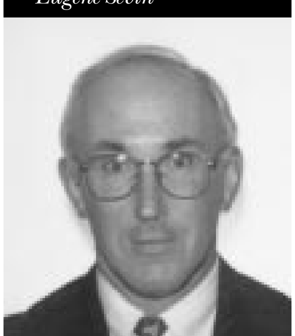
George Bugliarello

Mitigating Terrorist Hazards

Eugene Sevin and Richard G. Little

The engineering community has a critical role to play in finding and promoting rational, balanced solutions to terrorist violence.

Eugene Sevin



Richard G. Little

In 1995, the National Research Council published *Protecting Buildings From Bomb Damage: Transfer of Blast-Effects Mitigation Technologies from Military to Civilian Applications* (National Research Council, 1995). Of the several findings reached by the study committee that prepared the report, two appear particularly germane today. The first, "Attacks against civilian buildings pose an unquantifiable but real threat to the people of the United States," has been borne out by events over the past 3 years. The second, "Blast-hardening technologies and design principles developed for military purposes are generally relevant for civilian design practice," has spawned an ambitious research and testing program within the U.S. government. This effort is being led by the Department of Defense (DOD) and is intended to identify design and construction practices as well as improved materials that would

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produce more durable construction to protect its forces from terrorist attack. However, the extension of this existing body of knowledge of blast-effects on structures, appropriately refined and applied to commercial design and construction practice, also could save civilian lives and reduce property damage.

In the aftermath of the embassy bombings in Africa, the most recent in a series of terrorist attacks against U.S. government facilities or symbols of the United States stretching back almost 20 years, the engineering community can legitimately ask itself whether technology, properly deployed, could have played a role in saving lives, reducing the number and severity of injuries, and protecting property from damage. And, after five devastating bombings in the United States or against U.S. facilities in other countries in as many years, as well as a heightened awareness in both government and industry of the need to protect the nation's critical infrastructure against a wide range of potential terrorist threats, the engineering community is finally coming to recognize both the scope of the problem and the domain of the solution.

Military-force protection within structures is a "critical mission parameter."

Although designing and building structures to withstand the effects of explosive devices has been a topic of active interest and research within the defense community for many years, these efforts have focused mostly on structural and systems survivability, leading to heavily reinforced bunker-type or underground construction where human safety is less a direct design consideration. However, the government also makes extensive use of commercial facilities to house military troops and civilian personnel. Because of the high casualties experienced in the Oklahoma City and Saudi Arabia (Khobar Towers) bombings, force protection—ensuring the safety of personnel within all types of structures—is now considered by the U.S. military to be a critical mission parameter. Addressing the threat of terrorist bombings of commercial buildings requires a solid understanding of how structures are affected by explosions and the ensuing role that the structure plays in both causing and mitigating injuries and death.

The primary objectives of any efforts to improve the blast resistance of commercial buildings should be to minimize the number and severity of casualties sustained in the initial blast; limit the subsequent response of the building; and improve the chances of successful rescue and recovery of the survivors. Given the many possible consequences of a bomb attack against a building, a thorough and detailed knowledge of how people are injured and killed in a bombing is an important step to achieving this objective.

A fuller understanding of blast-related injuries could guide the development of procedures for rapid response and rescue, facilitate planning for emergency medical treatment, and help set priorities for building-related research aimed at minimizing casualties.

Data from a growing number of incidents continues to extend the knowledge of blast-related injuries that has been developed within DOD. For example, the Oklahoma City Health Department conducted a detailed epidemiological study of the bombing of the Alfred P. Murrah Federal Building (Mallonee et al., 1996). The study concluded that the primary cause of death in the tragedy was related to building collapse, and most nonfatal injuries were caused by blast-generated debris, mainly glass fragments. (In the milliseconds following an explosion, much of the glass in a building is transformed into fragments and shards and propelled into the building at high velocity or sucked out of the structure during the subsequent vacuum phase. Many blast-related deaths and injuries are attributable to the body of the victim being penetrated by these missiles.)

Reducing Collapse, Blast Debris Critical

In the case of the Khobar Towers bombing in 1996, the structure did not collapse, and a smaller percentage of the occupants received fatal injuries compared with the Oklahoma City bombing. At Khobar Towers, both fatal and nonfatal injuries were attributed to blast-induced debris, with glass fragments again a prominent cause of nonfatal injury. Although these two incidents do not constitute a comprehensive data set, observations from other terrorist acts and accidental explosions offer compelling evidence that high fatality rates are strongly correlated with collapse of an occupied building and that glass fragments are a leading cause of nonfatal injury. This suggests two critical challenges for the structural engineer: ensure against the progressive collapse of the structure and minimize the quantity and hazards of broken glass and other blast-induced debris. These are active areas of research both here and abroad (e.g., Britain, Israel).

Progressive collapse occurs when the loss of load-bearing capacity (for example, through the destruction of one or more columns, or of load-bearing walls) results in localized structural failure which leads to further loss of support and, ultimately, collapse of all or part of the structure. Redundancy in the design can provide multiple load paths to the ground so that if one or more load-bearing elements are compromised, sufficient capacity remains to support the structure. Better continuity in structural joints between beams, columns, and floor slabs by means of increased reinforcement is one means of ensuring redundant load paths. (See Levy and Salvadori, 1992, for an overview of the phenomena of progressive collapse.) In California, concrete bridge piers have been wrapped with carbon-fiber materials to increase their strength and improve their performance in an earthquake. Applying such composite materials to building columns and slabs in the form of wraps or blankets can also increase the confinement strength of concrete members that are subject to blast loading.

Although there are ways to reduce the tendency of a building to undergo progressive collapse, there is no uniform, straightforward solution to this problem, because our current knowledge of the mechanisms of progressive collapse is incomplete. Following the collapse of an apartment building in Great Britain as the result of a gas explosion in 1968, there was considerable interest in progressive collapse. Although some advances were made in the 1970s, research funding waned in the absence of continuing public concern. Further increasing our understanding of progressive collapse will require physical testing of structures at full and partial scales, coupled with advanced computer modeling.

Research on Glazing Materials

Modern buildings typically contain several tons of glass in the form of windows, curtain walls, and skylights. As noted previously, following an explosion, much of this glass in transformed into hazardous projectiles. An obvious solution to this problem, greatly reducing the size and number of windows, has been implemented by the U.S. State Department in several embassy applications and found to be aesthetically wanting. A more proactive approach is to develop glazing materials that meet aesthetic and functional design objectives but do not contribute to the explosion-induced projectile hazard, either by controlling the nature of the projectile patterns or limiting their range and dispersion patterns.

Glazing materials for security applications are available in many forms. There are several types of glass (e.g., tempered, annealed, laminated), protective window films, and glass substitutes such as polycarbonates. All of these have different performance characteristics under blast loading. This is an active field of research with potentially large payoffs. Recent tests of glazing materials by the Defense Special Weapons Agency (DSWA) and others indicate that suitable glazing materials are being developed that will permit the design of open, attractive structures that reduce the risk to the building's occupants and neighbors. Fiber composite materials also show promise for retrofit applications. When window replacement is not feasible, materials such as Kevlar™ can be woven into blast curtains and drapes to limit the dispersion of blast-generated debris.

"Intelligent building technologies" offer capability to detect and respond instantly to attack.

As the 1995 sarin gas attack in the Tokyo subway system revealed, the use of weapons of mass destruction (WMD), such as chemical and biological agents, by terrorist groups is cause for increasing concern. Although acting in a fundamentally different manner than a bomb, such agents place building populations at considerable risk and require the design of appropriate intervention strategies and systems. These systems could incorporate sophisticated sensor, microprocessor, and control technologies coupled with ultra-high-efficiency filtration devices to react instantly to an attack and automatically initiate an appropriate response. The capability to implement this type of intervention strategy is resident in what is termed "intelligent building technologies" that are available today to monitor and control building systems and equipment. Unfortunately, if the nation's reaction to the bombing threat is any guide, public demand to consider deployment of such technology will await an actual attack utilizing WMD.

Among the earliest practitioners of protective construction were military engineers who were concerned with the design and construction of fortifications on one hand and their destruction and defeat on the other. Vitruvius, the noted Roman architect and engineer who practiced in the first century B.C., included in *The Ten Books on Architecture* (Morgan, 1960) a discussion of siege engines and how they could be both employed and defeated. Several hundred years earlier, Sun Tzu in *The Art of War* (Griffith, 1971) had discussed the siege of cities and how that might be physically accomplished. In fact, the earliest formalized training in engineering was provided at schools such as the École Polytechnique, British Royal Military Academy, and West Point, which were established in the 18th and 19th centuries with the goal of training military engineers as a core part of their mission. Much more recently, the United States sponsored a comprehensive program of research to increase the blast resistance of military structures, largely in response to the nuclear threats of the Cold War. During this period, work was also begun on developing design procedures for structures subject to accidental explosion and attacks from conventional weapons. Although these activities were driven by military needs and concerns, they provided a technical basis to address the threat of terrorist attacks against commercial structures.

Current concern with protecting buildings is an extension of basic military engineering principles.

The current concern with protecting buildings and those they shelter may be viewed as a logical extension of basic military engineering principles. In this light, it is useful to think of a strategy to *prevent, mitigate,* and *respond* to future attacks, if and when they occur, in terms of the integration of four fundamental security design objectives: (1) denying the means of attack; (2) maintaining safe separation of attackers and targets through good planning and architectural practice; (3) providing strong, resilient construction to protect personnel and other key building assets; and (4) facilitating rescue and recovery operations in the event an attack occurs.

The first line of defense is denying access to explosives and detecting and apprehending potential perpetrators before they can act. This is primarily a law enforcement and security function and encompasses a broad range of activities such as explosive-detection devices, research to determine the feasibility of rendering inert common chemicals used in explosives such as ammonium nitrate fertilizer, and tagging explosive materials so that their source may be traced more easily.

The second and third objectives will challenge the engineer to work closely with other professionals such as architects, landscape architects, and security specialists to ensure the attractive integration of site and structure in a manner that minimizes the opportunity for attackers to approach or enter a building. This approach uses such features as landscaped berms that function as blast barriers and traffic controls and bollards disguised as planter boxes that prevent vehicular access. The building itself may have a range of blast-resistant features such as additional steel reinforcement, composite fiber wraps, and high-performance glazing materials. The structure's electrical and utility systems may be placed in protected raceways, critical facilities or operations housed in specially hardened areas or underground, and primary and backup systems located in different parts of the building.

Engineering Role in Rescue and Recovery

It is difficult if not impossible to prevent destructive acts by persons unconcerned with their own safety or survival. Therefore, engineering design also plays a key role in facilitating rapid rescue and recovery of victims in the aftermath of an attack. The speed with which rescue personnel can safely enter and secure a damaged building can reduce the loss of life, mitigate injuries, prevent further damage to the structure, and help restore the building to productive use. These efforts will be aided by computerized building plans, structural analysis programs, and damage assessment models—all tools requiring the active involvement of the engineering professions.

The engineer is also in an excellent position to frame the discussion of the cost-benefit tradeoffs that occur in the risk management process. For example, the enormous cost of implementing safety strategies for the U.S. nuclear weapons program was acceptable given the potential consequences of failure. It was, in essence, risk avoidance regardless of cost.

This level of surety is not practical or appropriate for commercial buildings and civilian infrastructure. An initial risk management strategy might reasonably assume that risk should be avoided only up to the point where the costs incurred are less than the cost of failure multiplied by the probability of the failure occurring. The analysis can treat life-safety issues differently from property damage but the principles are the same. The values that the general public places on various safety and security upgrades can be determined through survey and interview techniques that are more appropriately in the realm of the social scientist.

Addressing Risk through Design

Because people are notoriously unwilling or unable to state specifically what level of risk they will accept, the engineering community does this by default in the design process (or by providing passive restraints like airbags in automobiles). But this is not an issue for the engineer alone to solve. It needs to be elevated to a high level of public discourse. This is particularly true for the private sector. *Protecting Buildings From Bomb Damage* found that financial considerations were a serious barrier to the deployment of blast-resistant practices in commercial structures.

The NRC has been advising the U.S. government on issues of blast-effects mitigation and physical security for over 50 years. *Protecting Buildings From Bomb Damage* was supported by DSWA, which in 1996 was directed by Congress to apply its extensive knowledge of the effects of high explosives and WMD to counterterrorism activities within the United States. In response to this directive, DSWA, through the DOD Technical Support Working Group (TSWG), has initiated a comprehensive research and assessment program to address a number of interrelated issues, including threat analysis methods for federal buildings, blast response of structural components and nonstructural systems, and the value of computer-based tools for design and consequence assessment and management.

More recently, the President's Commission on Critical Infrastructure Protection proposed a national strategy for protecting and assuring critical infrastructures from physical and cyber threats. For the purposes of the commission's work, critical infrastructures are systems whose incapacity or destruction would have a debilitating impact on the defense or economic security of the nation. They include telecommunications, electrical power systems, gas and oil, banking and finance, transportation, water supply systems, and government and emergency services.

The commission's final report (President's Commission on Critical Infrastructure Protection, 1997) identified electronic, or cyber, attacks as a major challenge that will confront the nation in the 21st century. While primarily in the realm of computer technology and electronic security, the systems (and the people who operate them) on which we depend so critically also have physical components that must be protected. Despite the commission's emphasis on cyber attack, recent experience and the considered opinion of antiterrorism experts suggest that attacks against buildings using conventional explosives will, in all likelihood, continue to be the primary tactic of terrorists for the foreseeable future.

NAS-NAE critical-infrastructure roundtable envisioned in administration plan.

Implementation of the commission's recommendations is under way. The Clinton administration has set forth its policy for addressing terrorist acts against the built environment in two recent Presidential Decision Directives, PDD–62 (Combating Terrorism) and PDD–63 (Protecting America's Critical Infrastructures). The former document highlights the growing threat of unconventional attacks against the United States and details a new and more systematic approach to fighting terrorism by bringing a program management approach to U.S. counterterrorism efforts. PDD-63 calls for a national effort to assure the security of the increasingly vulnerable and interconnected infrastructures of the United States. The directive requires immediate federal government action, including risk assessment and planning to reduce exposure to attack. It stresses the importance of cooperation between the government and the private sector by linking designated agencies with private-sector representatives.

The administration's policy for protecting critical infrastructures also calls for the National Academy of Sciences and the National Academy of Engineering to consider establishing a roundtable for bringing together federal, state, and local officials with industry and academic leaders to develop national strategies for enhancing infrastructure security (The White House, 1998).

Separately, DSWA has asked NRC to establish a standing committee to assist the agency develop a blast-effects research agenda and provide recommendations on priority activities. The committee will also recommend appropriate mechanisms for transferring the results of such research to civilian government agencies and commercial engineering and architectural practice. Providing this information to the private sector is viewed as a key step in ensuring that technological advances are incorporated into the building stock. The committee will also provide a forum for enhancing interaction and information sharing among other federal government agencies, state and local governments, and professional organizations and societies. This effort will provide an intellectual basis for the debate of such public policy questions as the level of security protection for different types of buildings (e.g., government vs. private) and whether to consider retrofitting existing buildings for blast effects.

In an open, democratic society, there is inevitable friction between national security needs and personal freedom. In the built environment, these conflicts often manifest themselves in the design and accessibility of our public buildings. Unfortunately, the state of the world as we approach the 21st century requires that a prudent balance be struck between free and open access on the one hand, and security-driven fortresses on the other. Ongoing research is aimed at finding technical solutions to combat terrorism. How and where these technologies are deployed is an issue for a broader debate. At the conclusion of their 1992 book, *Why Buildings Fall Down,* NAE members Matthys Levy and Mario Salvadori posed a question with perhaps unintended relevance to the threat of terrorism: "Will progress in the field of structures reduce the number of failures?"

Although more robust construction in and of itself will not eliminate the consequences of terrorist attacks on commercial buildings, the engineering community has a valuable role to play in finding and promoting rational, balanced solutions to what remains an unbounded threat. Ultimately, the goal should be to develop and disseminate knowledge that will enable the construction of a generation of buildings that are more robust and safer but still aesthetically appealing.

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Preventing Aircraft Bombings

Lyle Malotky and Sandra Hyland

Advanced explosive-detection technologies are beginning to make a positive change worldwide in the quality of aviation security.

Lyle Malotky

Sandra Hyland

Commercial aviation is an integral part of the American economy. More than 546 million passengers flew within the United States in 1997 (Air Transport Association, 1998), an average of more than 1.5 million people a day. An additional 52 million people boarded international flights that same year. Of the world's 10 busiest airports, 8 are in the United States. With a continually growing population of Americans on the move, the Federal Aviation Administration's (FAA's) mission to promote and ensure the safety and security of air travel in the United States proves more difficult every day. In spite of the challenge, the FAA has fostered an air travel system that is safer than virtually any other means of transportation (White House Commission on Aviation Safety and Security, 1996, 1997).

Civil aviation security in the United States is the shared responsibility of the FAA, the air carriers, and the over 450 airports that have scheduled com-

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mercial flights. The FAA is responsible for developing the regulations that ensure security, assuring compliance with these regulations, interacting with international security partners, conducting research to develop technology to improve security, and most recently, purchasing and deploying this advanced security technology. Air carriers are in charge of the in-flight safety of passengers; they accomplish this by screening passengers, baggage, and cargo to prevent explosives, weapons, or other dangerous objects from getting on an airplane. Airports are responsible for providing a safe and secure location for air travel and air travelers. The need to ensure passenger safety while also providing opportunity for air carriers and airports to make a profit results in a dynamic tension among the three parties.

Safety, profit goals create "dynamic tension" among FAA, carriers, and airports.

One area of FAA focus has been the development of technology to detect weapons and explosives contained in passenger baggage or carried on passengers themselves. An increase in hijackings in the late 1960s led to establishment, through the Air Transportation Security Act of 1974 (P.L. 93-366), of the FAA anti-hijacking program. The program spurred the introduction in U.S. airports of the now-familiar metal-detection screening portals for passengers and the X-ray inspection systems for carry-on baggage. In the early 1970s, hijackings were occurring at a rate of more than 1 every 2 weeks. More recently, events such as the 1988 destruction of Pan American Airlines Flight 103 over Lockerbie, Scotland, by a terrorist bomb and the 1996 catastrophic loss of TWA Flight 800 by still-undetermined causes, have added urgency to efforts to develop new technologies that could find a single bag containing explosives among the millions of bags loaded onto airplanes each day.

There are many obstacles to deploying such technologies. For example, the introduction of walk-through metal detectors and carry-on baggage screening X-ray systems in the early 1970s created negative public perceptions, raised questions about the legality and safety of the searches, and prompted concerns about the cost of security-system deployment and use.

Ultimately, the public accepted that the FAA, air carriers, and airports had to take steps to reduce the number of dangerous objects allowed onto airplanes. Questions about the constitutionality of the searches were addressed by subjecting each passenger to the same search criteria and by limiting the scope of the search to only those objects that could be a danger to the aircraft, crew, or passengers.

The initial deployment of screening devices was paid for by the federal government; subsequent purchases have been the responsibility of the air carriers. The expenses associated with operating the devices also falls to the carriers. Standards were established for the X-ray baggage-screening equipment and the walk-through metal detectors to ensure there was no health hazard to either the public or the security work force. The United States currently has a total of about 1,400 walk-through detectors and a similar number of carry-on baggage screening systems. Minimizing operational costs by matching the number of open checkpoints to the peaks and valleys of passenger flow through the day is a challenge for air carriers.

Funding for Advanced Security Technologies

Issues such as initial cost, level of personnel required, and matching personnel to demand must be addressed every time a threat-driven decision is made to deploy an additional piece of technology. To raise the level of aviation security throughout the country and to introduce state-of-the-art equipment, the FAA is again funding the procurement of advanced security technologies. This recent deployment includes automated explosive-detection systems, X-ray systems that alert the screener to threat items, and highly mobile trace explosive-detection devices.

Identifying explosives within a passenger bag has some parallels to classic fault inspection. Such tasks as finding cracks in the walls of nuclear containment vessels, identifying cold-welds in automobile body pieces, or verifying proper shape and depth of contact holes in integrated circuits have driven large and successful efforts to develop inspection techniques and related computer analysis. However, explosives detection is different from these inspection tasks in two important ways: There is no way to know in advance what a passenger's bag should look like, and there is no way to know in advance what a terrorist bomb will look like.

Passengers' bags can contain anything that can be purchased, and a great deal more. And there is no standard method for packing a bag. Convolving the number of items you might expect to find in a passenger's bag with the variety of ways that these items can be arranged within that bag, not to mention the diversity of bags available, leads quickly to the realization that it is not possible to construct a "typical bag" that could be used as a model system. For the "fault" being detected, the FAA has identified a wide range of materials that could damage an aircraft, each of which could take on many different shapes. Many of the techniques developed for fault inspection, especially advancements in multidimensional analysis, are useful in explosives detection. But the most challenging task by far is identifying a property of explosives that can be distinguished quickly and easily from the properties of the benign contents of a passenger's bag.

Bulk and Trace Detection

The goal of passenger and passenger-baggage inspection is to get people and their bags on airplanes quickly, without passing a person or bag that is carrying a threat to the aircraft. As anyone who travels by air today knows, the current system of passenger and baggage inspection is prone to identify belt buckles, steel-shanked shoes, and liquids in suitcases as potential threat objects that warrant further inspection. The result is delay to that passenger, and likely to all who are lined up behind. An ideal weapon- or explosive-detection technology would only identify threat objects, never sounding an alarm for benign materials, and would never miss a detection. The FAA has supported the development of a wide variety of technologies with the aim of identifying methods that promise to move the aviation security system toward that ideal.

Explosives-detection technologies can be divided into two categories depending on what material properties the technology exploits. Bulk detection technologies remotely sense a physical or chemical property of the object under investigation; trace detection technologies physically sample particles or vapor from the object under investigation. Because of their individual strengths and weaknesses, bulk- and trace-detection technologies are developing niche applications, which can be combined to offer more complete detection capabilities.

The remainder of this paper lays out some of the primary technologies for detecting explosives. We will first discuss technologies used to screen checked and carry-on baggage. These systems use enhanced X-ray, thermal neutron analysis, quadrupole resonance, computed tomography, and trace explosive-detection techniques. We will then address technologies for passenger screening. These approaches utilize low-intensity microwave energy, quadrupole resonance, millimeter-wavelength imaging, X-ray backscatter, and trace detection.

The first baggage-screening systems employed simple X-ray attenuation to produce a shadowgraph of the object being screened. This approach works well for high-contrast targets such as handguns, but is not as effective for more subtle targets like explosives. In the early 1990s, devices were developed that could probe using two different X-ray energies. These machines could differentiate materials of relatively high atomic number, such as the iron of a gun, and materials with low atomic numbers, such as explosives, from benign materials. These dual-energy systems are in use today. Typically, the bag being screened is imaged in discrete segments and those segments are automatically evaluated against explosive-threat criteria. Images obtained from bags containing segments that are not clearly distinguishable from the threat criteria can be inspected by a human operator. An important attribute of the dual-energy automated X-ray systems is their high throughput.

Dual-energy X-ray systems able to differentiate potentially dangerous from benign materials.

Throughout the 1980s, thermal neutron analysis (TNA) was explored for the detection of explosives concealed in checked baggage and cargo. Neutrons from radioactive decay or an electronic neutron generator were used. The neutrons react with the nitrogen in commercial and military explosives to produce a high-energy gamma ray. This 10.8 MeV gamma ray is rare and stands out from the background, allowing an estimation of the amount of nitrogen present. Following the downing of Pan American Flight 103, TNA systems were deployed in six different airports. The performance and operational availability of the systems were good, but they were not accepted by the air carriers because of their size, cost, relatively low throughput, and limited ability to detect small amounts of explosives.

So-called fast neutrons, which have been employed in the detection of contraband materials such as drugs, can also be used to detect certain explosives. The type of gamma rays given off as a result of fast-neutron scattering are characteristic of the elements encountered by the beam. Timing the arrival of a gamma ray following the interaction of the fast neutron with a nucleus allows one to determine the element's location in space. Combining the elemental and locational information allows for identification of explosives. Typical commercial and military explosives can be recognized by their characteristic ratios of oxygen, carbon, and nitrogen. Elements present in improvised explosives, for example chlorine and high levels of oxygen, may assist in the detection of explosives manufactured by an individual.

Transmission shadowgraphs can also be done using broad-energy-range fast neutrons. Specific elements in the beam will scatter selected neutron energies. Determining which energies are absent allows one to discern which elements are in the beam line, potentially indicating the presence of explosives. All of these neutron-based detection approaches are in the experimental stage. The pulsed fast-neutron technology is the most mature with an operational prototype under construction.

Quadrupole resonance's detection specificity both asset and disadvantage.

Quadrupole resonance uses radio-frequency radiation to excite the nuclei of selected atoms. Commercial equipment using this technology has been produced and tested on checked baggage and mail. The primary advantage of quadrupole resonance is also its major disadvantage: It is very specific, with discrete frequencies and pulse sequences for each explosive. There are virtually no false alarms, but the optimum pulse sequencing and frequencies must be discovered for each explosive. This can be challenging given the variety of explosives available and the compositional variation in even commercially produced explosives.

In 1994, FAA certified InVision's CTX-5000, an automated explosive detection system. The CTX-5000 takes selected tomographic slices through the object being screened and uses the information to make a decision on the presence of an explosive threat. The system is the only one demonstrated to detect threat quantities across the broad range of commercial and military explosives required for FAA certification. CTX-5000 systems are now deployed in airports in the United States and abroad. The FAA is in the process of purchasing over 50 units for air carriers to use in screening checked baggage. InVision and other vendors are developing systems with higher speed and lower costs.

R&D on an "Electronic Dog"

Experience and research have shown that individuals who are transporting explosives often have traces of the material on their hands and clothing. Dogs, which have very sensitive olfactory capabilities, are capable of detecting the characteristic scent of explosives or other ingredients in explosive formulations. For routine baggage screening, however, the animals present a variety of operational problems, including a short attention span and reduced detection capability when ill.

Scientists have been working to develop an electronic equivalent to the dog since the early 1970s. Several detection technologies similar to those used to screen baggage are able to detect traces of explosives. The current problem with these approaches relates to how the sample is collected. Previous research focused on collecting vapors given off by the explosives themselves. This approach will work for volatile explosives like the nitroglycerin in smokeless powder or dynamite, but it will not work for plastic military or commercial explosives. In the latter instances, intimate sampling may be necessary. Such sample collection could be done using contact paddles or an air shower. Indirect, nonintrusive sampling could be achieved by inspecting a handled object such as a passport or boarding card. Systems under development use either chemiluminescence or ion mobility to identify substances of interest.

Current commercial technologies employ ion-mobility spectroscopy or chemiluminescence detectors. Sample collection depends on vacuuming or wiping exposed surfaces with a glove or other collection medium. The shortfall of current technology is the need for intimate sampling (i.e., direct contact with surfaces that contain the residues of low-vapor-pressure military explosives).

Some of the systems employ very fast (typically 5–10 seconds) gas chromatography to separate the explosive molecules collected from all the other materials that may interfere with detection. Trace explosive-detection systems have been operationally evaluated in airports and are most commonly used to examine electronic items for concealed explosives. The nuisance alarm rate is less than 0.25 percent with a majority of false alarms attributable to the legitimate presence of explosive residues. The FAA purchased over 400 trace detectors and is deploying them in U.S. airports. These systems have been used in airports in Germany and other locations and to protect selected federal installations.

In addition to looking for traces of explosives on a person's body or clothing, several technologies are being developed that can detect threat quantities of explosives concealed under clothing. This type of detection presents challenges different from those of detecting these substances concealed in baggage. People have the expectation of being quickly and efficiently moved through security checkpoints with no perceived or actual insult to their personal privacy, health, or safety.

Low-Intensity Microwave

Low-intensity microwave energy can be used to measure the dielectric constant of objects present on the body. In one approach, an array of sensor elements is rotated around the person being screened, and changes in the dielectric characteristics of the field are measured. If explosives are present, their reflection or absorption of microwaves is recognized, an alarm sounds, and the position of the anomalous object appears on a wire-frame representation of the person. No human interpretation is required, and no actual images of the person being screened are presented.

The detection of explosives by quadrupole resonance is commercialized in a baggage-screening configuration. Quadrupole resonance uses a radio-frequency field to cause characteristic absorption and emission, giving a specific signature for the molecules of interest. Work is under way to adapt the technology to screen people using either a walk-through portal or a hand-wand sensor. The approach uses acceptable levels of electromagnetic fields and does not produce an image of the person being screened.

Millimeter wavelength electromagnetic radiation is given off by any warm body, penetrates clothing, and can be used to form an image. Active systems, where the person being screened is illuminated and objects on the body are imaged, are reaching maturity. One of the problems with this approach is that the image provides considerable detail, raising concerns about personal privacy. Scanning takes a few seconds with a low-intensity source. Passive systems, in which the human being is the radiation source, are in the research phase.

Very low intensity X-rays can be used to image objects on the body. Using the flying spot approach, a backscatter image of the body is taken. Fat and water, which make up most of the underlying surface of the body, are good low-energy X-ray scatterers. Objects on the body show up as areas of increased scatter or, if metallic, as X-ray absorbers. The approach currently requires that an operator interpret an image of the person being screened. The X-ray dose used is equal to a few minutes background at sea level. Nevertheless, the use of X-ray along with the resulting high-resolution image may pose a public acceptance problem.

Advanced explosive detection technologies are beginning to make a positive change worldwide in the quality of aviation security. Automation of baggage screening has the potential to further improve passenger safety and the convenience of air travel. The automated detection of explosives concealed on people is already becoming a reality. There will be challenges during the transition to automated systems. The size, speed, and high capital cost of the automated explosive-detection equipment are significant obstacles. However, the long-term survival of the aviation industry will depend on public confidence, which will be enhanced with the widespread use of highly reliable high- technology security systems.

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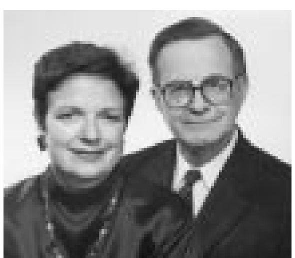
Modern Mutations of Global Terrorism

Glenn E. Schweitzer and Carole C. Dorsch

The triumvirate of high technology, uninhibited criminals, and ready cash have come together to create "superterrorism," a lethal synergy that threatens larger and larger segments of the world's population.



Glenn E. Schweitzer and Carole C. Dorsch are the coauthors of Superterrorism: Assassins, Mobsters, and Weapons of Mass Destruction (Plenum Press, 1998). *Schweitzer is a staff member at the National Research Council Office of International Affairs, and Dorsch is the owner and principal of the editorial consulting firm Cameron Publications Services.*

The near-simultaneous bombings of U.S. embassies in Nairobi and Dar es Salaam in early August sent chilling messages about the new dimensions of global terrorism. These devastating acts underscored the success of terrorists in raising large sums of money to finance and dispatch mercenaries to do their bidding anywhere in the world. They showed that the chemical ingredients for terrorists' bombs can be produced in many countries. They demonstrated that the distinction between terrorism sponsored by states and similar actions carried out by independent terrorist organizations is fading fast. At the same time, the cruise-missile strikes launched by the United States 2 weeks later against terrorist training bases in Afghanistan and a pharmaceutical plant in Sudan suspected of producing ingredients for chemical weapons were a warning to terrorists that national boundaries may not be a protection against retaliation.

Terrorists have plied their trade throughout human history. During recent decades, we have witnessed a spate of aircraft hijackings, the Iranian seizure of the U.S. embassy in Teheran, destruction of other embassies and facilities in the Middle East, and repeated attacks on valuable property and equipment of American companies in Colombia and elsewhere. The bombings at the Murrah building in Oklahoma City, the World Trade Center in New York, and Centennial Park in Atlanta have demonstrated vulnerabilities that put us in the crosshairs of the terrorists' sights—right where we live (Box 1).

As a result, architects now hesitate to design buildings with parking garages. We question every unattended piece of luggage. We wrap security blankets around our national celebrations. In many American cities, we see hazardous-materials teams in space-age garb conducting training exercises. Our Secretary of Defense warns of the possibility of chemical or biological attacks on American soil. Is it any wonder that the nation's paranoia pulse is rising?

The triumvirate of high technology, uninhibited criminals, and ready cash have come together to create *superterrorism,* a lethal synergy that threatens larger and larger segments of the world's population. Although the definition of superterrorism will continue to evolve, we consider it to mean using advanced technologies in the commission of violent acts that cause massive damage to populations and public and private support networks.

A number of events have contributed to the ramping up of terrorism. The political fragmentation of the Soviet Union and the recent near-collapse of Russia's economy have heightened the specter of leakage of missile and nuclear weapons technologies from poverty-stricken Russian institutions. Saddam Hussein has

Box 1

Domestic Terrorism Since the Oklahoma City Bombing

- Midwest, 1994–95: Members of the white supremacist Aryan Republican Army go on a 7-state crime spree, leaving behind pipe bombs as they rob 22 banks from Nebraska to Ohio.
- Vernon, Oklahoma, November 1995: A self-proclaimed prophet and leader of an Oklahoma militia is arrested while preparing a bombing spree against civil-rights offices, abortion clinics, welfare offices, and gay bars.
- Spokane, Washington, April-July 1996: Citing biblical law, three self-described "Phineas Priests" commit bank robberies and bomb offices of the daily Spokesman-Review, Planned Parenthood, and a local bank.
- Atlanta, Georgia, July 1996–February 1997: Pipe bombs explode at Centennial Olympic Park, an abortion clinic, and a gay bar, killing 1 and injuring more than 100 people. The so-called Army of God takes credit for the clinic and bar bombings.
- Phoenix, Arizona, July 1996: Federal agents arrest 12 members of the Viper Militia and seize over 300 pounds of ammonium nitrate—a key ingredient of the Oklahoma City bomb—plus 70 automatic rifles, thousands of bullets, and 200 blasting caps.
- Clarksburg, West Virginia, October 1996: Federal agents arrest Mountaineer Militia members for possession of explosives and for allegedly plotting to blow up the FBI's fingerprint facility, where 2,000 people work. Authorities seize TNT, grenades, and C-4 plastic explosives.
- Kalamazoo, Michigan, March 1997: Federal agents arrest a local militia activist for allegedly giving 11 pipe bombs to a government informant and plotting to bomb government offices, armories, and a TV station.
- Yuba City, California, April 1997: A blast that shatters area windows leads police to 550 pounds of petrogel, a gelatin dynamite, allegedly stored by local militia activists. The explosives are enough to level three city blocks.
- Wise County, Texas, April 1997: Federal officials arrest four Ku Klux Klan members who had planned to blow up a natural-gas refinery and use the disaster as cover for an armored-car robbery.
- Fort Hood, Texas, July 1997: Convinced that army bases are training United Nations troops to stage a coup, an antigovernment group plans to attack Fort Hood on July 4. Authorities arrest seven people and seize machine guns and pipe bombs.

SOURCE: Schweitzer and Dorsch, 1998, p. 272.

shown how a determined leader with financial resources can assemble arsenals of devastating destructive power for use either on the battlefield or in terrorist strikes. In 1995, the Aum Shinrikyo cult—with a war chest of $1 billion—dispersed sarin gas in the Tokyo subway, causing thousands of injuries. With $600 billion of laundered money being cycled through the world each year, any financial constraints that prevented mass killings in the past are fast disappearing (Raine and Cilluffo, 1994). Much of this illicit worldwide fortune springs from drug sales that overlap activities of a number of terrorist groups. And while most terrorists will continue to prefer the "sophistication of simplicity" of the conventional bomb and the pistol, even one group with access to a single weapon of mass destruction could cause massive devastation.

Even one group with access to a single weapon of mass destruction could cause massive devastation.

In our view, superterrorism includes

- the use of nuclear weapons or conventional explosives configured to scatter radioactive material;
- the release of chemical or biological agents, other than minor poisoning incidents;
- the detonation of plastic explosives; and
- cyber attacks on electronic networks that underpin a nation's physical infrastructure.

To understand the full dimensions of superterrorism, we must look beyond the increased firepower available throughout the world. Other developments play a part in ratcheting up the threat:

- Whereas terrorism of the 1970s was largely politically motivated, beginning in the 1980s, terrorism has become rooted more broadly in economic and religious issues.
- Links forged between the forces of organized criminals, drug traffickers, money launderers, and gatekeepers of sophisticated weaponry are growing tighter. More than a decade ago, the Pakistani nuclear program received money laundered through the now-discredited Bank of Credit and Commerce International. Aum Shinrikyo has relied on money from narcotrafficking. In Colombia, where narcoterrorists thrive, bartering of cocaine for Russian advanced conventional weapons has been uncovered. Increasingly, drug money provides fuel for conventional terrorism in Europe, Africa, the Middle East, and South Asia.
- Liaisons between international terrorist groups and their surrogates living in the United States are growing. The bombing of the World Trade Center, a plot to blow 11 American planes out of the skies over the Pacific Ocean, and the attacks in Nairobi and Dar es Salaam exposed the reach of foreign terrorist groups into the United States. Aum Shinrikyo, for example, maintained offices in the United States. Also, according to the FBI, many of the roughly 400 Iranian students attending U.S. universities and technical institutions in 1997–1998 were anti-American Shiite Muslims who provided Iran the capability to launch operations against the United States (Watson, 1998).
- Megacities of the developing world with populations exceeding 10 million will soon number more than 20. Disenfranchised urban youth provide a large recruitment pool for international crime, attracted by opportunities for an amorphous type of revenge or for simply destroying what they cannot hope to have.
- The media provide terrorists with unprecedented global coverage, magnifying extortion demands and helping send political messages.

Availability of Nuclear Technologies

Americans are no novices to the threat of nuclear holocaust. But during the Cold War, the enemy was tangible and the targets reasonably clear. Now, nuclear technologies are becoming available to terrorists. Packing radioactive material around explosives is not difficult; indeed, it was seriously considered by the World Trade Center bombers. And although constructing nuclear weapons with far greater destructive power is much more complicated, such weapons are not out of reach of governments with patience and resources. Even Aum Shinrikyo had plans to develop its own device.

A key chokepoint in constructing a nuclear weapon has been the availability of highly enriched uranium or plutonium, materials that are difficult to produce. But over the years, India, Pakistan, and North Korea have produced such material. Should even 20 kg of highly enriched uranium find its way out of Russia or another nuclear state, a crude nuclear device might well be constructed by a terrorist group with more limited technical and financial resources.

Terrorist organizations have already shown they can overcome the technical difficulties of assembling the ingredients for a chemical attack on a metropolitan area. We would like to believe that the Tokyo subway experience has heightened our awareness of the telltale signs of such plotting, but advance discovery is far from certain. While our police and fire departments have considerable experience responding to chemical accidents, they fear that a deliberate chemical release would be followed by a second attack, using high explosives, aimed at the emergency workers. A number of toxic agents—including some originally developed by military organizations and others routinely used in agriculture or industry—could wreak havoc if released in crowded sports arenas, airports, or convention halls.

Biological agents, while more difficult to handle and package into effective weapons, lurk on the horizon as a danger of untold proportions. The possibility of anthrax spores, plague bacteria, or new flu viruses being injected into air conditioning or heating systems has frightened local officials in every major American city. Detection devices are in a primitive stage of development, and the effects of exposure to biological pathogens may not be apparent for days. Few hospitals are equipped to treat more than a handful of infected patients. The challenges of responding to such incidents and tracking down the perpetrators are clearly complex.

Given the devastation inherent in high-tech weaponry—whether it be a SCUD missile, a crippling electronic communication, or a biological or chemical agent—putting the brakes on superterrorism will not be easy. This task demands special and more sweeping types of preventive actions. The international and national responses to the planning or carrying out of superterrorism must include harsh disincentives: swifter and more severe punishments than those used to deal with less menacing types of violence.

The U.S. government has launched a massive response to the possibility that American soil could soon become a battleground for superterrorism (Box 2).

Box 2

New Counterterrorism Measures Adopted by the Clinton Administration

- Upgraded airport security through new devices for screening carry-on and checked baggage, new technologies for inspecting international air cargoes, additional canine teams, better passenger profiling, and expanded security forces.
- Improved bomb detection through studies of the feasibility of tagging and licensing explosives, increased inspections of explosive manufacturing facilities, expanded training for explosive detection specialists, and assessments of previously encountered devices.
- Increased staff for the FBI to assess vulnerabilities in the physical infrastructure of the country, to improve daytime and nighttime overhead surveillance of suspicious activities (a new Project Nightstalker), and to expand technical capabilities to address nuclear, chemical, and biological threats.
- Better physical protection overseas for American troops in the Persian Gulf region, for senior diplomats, and for diplomatic and trade offices.
- Expanded capabilities of U.S. attorneys and courts to handle additional workloads generated by counterterrorism measures.
- Reinforcement of many U.S. federal buildings, particularly those occupied by law enforcement agencies.
- Contingency funds to respond to unanticipated events.
- Expanded efforts to detect illegal exports of relevance to weapons of mass destruction, to prevent nuclear smuggling, and to respond to nuclear incidents.
- Expanded efforts and improved coordination among intelligence collection agencies.

SOURCE: Schweitzer and Dorsch, 1998, p. 254.

Immediate objectives, as evidenced by the prompt retaliation to the recent embassy bombings in Africa, include broadening the hunt for known international terrorists and hitting them before they hit us—or before they hit us again. Strengthening the international legal framework for containing weapons of mass destruction and for penalizing renegade states will provide an improved basis for decisive intervention. With or without international support, we frequently apply trade sanctions to force rogue countries to comply with acceptable norms of behavior, uncertain of the effectiveness of such economic pressure. Russia, while not a rogue state, is an interesting case. We have cooperated with Russia to help secure its stockpiles of nuclear-weapons-related materials and provide the nation's scientific and technical work force civilian research opportunities. This is so even though some in the West are reluctant to become financially involved with a country that may be backsliding on its commitment to economic reform.

Many ingredients needed for an effective terrorism prevention and response strategy.

U.S. researchers are developing more-sophisticated sensors to detect weapons and dangerous materials and uncover drugs hidden in freight shipments, luggage, and concealed compartments of vehicles. They are also investigating new antidotes to reduce the health impacts of exposures to chemical and biological agents. Meanwhile, many federal agencies are working at a frenzied pace with local officials to strengthen capabilities to cope with a catastrophic incident.

To mount an effective prevention and response strategy, however, other essential ingredients must be added to the mix.

Since terrorists can strike almost anywhere, stronger partnerships between law enforcement agencies and the private sector are critical. Partnerships must include retailers and distributors of dangerous chemicals; owners and operators of power, water, communication, and transportation systems; importers of goods from drug-producing and drug-transit countries; administrators of high-tech training programs that involve participants from questionable countries; officials of financial institutions; and executives of multinational companies that might inadvertently sell dual-use products to unreliable customers.

Additional approaches to intelligence collection and dissemination can increase the odds of detecting terrorist plots in their formative stages and in bringing perpetrators to justice. Intelligence agencies play a crucial role in detecting terrorist activity. Standard intelligence methods—eavesdropping, satellite photography, reports from informants, observations by hardworking gumshoes, and analyses of media reports—are indispensable. However, the number and variety of known groups of concern, let alone the unknown groups, are staggering. Missing just one could have enormous consequences.

Multiple Customers for Intelligence Information

At the same time, no longer are the president, his advisers, and various government agencies the only customers for intelligence information. Many private-sector organizations, local law enforcement officials, first responders, and even ordinary citizens who are likely to face the initial fallout of attacks need information. Most of these individuals do not have security clearances for secret briefings. Higher priority should be given to collecting and sharing open-source information, including improved methods for filtering reliable and unreliable information now flooding the Internet.

If maintaining stability within Europe and on its periphery is the new goal of NATO, then confronting the threat of international terrorism and organized crime is a central agenda item for an organization with both political and military muscle. While terrorists will not tumble European governments, they can cause considerable damage. As Iranian agents have demonstrated in Germany and Algerian dissidents in France, terrorist activities rooted abroad can divert attention from other pressing issues. Of course, in some Balkan countries, terrorism has become a way of life, and drug trafficking and money laundering throughout the continent are often directly tied to U.S. interests. NATO should play a role in better integrating intelligence and analysis functions and should sponsor joint exercises for responding to major international terrorist incidents. These steps should support rather than compete with efforts of law enforcement organizations that consider counterterrorism to be their turf.

Finally, we can no longer ignore the root causes of terrorism—whether they be grievances over access to land and water, frustrations over exploitation of the poor by the rich, or simply lack of alternative forms of employment. We must address the future of deprived populations. Otherwise, succeeding generations will turn increasingly to violence as their only route of escape from lives of subjugation, misery, and unfulfilled expectations. In thinking through such a strategy, we should remember our willingness to spend trillions of dollars to develop and build a nuclear arsenal to protect ourselves during the Cold War. Efforts to combat superterrorism may demand expenditures on a similar scale. What is needed is a multilevel defense and development program designed to ensure our national security. Such an initiative needs to recognize that population growth, hunger, disease, and environmental degradation are integral aspects of national security.

Some warn that the root causes of terrorism can seldom be effectively addressed (Ostrovitz and Schwartz, 1998). They argue that terrorists are motivated by hatred and revenge so deep that nothing will dissuade them from their goals. We must deal harshly with such individuals. But in some cases, root causes can be addressed, as we have seen in Ireland. Also, some will balk at the price tag of a program that attempts to address such widespread and ingrained problems. But the price of inaction is much, much higher.

Collisions with Personal Liberty Inevitable

As we raise our defenses against terrorism, collisions with personal liberties are inevitable. In some American cities, security surveillance cameras monitor the movement of people without their knowledge or consent. Sensitive scanners have been developed that can expose the naked body to public view and even penetrate the walls of lightly constructed houses. The American public is rightfully wary of such intrusions into their lives.

No discussion of modern terrorism would be complete without a commentary on Iraq. No matter how many times U.N. inspectors or U.S. aircraft destroy Iraq's chemical and biological weapons stockpiles, the threat of that nation rebuilding dismantled capabilities will persist. Evidence gathered by U.N. arms inspectors and recently made public confirms that despite Western dismantlement efforts, Iraq lacks only fissile material to rapidly complete construction of one or more nuclear devices (Gellman, 1998). It is imperative to redirect the efforts of Iraqi scientists and engineers to peaceful pursuits.

Clearly, the difficult Middle East peace process must continue. New components of the effort to address weapons of mass destruction more directly should be considered. For example, the region could be declared free of chemical and biological weapons in accordance with the international chemical and biological weapons conventions. In doing so, countries in the zone would accept the principle of complete transparency of their weapons-related activities. As an incentive, they would be given the opportunity to participate in programs that redirect military scientists to peaceful purposes, with active involvement of American and European research institutions.

In some cases, the root causes of terrorism can be addressed.

Similar initiatives, which allow former weapons scientists to join international efforts to address global development problems, particularly in the fields of health and agriculture, are under way in the former Soviet Union. The United States and a number of other countries are funding these activities. The relevance of this experience to the Middle East needs careful examination. However, if the Moslem states are to foreswear chemical and biological weapons, regional arrangements to limit nuclear weapons must also be considered, undoubtedly with a more extended timeline in view of the difficulty Israel will have in giving up any portion of its nuclear arsenal.

In the near term, we must focus on developing an array of defense measures to deter terrorists before they strike. From a nationwide "neighborhood watch" to international partnerships and legal frameworks, a tightly woven web of deterrents is imperative.

At the same time, the only end-game that makes sense is one that redirects the momentum of terrorism toward building rather than destroying the nations of the world—a process that will take decades to accomplish and financial commitments that must constantly be renewed. Economic progress as a result of massive support to deprived nations and groups will never completely drown out the ethnic and religious animosity that fuels much of the terrorism around the world. However, it can provide new incentives to start the process of political accommodation. With superterrorism rapidly becoming a reality, the alternative to seeking new paths to peace is a future in which all societies are doomed to internecine warfare of the worst kind.

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NAE News and Notes

NAE Newsmakers

John C. Angus, professor, department of chemical engineering, Case Western Reserve University, received an honorary Doctor of Science degree from Ohio University in June. The degree was awarded for his work in low-pressure diamond synthesis.

Gordon E. Forward has been named vice chairman of the board of Dallas-based TXI. Forward was formerly president and CEO of Chaparral Steel, a wholly owned subsidiary of TXI specializing in the production of structural steel beams.

Thomas S. Maddock, chair and CEO, Boyle Engineering, Newport Beach, Calif., was selected for induction as a charter member of the Academy of Distinguished Alumni of the Virginia Polytechnic Institute and State University, Blacksburg.

NAE foreign associate **John R. Philip**, fellow emeritus, Commonwealth Scientific and Industrial Research Organization, Land and Water, Canberra, was made an Officer of the Order of Australia. He was cited "for service to the science of hydrology."

Joanne Simpson, Goddard Senior Fellow and chief scientist for meteorology, Earth Sciences Directorate, Goddard Space Flight Center, Greenbelt, Md., received NASA's **Outstanding Leadership Medal** for her "exceptional leadership in the atmospheric sciences culminating in the successful launching and performance of the Tropical Rainfall Measuring Mission (TRMM) satellite."

Ponisseril Somasundaran, director, NSF/IUCR Center for Surfactants and La Von Duddleson Krumb Professor, School of Engineering and Applied Science, Columbia University, has been elected a member of the Chinese Academy of Engineering.

Sheila E. Widnall, Abby Rockefeller Mauzé Professor of Aeronautics, Massachusetts Institute of Technology, was presented the 1998 **Dr. Robert H. Goddard Memorial Trophy** by the National Space Club. The award recognizes her "extraordinary vision and strength of purpose in leading the U.S. Air Force efforts to modernize the space and launch systems of the Department of Defense and enhance the integration of space operations into the military service of the United States."

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The Institute of Electrical and Electronics Engineers (IEEE) recognized several NAE members recently at their annual honors ceremony.

Stephen W. Director, Robert J. Vlasic Dean of Engineering, University of Michigan, Ann Arbor, has been named the 1998 recipient of the IEEE **Education Medal**. He was honored "for contributions to electrical engineering education through innovative textbooks, leadership in undergraduate curriculum reform, and inspired graduate teaching."

Donald O. Pederson, professor emeritus of electrical engineering, University of California, Berkeley, was named the recipient of the 1998 IEEE **Medal of Honor**. He was cited for the "creation of the SPICE Program, universally used for the computer-aided design of integrated circuits."

The IEEE **John von Neumann Medal** was presented to **Ivan E. Sutherland**, vice president and Sun Fellow, Sun Microsystems, Palo Alto, Calif. He was honored "for pioneering contributions to computer graphics and microelectronic design, and leadership in the support of computer science and engineering research."

The **Heinrich Hertz Medal** of the IEEE was awarded to **Chen-To Tai**, professor emeritus, department of electrical engineering and computer sciences, University of Michigan, Ann Arbor. He was honored "for outstanding contributions to electromagnetic and antenna theory and the development and application of Green's Dyadics."

Draper Call for Nominations

The National Academy of Engineering will make its call for nominations for the 1999 Charles Stark Draper Prize in November 1998. All NAE members and foreign associates will be sent a nomination package and are encouraged to participate in this prestigious awards program.

The Draper Prize now carries a $500,000 honorarium. In addition, because of a generous grant from the Draper Laboratory, the prize will now be given on an annual basis.

The award honors engineering achievements that have contributed to the advancement of human welfare and freedom.

The first prize was awarded in 1989 to **Jack S. Kilby** and **Robert N. Noyce** for the development of the integrated circuit. In 1991, the second prize was awarded to **Sir Frank Whittle** and **Hans J. P. von Ohain** for the development of the turbojet engine. The 1993 prize was presented to **John Backus** for his development of the programming language FORTRAN. **John R. Pierce** and **Harold A. Rosen** shared the 1995 Draper Prize for the development of communication satellite technology. In 1997, the Draper Prize was presented to **Vladimir Haensel** for his invention of the Platforming process of petroleum refining.

Any living person from any nation can receive the prize.

For further information, contact the NAE Public Information Office on (202) 334-1628, fax (202) 334-1563, or via the Internet at http://www.nae.edu.

Fourth Frontiers Held

Biomimetic robotic locomotion, tissue engineering, computational materials science, and simulation in manufacturing aluminum parts were some of the exciting topics covered at NAE's fourth Frontiers of Engineering Symposium, held at the Beckman Center in Irvine, California, 17–19 September.

The 100 engineers who attended this year's meeting learned about leading-edge engineering research and technical work in four areas: robotics, biomaterials and optical engineering for biomedicine, advanced materials, and simulation in manufacturing. In the robotics session, for example, participants heard about snakelike robots that could assist in urban search-and-rescue operations following earthquakes; Mars rovers; and cobots, collaborative robots that interact with a human operator within a shared workspace.

Presenters in the bio session addressed such topics as creating living, multidimensional tissues and organs; engineering macromolecular materials that combine the virtues of natural and synthetic polymers; the benefits of optical coherence tomography, a type of optical biopsy that provides images of tissue in situ and in real time; and the development of a confocal scanning laser microscope for the diagnosis of skin cancer without biopsy.

As with past Frontiers of Engineering symposia, one of the high points of the meeting was the after-dinner speech given on the first evening of the symposium. This year's speaker was The Hon. **William J. Perry**, for-

Mike Shaw from Rockwell Science Center raises a question following one of the presentations at the Frontiers meeting.

Linda Griffith, Massachusetts Institute of Technology, speaks about the integration of materials science and cell biology in tissue engineering.

mer secretary of defense and Berberian Professor of Engineering-Economic Systems and Operations Research at Stanford University. He spoke about technology innovation and American leadership. NAE member **Robert H. Wagoner**, professor of materials science and engineering at Ohio State University, chaired the organizing committee and the symposium.

NAE has held the annual Frontiers of Engineering meeting since 1995. The event brings together some of the country's best and brightest engineers from industry, academe, and government at a relatively early point in their careers. All participants are 30–45 years old. Frontiers provides an opportunity for them to learn about developments, techniques, and approaches at the forefront of fields other than their own, something that has become increasingly important as engineering has become more interdisciplinary. The meetings also facilitate the establishment of contacts and collaboration among the next generation of engineering leaders.

NAE was pleased to welcome three Japanese engineers as observers at this year's meeting. One of their objectives was to better understand the goals and format of the meeting in order to start a similar symposium series in Japan. The Japanese visitors also spoke with NAE president **Wm. A. Wulf** about the possibility of holding a U.S.-Japan Frontiers of Engineering symposium, which could take place as early as June 2000 in Japan. This would be the second international Frontiers activity for NAE, joining the German-American Frontiers of Engineering, which held its first meeting in May 1998.

Funding for this year's U.S. Frontiers of Engineering Symposium was provided by the National Science Foundation and the Department of Defense. In February 1999, the NAE will publish a symposium volume containing extended summaries of the presentations. An organizing committee, chaired again by Robert Wagoner, has begun planning for the fifth Frontiers meeting, to be held 14–16 October 1999, at the Beckman Center.

For more information about the symposium series or to nominate an outstanding engineer to participate in the 1999 meeting, contact Janet Hunziker at the NAE Program Office, (202) 334-1571 or by e-mail at jhunzike@nae.edu.

Women in Engineering Website

The National Academy of Engineering has launched a new website as part of a major effort to encourage young girls and women to choose engineering as a profession. Located at www.nae.edu/cwe, the site highlights the achievements of women engineers and provides information on education, careers, and mentoring.

Each week, two outstanding women engineers and their achievements will be featured on the site's Gallery of Engineers. Future components will include a job bank, educational games, and information on engineering fields and academic programs. To ensure that young women learn about the site, the NAE has planned an outreach campaign geared toward universities, professional teaching organizations, and youth outreach groups such as the Girl Scouts.

The website is part of NAE's Celebration of Women in Engineering project, which will conclude with a national summit on recruiting and retaining women engineers, to be held May 17–18, 1999, in Washington, D.C.

Manufacturing Fellows

Twelve predoctoral fellows in integrated manufacturing and processing have been selected following a nationwide competition. The program is sponsored by the Office of Basic Energy Sciences-Engineering Research Program of the U.S. Department of Energy (DOE) and administered by the Fellowship Office of the National Research Council (NRC), under the guidance of the NAE. The goal of the DOE program is to create new manufacturing and processing methods that will contribute to improved energy efficiency, better utilization of scarce resources, and less degradation of the environment. Each fellowship carries a stipend of $20,000 and a cost-of-education allowance of up to $15,000.

The 1998 recipients and the institutions they will attend are: Antonio Alcazar, Stanford University; Alexander G. Cooper, Stanford University; Brad L. Kinsey, Northwestern University; Sabine V. Kunig, University of Washington, Seattle; Mary E. Kurz, University of Arizona, Tucson; Burton H. Lee, Stanford University; Mary A. Mahler, University of California, Los Angeles; Joseph T. Napoli, Washington University, St. Louis; John F. O'Brien, Rensselaer Polytechnic Institute; Barry L. Reed, Cornell University; Pete Retondo, University of California, Berkeley; and Tony L. Schmitz, University of Florida, Gainesville.

A panel of 10 engineers, convened in Washington by the NRC Fellowship Office, selected the twelve fellows. NAE members serving on the panel were **Yu-Chi Ho**, Gordon McKay Professor of Engineering and T. Jefferson Coolidge Professor of Applied Mathematics at Harvard University and **Frederick F. Ling**, Ernest F. Gloyna Regents Chair in Engineering at the University of Texas-Austin. Seventy-two fellows have been selected since the program began in 1993. They attend, or have attended, 25 universities throughout the nation.

The program emphasizes research in integrated, large-scale manufacturing and processing systems. Proposals may address how the processing characteristics of a product depend on its structure and how that structure depends on the starting materials and processing conditions by which the product is created. Related areas of research are unit operations, tooling and equipment, and intelligent sensors and manufacturing systems as they relate to product design. Of special interest are proposals that extend the process-control methods of continuous production systems to manage the discrete parts manufacturing process.

Some of the 1998 award-winning projects include implementing an innovative tooling design to improve the sheet-metal forming process for the automotive industry; developing mold-shape deposition manufacturing to produce wax molds used to gelcast ceramic parts; proposing a simplified approach to the problem of composite repair in the aircraft industry by identifying the integration of initial design, strength requirements, and manufacturing challenges; using a software integrated system to design and manufacture "smart" roofs that, produced in segments, would be uniquely adapted to their daylight, ventilation, and photovoltaic power circumstances.

More information on the research plans of all 1998 U.S. Department of Energy Integrated Manufacturing Predoctoral Fellows, as well as those of the 1997 fellows, can be found on the Fellowship Office home page, http://fellowships.nas.edu.

NAE Calendar of Meetings

12 Oct	Committee on the Impact of Academic Research on Industrial Performance—Information Technology in the Logistics, Transportation, and Distribution Industry: A Roundtable Discussion Anaheim, CA
13 Oct	Committee on the Impact of Academic Research on Industrial Performance—Challenges and Trends in the Logistics, Transportation, and Distribution Industry: A Roundtable Discussion Anaheim, CA
15 Oct	Committee on the Impact of Academic Research on Industrial Performance Enhancing Academic Research Contributions to the Financial Services Industry (Workshop)
	NRC Governing Board Executive Committee
26 Oct	Program Advisory Committee Meeting
30 Oct	Committee on the Impact of Academic Research on Industrial Performance How Can Academic Research Best Contribute to Network Systems and Communications? (Workshop)
1–4 Nov	International Conference on Industrial Environmental Performance Metrics Irvine, Calif.
2 Nov	Committee on the Impact of Academic Research on Industrial Performance—Medical Devices and the University-Industry Connection: Future Directions (Workshop)
3 Nov	NRC Governing Board Executive Committee
3–4 Nov	NRC Governing Board
4 Nov	Steering Committee for the Celebration of Women in Engineering
9 Nov	NAE Technology Education Standards Committee
	NAE Task Group on Election of Officers and Councillors
10 Nov	NAE Finance and Budget Committee
16 Nov	International Technology Education Association Advisory Group Meeting (NAE hosts)
2 Dec	Steering Committee for the Celebration of Women in Engineering
4 Dec	Committee on the Impact of Academic Research on Industrial Performance—Workshop on Enhancing Academic Research Contributions to the Aerospace Industry
	Committee on Membership Dinner
5 Dec	Committee on Membership Meeting
8 Dec	Governing Board Executive Committee

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14 Jan	Steering Committee for the Celebration of Women in Engineering
	Membership Task Group Meeting

All meetings are held in the Academies Building, Washington, D.C., unless otherwise noted.

In Memoriam

WALLACE H. COULTER, 85, former chairman and founder, Coulter Corp., died on 7 August 1998. Mr. Coulter was elected to the NAE in 1998 for the discovery of the method that has become the most widely used for counting and sizing microscopic particles suspended in a fluid.

GEORGES A. DESCHAMPS, 86, professor of electrical engineering, emeritus, University of Illinois, Urbana Champaign, died on 20 June 1998. Prof. Deschamps was elected to the NAE in 1978 for contributions to electromagnetic scattering, microwave engineering, and laser beam propagation.

ROLF ELIASSEN, 85, professor emeritus of environmental engineering, Stanford University, died on 14 March 1997. Dr. Eliassen was elected to the NAE in 1971 for leadership in education and research for the improvement of man and his environment.

CLAIR A. HILL, 88, senior consultant, CH_2M Hill, died 11 April 1998. Mr. Hill was elected to the NAE in 1992 for outstanding service to the state of California, the nation, and internationally in the fields of water resources and wastewater.

HOYT C. HOTTEL, 95, professor emeritus, department of chemical engineering, Massachusetts Institute of Technology, died on 18 August 1998. Dr. Hottel was elected to the NAE in 1974 for contributions in radioactive heat transfer, combustion, and fuels technology.

CHALMER G. KIRKBRIDE, 92, died on 15 June 1998. Dr. Kirkbride was elected to the NAE in 1967 for development of catalytic cracking and petroleum processes.

ROBERT A. LAUDISE, 67, consulting director, Bell Laboratories, Lucent Technologies, died on 20 August 1998. Dr. Laudise was elected to the NAE in 1980 for achievements in growing single crystals and pioneering efforts in the discovery of electronic materials.

M. JAMES LIGHTHILL, 74, honorary research fellow, department of mathematics, University College London, died on 17 July 1998. Sir James was elected a foreign associate of the NAE in 1977 for contributions to aerodynamics and in recognition of an outstanding career in teaching and research management.

ROBERT E. MCINTOSH, 58, distinguished professor, University of Massachusetts, died on 10 July 1998. Professor McIntosh was elected to the NAE in 1997 for contributions to microwave and millimeter wave radar remote sensing and its applications.

WALTER P. MOORE JR., 61, Bullock Chair for Leadership and Innovation, Texas A&M University, died on 21 June 1998. Dr. Moore was elected to the NAE in 1991 for leadership in improving the quality of structures and for creative design.

MORRIS MUSKAT, 92, independent consultant, died on 20 June 1998. Dr. Muskat was elected to the NAE in 1983 in recognition of pioneering work in establishing the basic concepts defining the flow of fluids in the earth and establishing the field of reservoir engineering.

EARL R. PARKER, 85, professor emeritus of metallurgy, University of California at Berkeley, died on 9 May 1998. Mr. Parker was elected to the NAE in 1969 for application of basic concepts of dislocation theory and the theory of phase transformations to the understanding and improvement of the properties of useful engineering alloys.

JOHN B. SKILLING, 76, chairman, Skilling Ward Magnusson Barkshire Inc., died on 5 March 1998. Mr. Skilling was elected to the NAE in 1965 for pioneering building engineer.

CARLOS C. WOOD, 83, retired vice president, engineering, Sikorsky Aircraft Division, United Technologies Corp., died on 14 May 1997. Mr. Wood was elected to the NAE in 1967 for development of aircraft and missiles.

National Research Council Update

Health Effects of Bomb-Related Radiation

A new report by committees of the Institute of Medicine and the National Research Council finds that Americans are at higher risk for developing thyroid cancer after being exposed to radioactive iodine released during nuclear bomb tests in the 1950s and 1960s. The report concludes, however, that this increased risk is insufficient to warrant government-sponsored national or regional thyroid cancer screening.

According to *Exposure of the American People to Iodine-131 from Nevada Atomic Bomb Tests: Review of the National Cancer Institute Report and Public Health Implications,* there is no evidence to suggest that early detection of thyroid cancer through a routine screening program would prolong lives or lead to other health benefits. Instead, the report recommends that the government involve the public and the medical community in designing an information program about exposure to fallout, the risks of developing thyroid cancer, and potential benefits and drawbacks of testing for the disease.

After examining analyses of population data on thyroid cancer and mortality from several national cancer registries, the IOM and NRC committees found little evidence of widespread increases in thyroid cancer related to the patterns of iodine-131 exposure described in the National Cancer Institute (NCI) report. The number of additional thyroid cancers is likely to be at the low end of NCI's estimated range, the report says. Moreover, almost half of the thyroid cancers resulting from this exposure already have appeared.

NAE member **Dade W. Moeller**, president, Dade Moeller & Associates Inc., New Bern, N.C., served on the NRC committee.

Port and Freight Terminal Projects

Freight transportation is critical for nearly every item and service that U.S. consumers purchase. Movement of goods transferred between truck and rail, or rail and water—known as "intermodal" freight transportation—plays a growing role in the nation's freight sector.

Because intermodal freight competes with traditional "single-mode" freight, the intermodal option has spurred efficiency in a large segment of the freight industry overall. The growth of intermodal freight has helped to control the costs of operating highways and to reduce pollution, and it has stimulated employment in some local areas.

A new report from NRC's Transportation Research Board (TRB), *Policy Options for Intermodal Freight,* recommends guidelines to help governments evaluate proposals for public investment in freight facility projects and to select financing arrangements. The report also examines government policies beyond infrastructure investment that affect freight efficiency, including regulations and operating practices for public roads, ports, and waterways.

NAE member **Richard C. Larson**, Massachusetts Institute of Technology, served on the TRB committee.

Publications of Interest

The following publications result from the program activities of the National Academy of Engineering or the National Research Council. Except where noted, each publication is for sale (prepaid) from the National Academy Press, 2101 Constitution Avenue, N.W., Lockbox 285, Washington, D.C. 20055. For more information or to place an order by phone, contact the NAP at (202) 334-3313 (in the Washington metropolitan area) or (800) 624-6242 (outside the Washington metro area). (*Note: Prices quoted by the National Academy Press (NAP) are subject to change without notice. Please add $4.00 for shipping and handling for the first book ordered and $0.50 for each additional book. Add applicable sales tax or GST if you live in CA, DC, FL, MD, MO, TX, or Canada.*)

Advanced Technologies for Human Support in Space. Argues that NASA research related to living and working in space would benefit from better internal evaluations and periodic external reviews. Recommends research to determine optimal crew schedules, workloads, distribution of tasks, and training procedures for long missions. Hardbound, $35.00.

Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering. Third in a series on science and engineering education and careers, this guide features a list of the fundamental practices of a successful mentor, vignettes that illustrate good and bad examples of mentoring, advice for new mentors, and pointers on the different kinds of guidance needed by undergraduate, graduate, and postdoctoral students as well as junior faculty. Paperbound, $7.95.

Containing the Threat from Illegal Bombings: An Integrated National Strategy for Marking, Tagging, Rendering Inert, and Licensing Explosives and Their Precursors. Until better technologies can be developed, recommends voluntary commercial controls and regulatory action, together with wider use of present methods for detecting explosives, to reduce the threat from illegal bombings. Hardbound, $45.00.

Engineering within Ecological Constraints. Presents a rare dialogue between engineers and environmental scientists about the many technical and legal challenges of ecologically sensitive engineering. The volume looks at the concepts of scale, resilience, and chaos as they apply to the interactions between ecological systems and technology. Hardbound, $37.95.

Exposure of the American People to Iodine-131 from Nevada Atomic Bomb Tests: Review of the National Cancer Institute Report and Public Health Implications. Finds a higher risk of thyroid cancer among those exposed to radioactive iodine during nuclear bomb tests but says there is no evidence that health benefits would be achieved by instituting government-sponsored screening efforts. Hardbound, $34.00.

Foreign Participation in U.S. Research and Development: Asset or Liability? Discusses the causes and scope of foreign involvement in U.S.-based R&D and the associated costs, risks, benefits, and opportunities of this trend. Paperbound, $29.95.

Maximizing U.S. Interests in Science and Technology Relations with Japan: Committee on Japan Framework Statement and Report of the Competitiveness Task Force. This congressionally mandated report examines the U.S.-Japan science and technology relationship and offers recommendations on what the U.S. government, industry, and research institutions should do to maximize the benefits of future interactions with Japan. Hardbound, $28.00.

Policy Options for Intermodal Freight. Recommends guidelines to help governments evaluate proposals for public investment in freight facility projects and to select financing arrangements. Copies available through the NRC's Transportation Research Board, (202) 334-5519.

Risk Assessment and Management at Deseret Chemical and the Tooele Chemical Agent Disposal Facility. Finds that two recent assessments of the potential risks involved in storing and disposing of chemical weapons stockpiled at Tooele, Utah, are accurate and based on sound methodology. Urges that similar assessments should proceed at the seven other sites in the continental United States where chemical agents and munitions are stored. Paperbound, $15.00.

Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology. Asserts that major changes in U.S. transportation policies, technologies, and practices may become necessary to reduce motor vehicle emissions and the subsequent risk of global warming during the next century. Copies available through the NRC's Transportation Research Board, (202) 334-3214.