

THE ROLE OF PULSED POWER IN INTERNATIONAL SECURITY AND COUNTERTERRORISM*

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Abstract

Advanced technologies, including pulsed power, play a vital role in preserving domestic and international security while working to counter terrorism. However, technology is not a universal sword and shield against terrorism. Technical countermeasures to terrorist activities must be cost effective and applied with some wisdom about terrorist objectives. The following paper features insightful perspectives on terrorism and terrorist organizations. The role of science and technology, as a tool against terrorism, is also discussed and examples of applied pulsed power technology are presented.

I. INTRODUCTION

On September 11, 2001 (911), a shocked nation watched as terrorists flew two commercial aircraft into the World Trade Center, one into the Pentagon, and crashed one into a field in Pennsylvania. Since that day, life in America changed forever and, since that day, all of us have witnessed a number of world-changing events: Letters laced with anthrax began arriving in several U.S. cities on October 5, shortly following the World Trade Center attack. By October 19, U.S. and Coalition Forces severely damaged the Al-Qaeda terrorist organization by attacking Taliban strongholds in Afghanistan. Warfare resumed on March 19, 2003, with U.S. and Coalition Forces engaging and defeating Saddam Hussein's regime in Iraq.

Despite swift and decisive outcomes in both Iraq and Afghanistan, the world remains an uncertain place. The threat of further terrorist attacks leaves people fearful about the future and with good reason: On January 9, 2003, North Korea withdrew from the International Arms Treaty, "restarted" their nuclear programs, and reported to the world that it possesses nuclear weapons and threatens to use them. As recently as May 12, suspected Al-Qaeda terrorists bombed a target in Saudi Arabia and again in Morocco on May 16. Continued terrorist violence and the threat of large-scale conflicts are political forces that shape national agendas in the U.S. and other western nations.

As nations worldwide build defenses against global terrorism, many are relying on advanced technology for additional security. Science and technology, if applied correctly, can help detect terrorist activities, deny them sanctuary, and destroy their organizations. Applying that technology correctly requires an understanding of the origins and objectives of today's terrorists.

II. COMMENTS ON TERRORISM: THE NEW FACE OF WAR

Our legal system defines "terrorism" as premeditated, politically motivated violence perpetrated against noncombatant targets by sub-national groups or clandestine agents, usually intended to influence an audience [1]. Within this definition, violence perpetrated by a sitting government against its people would not be terrorism. The same could be said for violence conducted by a national force against citizens of another country or against the forces of another country. Of course, these two examples could constitute murder, genocide or war crimes but, by the above definition, they would not constitute terrorism.

A. Origins of Terrorism

As deep into written history as we can look, terrorism, within our working definition, has been part of the human experience. Biblical stories such as Samson's tying firebrands to the tails of foxes and sending them scampering through the grain fields of the Philistines might be an example of terrorism. However, exactly when terrorism became part of our collective heritage is uncertain. The motive for this strategy of violence can be ascertained. Terrorism originated when an individual or group of individuals had unrealized but passionately sought objectives that far exceeded their ability and potential to achieve them by accepted means of behavior. This origin leads to the view that terrorism is violence committed against noncombatants to influence others in order to achieve an otherwise unachievable result. One sage described, terrorism is the loud cry of the otherwise unheard. Moreover, dialogue is essential as is the rooting out of those factors that encourage terrorism as a means

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14. ABSTRACT Advanced technologies, including pulsed power, play a vital role in preserving domestic and international security while working to counter terrorism. However, technology is not a universal sword and shield against terrorism. Technical countermeasures to terrorist activities must be cost effective and applied with some wisdom about terrorist objectives. The following paper features insightful perspectives on terrorism and terrorist organizations. The role of science and technology, as a tool against terrorism, is also discussed and examples of applied pulsed power technology are presented.					
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for achieving change. However, terrorism can never be elevated above what it really is: the wanton murder of innocents by criminal sociopaths. Understanding the origins of terrorism and its true nature allows us to define its fundamental characteristics and vulnerabilities.

B. Five Perspectives on Terrorism

First, as indicated, terrorism is a strategy of frustration and weakness and not a strategy of the strong. One might think otherwise from listening to the evening news. The 911 attack is frequently compared to Pearl Harbor and sometimes Al Qaeda is placed in a threat profile comparable to the Third Reich. Obviously, both conclusions are wrong. Pearl Harbor was a surprise attack carried out with aircraft far superior to anything we had at the time representing a massive projection of military power, and executed with great precision and discipline. Over the next five years, we would expend thousands of lives and unimaginable treasure locked in mortal combat with the Imperial Japanese Armed Forces all across the Pacific. A few terrorists armed with box cutters attacking innocent passengers who had been conditioned not to resist was a horrendous act of savagery, but it was no Pearl Harbor. As to placing Al Qaeda in the same threat league as the Third Reich, again we need a lesson in history. In spite of the international sanctions, the Third Reich enjoyed the second-largest industrial base on earth. In a number of technical disciplines such as rocketry, organic chemistry, physics, and metallurgy, it led the world. The technical capabilities of German military equipment, particularly in armor, aircraft, and artillery, exceeded that of any potential challenger. In the Wehrmacht, 10 million highly trained and motivated troops could be brought onto the field in mechanized and armored transports and provided air cover by the Luftwaffe. Another 13 million Heer reservists could be called upon as needed. By comparison, Al Qaeda is a weak, ineffective, gaggle of cowards, religious extremists, and malcontents. Even so, we still have to worry about Al Qaeda and other cabals of hate. They can cause severe damage particular if they acquire an improvised or stolen nuclear weapon. Terrorists might deploy infectious pathogens such as smallpox. Obviously, such an attack could be counter productive because, once released, the disease very likely would decimate the very populations the terrorists inveigh to represent. The use of chemical weapons also would be destructive, as would the release of certain classes of industrial chemicals. It is for that reason that, in the war against terrorism, we can most effectively spend our resources and efforts by focusing on such low probability but high consequence threats that terrorists could employ.

Second, controlling the agenda and shaping the response is the real strategy of terrorists. Since the terrorists lack the necessary strength to defeat their target in a classical military sense, they use violence to trigger a predictable response on the part of the target. If successful, the terrorist act will precipitate a response that

in itself constitutes the real attack against the target. For example, the terrorists cannot bring down our airline industry *per se*. However, they can cause us to have anxiety against flying even though the chance of being seriously injured or killed in a commercial aviation accident is about 0.00003% and to initiate security provisions that together push the industry over the precipice of bankruptcy. Similarly, the terrorists cannot destroy our society even though they may detest its opulence and freedoms. However, they can cause us to respond in a way that causes us to forego our First Amendment Rights and the openness and enjoyment of our life style as a cost of being secure. In that case, we have become the destroyer of our way of life and not the terrorist. Therefore, it is imperative that every action we take in response to terrorism be evaluated to ensure that we are not moving in the very direction planned by the terrorist. Technologies can play a significant role in helping achieve this imperative.

Third, compared to other dangers we face, terrorism is an abnormal and relatively rare occurrence. On 11 September 2001, nineteen terrorists hijacked four airplanes and flew two into the World Trade Center, one into the Pentagon, and one – because the brave passengers intervened – into a field in Pennsylvania. The horrendous death toll included 33 crewmembers, 214 passengers, 125 in the Pentagon, and over 2,000 dead and missing in New York. However, in that same year, 42,000 Americans died in traffic accidents and over 400,000 were injured. Fifteen thousand people were murdered in our streets and homes. In the anthrax letters of 2001, five people unfortunately died. In that year, 20,000 Americans died of influenza and 100,000 were hospitalized with serious flu-related complications. The anthrax-laced letters were just a few among the 20 billion pieces of uninfected mail handled by the U.S. postal service during the same month. The point is that, while terrorism is a threat to be concerned about, we need to keep that threat in the proper perspective.

Fourth, terrorist cells are highly disciplined and rational. We often think of terrorist as mad suicidal bombers. At the point of the spear, that image is not that far off the mark. Terrorist organizations can always find dupes somewhere, get them pumped up on hashish or inflammatory rhetoric, promise them rewards in the life to come, and have them drive an explosive laden truck into a building thereby proving Darwin right. At the controlling levels within terrorist organizations, however, actions are rational and it is the desire of most senior people in terrorist organizations to die at an advanced age in their beds. It is for that reason that deterrence, with the backing of technologies that can predictably find and incapacitate the senior controllers, could be an effective tool in discouraging terrorism.

Finally, terrorists have no defense but simplicity, secrecy and stealth unless they are given sanctuary.

Terrorists make their weapons out of materials that could be purchased in most hardware stores. Shrapnel is derived from nails and screws. Poisons are derived from materials we see everyday. Bomb cases are made from pipes. The 911 hijackers used box cutters. With help from state sponsors, they have been known to mold high explosive that they must get from others into common articles to avoid detection. William Reed used his shoe as a bomb and his shoelace as a fuse that fortunately did not light because, in his panicked state, he had soaked it with his urine. Had the bomb detonated in this situation, Mr. Reed might have found the trip to Paradise problematic. As Mohammed reminded his followers, “The deceased person is being tortured in the grave for a great thing to avoid, it is for being soiled his urine” [2]. Because terrorist operations operate from weakness, secrecy and stealth are essential to their success. A ‘found-out’ terrorist is a dead or incarcerated terrorist. Of course, obtaining sanctuary is an absolute requirement if terrorists hope to survive, operate, and succeed. The Aum Shinrikyo enjoyed sanctuary in Japan by hiding within the Japanese laws that made religious organizations “off limits” to police surveillance. That organization used our lax immigration laws as a sanctuary to train pilots in South Carolina that would have dispersed anthrax and sarin nerve agent over Japanese cities. Al Qaeda used that same sanctuary and other flight schools to train the 911 hijackers who carried out the one-way missions planned in the Afghani sanctuary provided by the Taliban.

III. TECHNOLOGY IS ADAPTING TO THE WAR ON TERROR

A. Pulsed Power is Changing for the Smaller

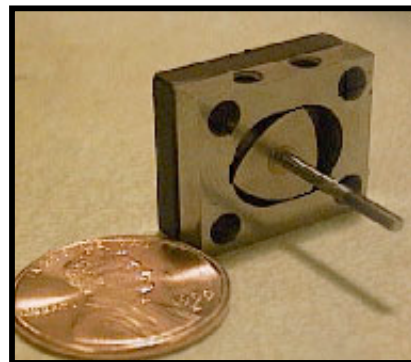
The U.S. and other countries are responding to global terrorism by engaging the threat head on, which means an active program of terrorist surveillance and confrontation. Technologies that are capable of meeting terrorism directly must be mobile enough to join the conflict, be it in the street or on the battlefield. Pulsed power technology is adapting to this challenge by leaving its historical roots – large, single-shot machines – in favor of ultra-compact, portable devices that produce pulses at a high repetition frequency.

For some time, pulsed-power devices have been steadily shrinking to meet market-driven demands for ever-smaller switch-mode power supplies, solid-state lasers, and other compact products. While pulsed power systems are shrinking in volume they are also growing in performance. Increases in peak power, average power, efficiency, repetition frequency, and reliability have all come about due to recent advancements in solid-state switching and high-energy-density components [3]. Ultra-compact pulsed power may be light enough to transport but to be truly portable requires the equipment to be unplugged from available utility power.

B. Tiny Portable Power

The Defense Advanced Research Projects Agency (DARPA) is sponsoring the development of radically small power sources for mobile applications. The program is called MicroPower Generation (MPG) and a list of current MPG projects may be found at <http://www.darpa.mil/mto/mpg/>. The principal aim of the research is the production of micro-scale power sources to replace batteries in a battlefield environment. Most of the effort consists of tiny machine prototypes that combust liquid hydrocarbon fuels to generate power on a very small scale. Other MPG work includes thermoelectric generators, micro hydrogen fuel cells, direct-methanol micro fuel cells, and radioisotope-based electric generators.

Interesting work is underway at the University of California at Berkeley where researchers are working to make a motorized chip, measuring 200 mm x 180 mm x 30 mm, that burns a liquid fuel [4, 5]. The chip not only contains the motor and generator, but also the power conditioning, engine controls, compressed-air starter, fuel reservoir and output contacts. The chip uses a 2.4-mm diameter Wankel engine that is under construction and is expected to generate about 100 mW of electric power. A larger 10-mm diameter “mini-engine,” shown in Figure 1, has already generated about 4 W of electrical power.



Carlos Fernandez-Pello photo

Figure 1. A 10-mm diameter Wankel engine developed at the University of California at Berkeley.

Fuel cells are getting smaller, too. At Case Western Reserve University, researchers in the Chemical Engineering Department are developing a metal-hydride fuel cell on a chip. The device measures 2 x 2 cm and will generate 10 times more power than a state-of-the-art, thin-film battery [6].

C. High Speed Turbo Alternators for Prime Power

A good candidate for portable prime power is a high-speed alternator coupled to a small turbine jet engine. The combination is known as a turbo alternator. A commercially available Turbogenset device produces 50 kW from an alternator that is about the size of an

automobile's alternator. The turbo alternator shown in Figure 2 is a small, 2-kW device that spins a permanent-magnet alternator at 140,000 rpm. The assembly weighs only 1.8 kg (4 lbs).

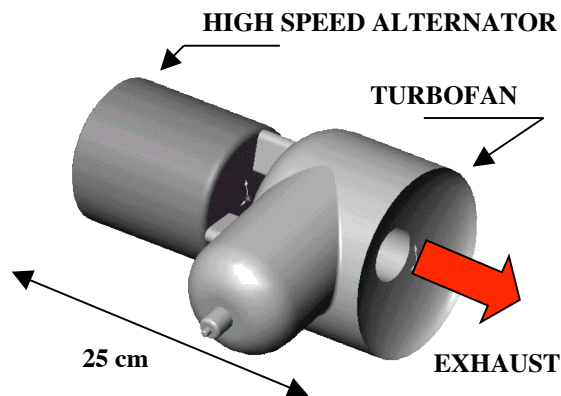


Figure 2. Illustration of a 2-kW turbo alternator from M-DOT Aerospace [7]

D. New Thermoelectric Converters

Scientists at Research Triangle Institute (RTI) International have recently developed a thermoelectric converter that is 2.4 times more efficient and 23,000 times faster than available thermoelectric devices [8]. The device converts thermal gradients into electricity, such that current flowing in one direction may deposit heat to a surface while current flowing in the opposite direction will remove heat from the same surface. For example, one of these small devices can cool a surface from room temperature down to minus 7 degrees centigrade – a difference of 32 degrees – while available thermoelectric devices make only a 3-degree difference. Just one square centimeter of this thermoelectric material can transport 700 W of heat [9].

E. Pulsed Power Without the Power Cord

The new source technologies described above will soon make ultra-compact pulsed power a truly portable technology. The tiny chip-on-board power sources are electrically isolated and well suited to power control systems in high-voltage applications. The turbo alternator technology is small, lightweight, robust and able to meet high average power demands for as long as there is fuel to burn. Any heat generated by the pulsed power system may be recovered with the remarkable thermoelectric converters described above.

IV. EXAMPLES OF APPLIED PULSED POWER

Technology contributes to the War on Terror in the following five areas:

Nonproliferation – Diplomatic-based activities that control the spread of weapons of mass destruction (WMD) through arms-control agreements, inspections, export controls and the decommissioning of various weapon systems. A technical understanding of WMD is essential.

Space and Remote Sensing – Intelligence-gathering activities that acquire and analyze wideband RF data, effluent plume information, and low-light-level images in order to catalog proliferation signatures. Technology contributes by advancing detector capability.

Homeland Security – Protecting people and infrastructure against a variety of assaults, including; cyber attack, the arrival of WMD, terrorist access to critical facilities, and attacks against sources of water, food, fuel and electricity. Technology plays a role by managing cyber attacks (software) and finding ways to detect hidden WMD (hardware).

Attach Response – On-site search and rescue efforts that follow a terrorist attack. Technology helps rescue workers locate survivors and react to a specific kind of attack, such as sterilizing an area contaminated by a biological weapon.

Use of Military Force – Locating and destroying a terrorist organization while protecting the civilian population. Technology contributes by providing the military with precise munitions and non-lethal weapons that are designed for urban warfare.

Of the five activity areas listed above, pulsed power technologies make the strongest contributions in the final three – *Homeland Security*, *Attach Response*, and *Use of Military Force*. A few examples of applied pulsed power are shown below.

A. Miniature Accelerators for Homeland Security

Work is underway at the Los Alamos National Laboratory to develop a 95-GHz, 8-MeV electron linac [10]. The system will be light and portable due to new research in high frequency sources. By going to higher drive frequencies, linacs make efficient use of the applied RF power and support higher electric fields. As a result, the accelerator is very compact, requires less drive power and should be very reliable. A schematic diagram of the linac is shown in Figure 3.

Electrons from the linac will strike a tantalum target and produce a 1500-Rad/min. dose rate at zero degrees and 1 meter from the target. The radiation will be used to interrogate shipping containers for the presence of nuclear material. The system's great portability will make active-interrogation possible at more remote ports and border crossings.

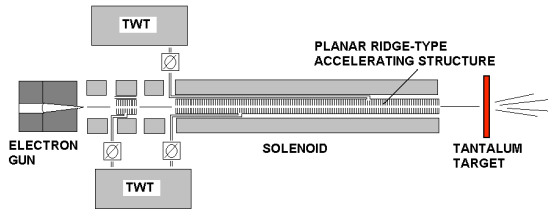


Figure 3. Illustration of 1-m planar ridge-type accelerating structure driven by two 95-GHz traveling wave tubes.

The accelerator receives RF power from two miniature W-band traveling wave tubes (TWT) operating at 95 GHz with a peak power of 500 kW. The tubes will use a 20-to-1-ratio sheet beam that passes over a 10-cm slow-wave structure fabricated by lithographic techniques. A depressed collector, as indicated in Figure 4, recovers much of the beam's energy giving an overall tube efficiency of about 50%. Further gains in system efficiency will be achieved by using newly developed thermoelectric converters. Modal calculations and particle-in-cell calculations indicate gains exceeding 1 dB/mm [11]. Earlier work on mm-wave sources [12] and additional information on this TWT [13] may be found in the literature.

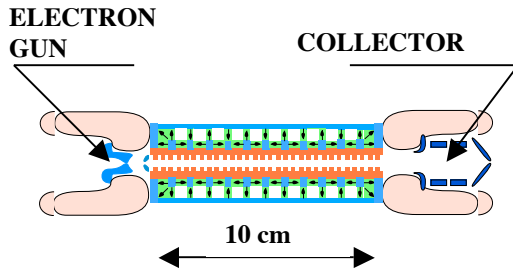


Figure 4. Schematic illustration of small TWT showing a 10-cm slow-wave structure, sheet-beam electron gun and depressed collector.

For the miniature accelerator system to maintain portability, the pulsed power source must also be very small and efficient. A design is underway for a compact, 100 kV IGBT-switched Marx bank to power the TWTs described above. The Marx generator produces high-voltage pulses without the need of a heavy pulse transformer. This Marx generator is a stack of 25 circuit boards, each containing four single-switch stages. One of several prototype board designs, measuring 13.3 cm by 22.3 cm, is illustrated in Figure 5. Eight ceramic capacitors at each stage are charged to 1200 V, which produces a 120-kV open-circuit output voltage. At this charge voltage, the capacitors store about 20x more energy than is extracted by the output pulse. Trigger command and gate control power are both derived from optical signals at each stage. Other IGBT-switched Marx

generators have been applied to TWTs [14] and additional research is underway to produce a 500-kV solid-state Marx generator for the Next Linear Collider [15].

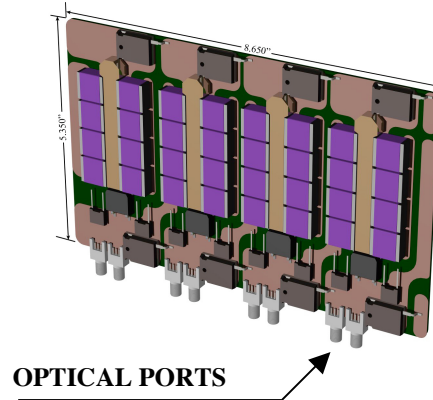


Figure 5. Single Marx generator circuit board showing ceramic capacitors and optical ports

B. Attack Response with Plasmas and Microwaves

Pulsed power has a role to play at a terrorist attack site, especially if the weapon involves a chemical or biological warfare (CBW) agent. Site decontamination is an important rescue operation and can be achieved on a large scale with foam products developed at Sandia National Laboratories [16]. However, the use of atmospheric pressure plasmas as a decontamination method [17] is under study for the smaller-scale treatment of highly valued equipment [18]. Pulsed power can also be used to locate people who are trapped beneath structural rubble at an attack site. For example, a team from Lawrence Livermore National Laboratory was called to the World Trade Center site to help search for survivors using a micro-power impulse radar (MIR) device. The team was able to locate several victims using the pulsed radar technology, but found no survivors [19].

C. Non-Lethal HPM for Military Use

Pulsed power technology has many military applications [20], but the area of high power microwaves (HPM) is a particularly interesting technology for terrorists. The U.S. and other industrialized nations are very dependent upon electronically controlled infrastructures for power, food, water, fuel, telecommunications and other vital services. Commercial and military use of off-the-shelf electronics introduces equipment into critical systems that is vulnerable to cyber, HPM and other forms of attack. Furthermore, low national reserves, brought about by just-in-time manufacturing, makes infrastructure disruption a very serious domestic defense issue.

Well before 911, various Congressional committees have been concerned that a HPM device could be used as a terrorist weapon because it is a relatively low-cost method to disrupt or destroy electronic systems that are not hardened against such an attack [21]. The media has

also adopted this concern and published a number of speculative articles on HPM weapons and their effects [22]. In fact, the United Kingdom, Australia, Germany, Russia, and Sweden are countries that have purchased or are developing HPM technologies for military use. The U. S. is also developing HPM technologies for the following military applications [23, 24]:

Ground Vehicle Stopper – Use of HPM to disrupt or destroy an automobile’s ignition

Vessel Stopper – Use of HPM to disable the motors on small vessels, such as the craft that attacked the USS Cole.

HPM Weapons – Single shot or multipulse HPM sources that will disable or destroy various electronic systems.

Crowd Control – Use of HPM to disperse hostile crowds near a military operation. Also called Active Denial.

Active Denial Technology (ADT) refers to the non-lethal use of mm-wave radiation to repel an advancing adversary without inflicting permanent injury [25,26]. This new weapons technology causes pain by heating the adversary’s skin, but only to a depth of 0.3 mm, where the pain sensing nerves are located. The subject feels pain, as if touching a hot object, but no burn occurs because the energy level is low. Possible deployments of ADT may include airborne, maritime, fixed-site, and vehicle mounted, as shown below in Figure 6.

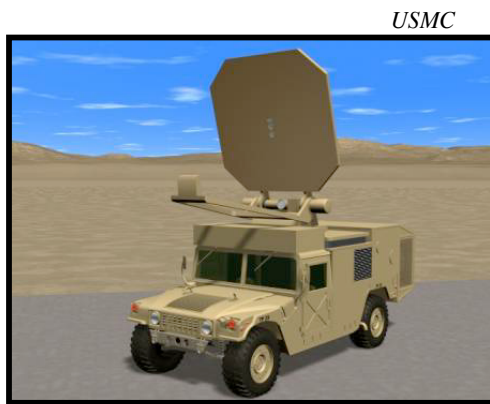


Figure 6. Concept illustration of a vehicle-mounted ADT source.

V. STRENGTHS AND LIMITATIONS OF SCIENCE AND TECHNOLOGY

Fundamentally, the war against terrorism is a war of ideas. Science and technology can play roles in denying terrorists the sanctuaries they need for directing, planning and training. The activities and communicative networks of terrorists can be detected thereby denying them secrecy

and stealth that they use to compensate for their basic weakness and vulnerability. Science and technology can be crucial in denying the terrorists their major goal, controlling the response agendas. That is, responses to terrorism can and must be designed and executed to make us stronger and more efficient and our freedoms and liberties more robust and expressive. If properly applied and planned, science and technologies including the tactical use of HPM technology can help achieve security by avoiding unnecessary intrusion into civil liberties and privacy. We can have our economy, privacy and liberties and still be secure. As the previous examples show, science and technologies, many now available or under development at Los Alamos, coupled with innovative policies and implementation can move us in the proper direction.

A. Strong Investments in Science and Technology

Science and technology applied as responsive actions to terrorism can be designed and implemented to conclude in more capable response infrastructures. For example, investments in our public health services aimed at dealing with acts of bioterrorism, if properly planned, can help ensure that more capacity will be available to deal with natural pandemics such as SARS, virulent influenza, or West Nile fever. We are developing systems, operating at the carbon-silicon interface, that combine the antigenic recognition capabilities of single cells with the information processing speed of modern electronic systems. These detectors will permit the rapid diagnosis of pathogens in the physician’s office without having to wait the hours involved culturing the pathogens. While the detector might be deployed to protect against bioterrorism, they can also identify such naturally occurring pathogens such as the *hanta* virus. The hours saved in identifying this particular virus can be the difference between surviving the infection and dying from it.

Science and technology can be used to simulate complex situations permitting national policy makers and legislators to authorize improvements designed to protect critical infrastructures against cyberterrorists that concurrently provide a more capable and secure information architecture for businesses and private citizens. For example, Los Alamos and Sandia National Laboratories have partnered to establish the National Infrastructure and Simulation Center (NISAC) to provide improved technical planning and decision support for the analysis of critical infrastructures. Simulation approaches developed in the center will permit effective routing of first responders, efficient allocation of resources, and effective defense options and strategies. This approach, while focused on counterterrorism, can be used to identify vulnerabilities that could grow out of natural disasters as well. The net result can be more robust and effective national infrastructures.

B. Limitations

Science and technology cannot deliver a solution proscribed by the laws of physics and chemistry. If we are required to assay a package passively for the presence of a radiological material, neutrons and gamma rays will always behave like neutrons and gamma rays and no new detector technology can change the rates of radiological decay, which are fixed in nature. In like manner, detection of a lethal amount of some pathogens, such as *pestis yersinia* or *hemorrhagic variola*, would require the detection of a single microbe, a difficult task in any situation and an impossible one if the microbe were placed inside an airtight package. In addition, science and technology can present national policy makers with difficult choices. For example, detectors placed in the cargo compartment of a large airliner can, if enough integration time, locate and characterize special nuclear material hidden in luggage. Since the detectors probably would not be able to define the configuration of that material, the national policy maker would have to decide what actions should be taken in the face of valid but inconclusive information. The consequence of making the wrong decision can be enormous. Finally, no combination of science and technology can provide absolute assurance that some clever or lucky terrorist, willing to die for some perverted cause, will not succeed in carrying out a deadly attack against our citizens.

VI. SUMMARY

Meeting a pervasive terrorist threat is an enormous undertaking that is complex, controversial, expensive, and always filled with contradictions. For example, securing the homeland requires federal, state, and local authorities to prevent terrorists and their weapons from coming into the country while minimizing any impact on the daily lives of the general population. While the goal is admirable, any experienced traveler will testify that searching for terrorists in airports has a great economic impact on the airlines and a very inconvenient impact on the traveler. Advanced technologies, like pulsed power, are being used to help implement these difficult tasks that often have conflicting objectives. On the battlefield, technical improvements in smart munitions and non-lethal weapons enable a military force to selectively engage terrorists within an urban setting while working to preserve and protect the civilian population.

By no means is technology a universal sword and shield against terrorism but select technologies, combined with an intimate understanding of terrorist organizations, are decisively effective.

VII. REFERENCES

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