The deadly terrorist attacks of September 11 served as a wake-up call to the nation, specifically to scientists and engineers. Grief soon gave way to action as the nation's laboratories began turning their attention to ways to help repair the damage and protect the country against future attacks. How can buildings be made safer? How can security in airports—and in all public spaces—be improved? And how can the citizenry be protected from invisible but deadly toxins like anthrax?

It's not unusual for scientists to mobilize in times of war. The submarine was invented during the Revolutionary War. Major advances in radar, atomic energy, and lasers were made during World War II, and improvements in space travel, surveillance, and semiconductors came about during the Cold War. Government grants typically provide the necessary seed money during times of crisis.

The impact of innovations that will undoubtedly come from the war on terrorism remains to be seen. But already engineers are taking previous research and adapting it in innovative ways. One project previously developed for the auto industry, for instance, may help law enforcement officials pick out potential terrorists in crowds of people. Improved batteries originally envisioned for electric vehicles may power military equipment. And research into improved microphones—based on the design of the ears of flies—could eventually help soldiers in the field locate war criminals like Osama Bin Laden.

Engineering schools across the nation are responding to the crisis, and many of the current experiments at university labs reverberate with popular patriotic sentiments. While the following 25 projects represent only a fraction of the research being conducted, they do illustrate the intensity of the efforts. They also show just how diverse the field of engineering is, as innovations in traditional disciplines such as civil and electrical engineering are joined by discoveries in newer fields like bioengineering and acoustics. The research and scientific advances these projects promise to yield will provide a fitting

Prism magazine has compiled an exclusive list of anti-terrorist innovations developed in engineering schools that could help put the citizens of this troubled nation at ease.
1. FINDING A FACE IN THE CROWD

Mug shots and photos of suspected terrorists are useless when the police are eyeballing mobs of people at airports or public events. That's why Tony Woo, a professor of industrial engineering at the University of Washington is one of many professors nationwide designing systems that can pluck a face out of a crowd. His software stretches and grafts a two-dimensional picture onto a three-dimensional head. The software can adjust and compare the enhanced model to real faces captured on surveillance cameras in order to find matches. The scheme, adapted from an industrial application for ensuring that auto headlights from subcontractors fit into their housings, currently filters faces at the rate of one per second. That's far more efficient than human monitors, but Woo wants to improve the speed by tenfold before the software is ready for deployment.

2. DRIVING AWAY

Car bombs are a favorite terrorist tool. Fortunately, researchers at Utah State University have already begun exploring ways to inspect parking lots full of vehicles. They've come up with a 4-inch tall, three-wheeled robot dubbed ODIS--for Omni-Directional Inspection System--which a remote control operator can direct by joystick to inspect the underbelly of cars. Smart, mobile wheels allow the robot to turn quickly and travel in any direction, much like a helicopter. Armed with a camera, the device streams video back to a central headquarters for analysis. Kevin Moore, an associate professor of electrical and computer engineering, hopes to test three ODIS robots during this month's Olympics. Future generations could use the robot to monitor other vehicle checkpoints such as international border crossings.

3. GETTING MUGGED

Seconds count in crime fighting, which is why highway patrol officers in North Carolina become frustrated whenever they stop a suspicious character. The slow wireless network they use means that downloading a mug shot from the law enforcement database takes up to 10 minutes before they know whether they have corralled the right person. But until the network gets an upgrade, Hamid Krim, a North Carolina State University assistant professor of electrical engineering, has created a way to shrink the size of the pictures. Using a new method of compression, optimized just for
faces, he believes he can reduce the transmission time to seconds. After September 11, he hopes the innovation will help national law enforcement as well as state patrol and says that it may even lead to new ways of storing digital photos for easier access.

4. SHARPENING X-RAY VISION

Finding concealed weapons or spying on hostage takers through the walls of buildings are just some of the advantages of improved processing technology for X-ray and radar images. Raghuveer Rao, an electrical engineering professor at the Rochester Institute of Technology, has come up with a way to more easily discern the edges of shapes by using wavelet analysis, a mathematical function that parses data into different frequency components. “Objects that you couldn’t detect previously now stand out,” says Rao, who believes the technology has broad applications when detection is necessary. The wavelet image enhancement technology allows improved detection of easily concealed objects such as the box cutters that were used to hijack the airplanes in the terrorist attacks of September 11. The technology is undergoing laboratory demonstrations and could be commercially available within the next two years.

5. DOUBLE-CHECKING IN

Metal detectors at airports provided only limited airport security prior to September 11; no more than 5 percent of all checked baggage was typically screened for explosives. That’s going to change now due to the terrorists attacks, and the Federal Aviation Authority is re-examining techniques to quickly scan more than one billion pieces of luggage checked each year. Since 1988, William Mayo, a professor of ceramic and materials engineering at Rutgers University, has been developing a machine using X-ray defraction that examines the unique atomic structure of each article in a suitcase. Bombs, like other objects, contain a unique molecular fingerprint, and Mayo’s machine can be updated to recognize new explosives as they are developed. Now, the FAA has asked Mayo to build a new version for testing that can scan a cargo-hold of luggage in less than an hour. Mayo hopes that the new generation of the 5-foot tall machines will be ready in the next year.

6. GOING POSTAL

With the prospect of anthrax-laced letters scaring many postal and office workers, Juyang Weng believes that robots ought to open the
mail. The Michigan State University associate computer science and engineering professor is developing a variety of smart robots that will have the ability to learn on their own. The key element is attaching the robot’s brain to a body with humanlike appendages, such as arms that can manipulate objects. The anthropomorphic creation, code named “Dave,” can then learn from its own actions. Weng expects to have a prototype ready by March.

7. STOPPING SPEEDING BULLETS

U.S. soldiers have the option of wearing near-impenetrable bulletproof armor. Trouble is, today’s thick ceramic or plastics protection is so heavy that the troops can barely move. Fortunately, the next generation of armor will benefit from nanotechnology research at Rensselaer Polytechnic Institute. Richard W. Siegel, professor of materials science and engineering, has created tiny nanoparticles much smaller than any natural substances. Added to a ceramic matrix, the tough but lightweight composite may one day help rapidly dissipate the energy of bullets, making the projectile nonlethal even if it manages to penetrate the armor. Siegel hopes that the material will be available for use by the end of the decade.

8. RECONSTRUCTING EVIDENCE

Discovering how a bomb fragments during an explosion may provide as much evidence as the fingerprints of criminals can. Otto Gregory, a professor of chemical engineering at the University of Rhode Island, is using a high-powered electron microscope to examine fragments of pipe bombs, one of the most common and destructive terrorist tools. By examining the metal fragments after the blast, Gregory hopes to help law enforcement officials determine the size and type of explosive used in the devices.

9. DECONTAMINATING THE AIR

An old invention may have important new uses. Yogi Goswami, professor of mechanical engineering at the University of Florida, designed an indoor air-cleaning technology in the mid 1990s to help rid buildings with poor ventilation of excessive mold or mildew. Now, with a few alterations, Goswami believes that his photocatalytic air-cleaning system, which uses the interaction between light and chemicals to destroy spores, could also eliminate airborne anthrax and other dangerous pathogens. The system could be used in central ventilation systems to decontaminate buildings and could also be adapted for use in single-family homes.

10. GOING WHERE HUMANS CANNOT TREAD
In the aftermath of the World Trade Center's collapse, a team of robots was sent into the rubble, dispatched to investigate crevices into which rescue workers could not fit. Robin Murphy, an associate professor of computer science at the University of South Florida, directed these search and recovery robots: luggage-size mechanical objects with bulldozer-like treads. The robots were armed with tiny video cameras, two-way audio capabilities, and infrared and thermal sonars in order to locate and assist survivors. The robots could even snake along intravenous tubes through the small pathways. In the absence of survivors, the robots collected pictures of the trade center's basement—which was deemed unsafe for humans—in order to assess structural damage. Murphy believes the robots could one day be used to rescue hostages and perform SWAT team missions in lieu of soldiers.

11. KEEPING WALLS FROM TUMBLING DOWN

Finding economical ways to bolster walls when buildings fall to pieces is the goal of the University of Missouri-Columbia's National Center for Explosion Resistant Design. Sam Kiger, the center's director, believes that non-load-bearing concrete walls common in most contemporary office buildings could be sprayed with a polyurethane liner like the kind used in truck beds. In the event of an explosion, the strong, flexible material could prevent debris from flying about. In walls with steel studs, found often in home construction, Kiger discovered that the addition of a single extra screw will nearly double a wall's load capacity, which increases its resilience in case of explosion. The Army has also asked the center to simulate explosions using
computers in order to help improve the design of its facilities.

12. SURFING FOR INFORMATION

With the unsettling prospect of random terrorist strikes throughout the country, local fire, police, and rescue crews--and even ordinary citizens--could benefit from a nationwide terrorist-tracking repository. At the University of Oklahoma, Le Gruenwald, a professor of computer science, and her husband, Hermann Gruenwald, a professor of civil engineering, are helping to create a publicly available Internet database of information about terrorism, including incidents, alleged perpetrators, targets, weaponry, and indictments. These lists could assist local investigators in their search for patterns as they try to identify perpetrators.

Information about counter-terrorism technologies and practices could help a community combat a biological attack. The $1.4 million research project is sponsored by the National Institute of Justice through the Oklahoma City National Memorial Institute for the Prevention of Terrorism. The database will be housed on the Institute's Web site at www.mipt.org.

13. TEEING OFF ON MINES

From years of warfare, the Afghanistan terrain--like many other strife-torn nations where terrorists tend to lurk--is chock-full of land mines. But detecting land mines is a tricky business because sensors often can't discriminate between harmless and dangerous objects. For instance, metal detectors might positively identify bits of shrapnel in the ground while chemical sniffers mistakenly tag it explosive residue. That's why the Army asked a number of universities to participate in the Humanitarian Demining Operation and come up with novel solutions. One of the more promising innovations has been developed at the University of Kansas, where James Stiles, an assistant professor of electrical engineering and computer science, has developed a type of radar that distinguishes human-made symmetrical objects from rocks no matter how deep the mine is buried. Although a can or shell next to the mine may still distort the symmetry, Stiles believes his technique can help. "No one has a sensor that works perfectly in all situations," he says. "Mine detection is like golf in that you'll need many different kinds of clubs."

14. TURNING UP THE HEAT

Designers of protective garb for firefighters have never really been able to ensure that the safety gear is truly safe. Current testing environments can only simulate small scale propane jet fires. But at Worcester Polytechnic Institute, Jonathan Barnett, professor of fire protection engineering, has built an 8-foot-by-12-foot testing room that can endure realistic severe fires such as the jet fuel blaze that engulfed the World Trade towers. Now with the ability to simulate fires of varying degrees, appropriate protective suits can be designed. The U.S. Navy has contributed $250,000 to the project so it can learn how to better safeguard troops in case of jet fuel fires on aircraft carriers, for instance.

15. REDUCING THE RISK OF FIRE
The chances of passengers surviving the crash of a large plane aren't all that great, but Morteza Gharib, a professor of aeronautics and bioengineering at the California Institute of Technology, thinks the collateral damage can be reduced. Gharib, who is working with a team of researchers at the Caltech-affiliated NASA Jet Propulsion Laboratory, hopes that a polymer added to jet fuel will transform it into a jelly-like substance that would stick together and not disperse into multiple small fires after a plane crash. The technique may also reduce the temperature of a fuel fire so it wouldn't get hot enough to melt the structure of a building, which caused the collapse of the World Trade towers.

16. WRAPPING UP

If a bullet or a knife wound doesn't kill a soldier outright, then the bleeding might. Roughly two-thirds of combat-related deaths are due to blood loss. And the age-old technique of applying a tourniquet to stop the gushing causes other problems, such as nerve damage. It can also lead to the amputation of a limb from lack of blood. So Gary Wnek, chair of Virginia Commonwealth University's chemical engineering department, has teamed up with VCU's medical school to design a futuristic tourniquet. A porous but elastic bag as small as a business card holds a diaper-like material. Applied to a wound, the bag soaks up blood, swelling to more than 10 times its original size, and the resulting pressure stems the bleeding temporarily until a soldier reaches a medical unit. The research, funded by the Army for $300,000 last spring, has taken on a new urgency with troops in battle abroad.

17. POWERING ON

It's a toss-up as to whether the average living room or the modern-day soldier has more electronic equipment. With communications devices, global positioning satellite trackers, and infrared night-vision goggles eating up energy, the military requires more juice than ever, and often the nearest outlet is miles away. The problem has arisen because the bigger the batteries, the hotter they become. Said Alhallaj, a professor of chemical engineering at the Illinois Institute of Technology, is adapting research that was originally intended for electric vehicles. His innovation adds special wax inside a lithium ion battery that melts when heated, consequently cooling the power source. Alhallaj says the battery gets four times the energy of previous generations and is just half the size.

18. CONSTRUCTING GATED COMMUNITIES
It's difficult to protect fenced-in areas of large facilities like airports or army bases from intruders. Heavy masonry walls or traditional electronic fence sensors used by prisons can cost up to $165 a foot, a prohibitively expensive amount. So at Penn State University's rare acoustics program, which combines mechanical and electrical engineering and physics, David Swanson has been developing a so-called "smart" fence. Tension wires embedded in a fence with a few attached standard $35 geophones (small microphones typically used for seismic measurements) are connected to a central computer that monitors vibrations. Using advanced software, the computer can discern whether the amplitudes of the vibration indicate the arrival of a fox or a fence-climber and alerts authorities accordingly. Swanson hopes to commercialize his invention in the next few months.

19. EATING RIGHT

Many soldiers in the field long for a taste of home cooking, which is not always what they get with MREs, shorthand for meals ready to eat. When the transportable food is being sterilized in packages, the current methods of using hot water heating or steaming can end up harming the flavor and texture. However, Juming Tang, associate professor of biological systems engineering at Washington State University, has developed an improved system to sterilize MREs by using microwave and radio frequencies. When these technologies are perfected, they could allow the military to offer such heat-sensitive, bacteria-prone rations as scrambled eggs along with current entrees like ham or spaghetti. Tang has received $580,000 from the Army and Defense Department to develop the new thermal processing technologies.

20. BUZZING ABOUT

The biological makeup of a fly's ears may one day help soldiers avoid surprise sniper attacks. Ronald Miles, chairman of the mechanical engineering department at SUNY-Binghamton, received a $3 million grant from the Defense Department to develop tiny microphones called "ormiaphones" that could be spread across a battlefield or city by American soldiers to detect the movements of enemy troops. The microphone's design is based on a fly's ear, which is able to more accurately discern the direction of sound than a human's ear. An early prototype of the microphone measures 1 millimeter by 2 millimeter; a less superior unit based on current technology is at least the size of a breadbox.

21. HEALING POWER

The body can usually heal from injuries like burns and wounds, but resulting infections can be even more serious than the traumas themselves when left untreated. Georgia Tech professors of
chemical engineering Jan Gooch and F. Joseph Schork are developing a "superbandage" for wounded soldiers caught far from medical treatment. After sustaining an injury, a soldier could grab a tube and, much like roll-on deodorant, apply the novel emulsion polymerized gel on the wound to create a transparent protective layer a thousandth of an inch thick. When the gel dries, it attaches to the skin so that only water and oxygen can pass through, not dangerous microorganisms, dirt, or sand. Anti-microbial agents in the gel fight bacteria, viruses, and fungi and promote healing for as long as two weeks. Animal testing is underway and the Army hopes to be able use the gel by next year.

22. USING PDAS TO WIN THE WAR

Military generals who once used binoculars and walkie-talkies may soon carry Palm Pilots instead to direct battlefront operations. That's the hope of Eugene Santos, an associate professor of computer science and engineering at the University of Connecticut. He's developing software for an advanced logistics system to give commanders in the field intelligent Palm Pilot-like devices to more easily move supplies and equipment during battle. The management of logistics can make the crucial difference between winning and losing, if for example, armaments or food doesn't end up at the correct location. The Air Force is sponsoring Santos's research.

23. EJECTING TERRORISTS FROM CYBERSPACE

Along with protecting public buildings and other facilities, the United States also has to safeguard cyberspace. A computer attack by terrorists could wreak havoc with power grids, communications systems, and financial networks. Raymond Hoare, a professor of electrical engineering at the University of Pittsburgh, is one of many researchers nationwide working to design new security systems for local computer networks. By retooling both hardware and software, Hoare has designed a program that would take a snapshot of normal network traffic patterns and monitor them for any deviations, which, for example, occur when a replicating virus begins to attack hard drives. The controls would then shut down the activity and alert network administrators. Hoare hopes to complete the research within 18 months.

24. RESCUING PHONE LINES

A devastating terrorist attack on a city that cripples communications could also hinder emergency responses. Charles Bostian, a professor of electrical and computer engineering at Virginia Tech, is head of a research team developing a portable wireless network for the exclusive use of emergency personnel. With special equipment placed near a disaster site, rescue workers could utilize a dedicated wireless network inaccessible to the public so that lines wouldn’t cross, a phenomenon that made it nearly impossible to use the phone in New York and Washington D.C. on September 11. The communications pipe would be broadband, allowing recovery pros to access the Internet and share checklists, inventories of supplies, and even maps and videos of the situation. The first version, which can broadcast wireless signals over 2 miles, could be ready for testing during this month's Winter Olympics. But Bostian hopes to eventually improve the range to 10 miles.
25. PLAYING WAR GAMES

During the Cold War, American military theorists simulated nuclear war on computers. But defending against terrorists makes those old war-game assumptions obsolete. That's why Boris Stilman, a computer science and engineering professor at the University of Colorado-Denver, has created new software to help the military prepare for the battles to come. Stilman’s software incorporates a variety of factors that would be relevant during a war against terrorism, including information on Army resources and geography. The software uses game theory and mathematical algorithms to find winning strategies. The program's other potential applications could help government and businesses practice decision making during crises like hurricanes or bombings.

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