BUILDING A BETTER BULWARK

By Steven Averett

New tools help delineate the best response to a worst-case scenario

Since 2001, elevated fears of terrorism, pandemic diseases, and other critical threats to national security have dominated the headlines and U.S. government policy. With the creation of the Department of Homeland Security, state and local governments were suddenly asked to shoulder much of the financial and logistical burden incurred in keeping America safe. To address these needs and to make the most of limited human and capital resources, many government agencies are turning to a new crop of tools to ensure that the response to a major disaster is swift, efficient, and effective.

Eva Lee, Ph.D., worked with the CDC to design RealOpt, a simulation that allows local officials to plan for the outbreak of infectious illness.

Inoculation optimization

After the anthrax attacks of 2001, the U.S. government began to take stock of the amount of available smallpox vaccine. While the fact that very little vaccine was readily available was cause for concern, more alarming was that there was little or no thought given to the process of administering the vaccine.

"Health and Human Services basically asked every single state to submit a mass vaccination plan for administering smallpox [vaccine]," says Eva Lee, Ph.D., a professor of industrial and systems engineering at the Georgia Institute of Technology. "And that was really the tip of the iceberg in the sense that that is really not so feasible to do because we actually have nothing in place to vaccinate everybody." This realization pushed the Centers for Disease Control and Prevention to look at what it could do in terms of giving the states guidelines, she says.

The CDC created a clinical model to isolate the challenges in running a triage center during a mass vaccination. Using this protocol, they ran a small-scale study centering on 7,000 people moving through a vaccination center. Though the CDC confirmed that there was a clear bottleneck stemming from a dearth of state resources, it was clear that the model itself was incapable of allowing for even small variations in a mass vaccination scenario. Initially called in simply to evaluate what the CDC had done, Lee ended up working with the agency to develop a more realistic simulation.

"You cannot really walk people through and say, 'Ah, now I understand this scenario' because there are just thousands of millions of scenarios that you have to understand. And that basically motivated our work," she explains.

Lee quickly discovered that it wasn't just the CDC's inexperience with simulation that made planning and optimization of vaccination centers difficult. "We have to look at simulating the patterns of how patients come into the center and how they go through every station. That means they're reviewed by the nurse, they get consultation, then they get vaccination, and they exit the system. We looked at all of these patterns. Then I saw that the optimization was indeed very difficult because trying to optimize an entire system that is dynamic is really not something we're very used to doing. So I basically started from scratch and built the system."

The idea was to design a system that could be used to recalibrate a vaccination center on the fly. Phase one of development involved setting up resource allocation. "That means if you tell me you have 24 first responders that could go to a vaccination center and each of them have different responsibilities, I can tell you how to assign them to different stations within the vaccination center and how many people, at maximum, you can actually expect to go through per day."

Lee built a discrete optimization system and married it to a simulation system, also built from the ground up. She unveiled her design, dubbed RealOpt, to Georgia state officials last August. It was enthusiastically received. Because Lee gave RealOpt the ability to make adjustments to patient flow on the fly, health officials found they could even use the software in other areas of their hospitals. Programmed in Java, RealOpt can be run on a PDA.

"We optimize right on that spot, getting the best resource allocation at that instant," says Lee. "As the patients come in we can observe that and dynamically change the configuration as it goes. That's really the power of the system."

Having established a system that will optimize individual vaccination centers in as little as 30 seconds, Lee has moved on to phase two: creating software that — given population density, available resources, transportation options, and confidential priority protocols — will determine the most

efficient places in which to establish vaccination centers and the optimal way to distribute resources and medical personnel.

In moving from phase two to phase three of RealOpt's development, Lee is considering disease propagation issues: "A critical part in this facility [planning] is if one of the vaccination centers collapses. That means it is massively contaminated by sick patients or something else happens. ... Suppose it is an anthrax vaccination that we are doing. If someone comes in and they are actually carrying some of the virus with them, they could contaminate the entire center. And that's the worst place to propagate the virus. So if we have to close up one facility, how are we going to redirect all of the other traffic?"

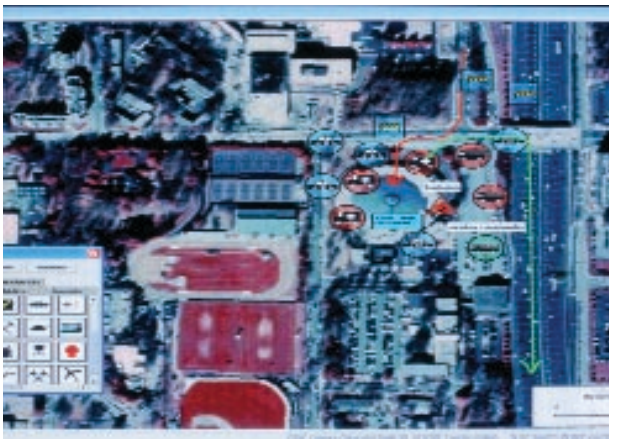
Here, Lee says RealOpt must be able to look beyond standard epidemiology to anticipate the deliberate propagation of an infectious agent as part of a terrorist attack: "Obviously, at the moment, I think I worry more about the pandemic flu and all of those. But from the government's point of view, their starting point was anthrax. ... So we are not just looking at disease propagation from the point of view of health care workers. We also worry about checkpoints and the security issue."

A map without edges

In June 2004, coastal Georgia prepared for the arrival of President Bush and other world leaders for the G8 Summit by flooding the region with federal, state, and local law enforcement officials. To impose some order on things, the Georgia Emergency Management Agency pioneered the use of the Geographic Tool for Visualization and Collaboration developed by the Georgia Tech Research Institute. In addition to local firefighters and emergency personnel, the Georgia Bureau of Investigation, the Georgia State Patrol, the Federal Bureau of Investigation, the National Guard, and the U.S. Secret Service all agreed to use the mapping system.

Kirk Pennywitt, a senior research engineer at GTRI, says the power of the GTVC starts with its ability to map large geographic areas in exacting detail: "We have one-meter imagery for the entire state loaded and one-foot imagery for many areas also available. It has the capability of having new maps added at any time. It directly supports GeoTIFF format imagery. The maps are raster-based, so they tend to look better than a vector-based line drawing type of map. These are real photographs of paper maps."

Further cementing the paper map analogy is the way in which different groups can create their own layers, analogous to layers of acetate on a military map. Each participating agency can set permissions that limit who can see or edit a particular layer.



The Geographic Tool for Visualization and Collaboration allows multiple agencies to access a shared, highly detailed map, which can be updated in real time with new information from any party.

Georgia Tech Research Institute engineers explain the features of the Geographic Tool for Visualization and Collaboration to Georgia Gov. Sonny Perdue (right).

"You can have large numbers of clients logging in from multiple locations. They all log into a session server and a map server. The map server delivers their maps. That can be on their local machine or on their local area network or at a remote location. There's a single-session server that coordinates everybody's activities, so all users log in to the same session server. Then each user indicates their activities or planned activities on the map and any other user who happens to be looking at that same area of the map will see their plans appearing on the map in real time," Pennywitt says.

Thankfully, there were no major law enforcement crises during the summit, so in addition to staging areas for all of the participating agencies, most of what got plotted on the map was the location of both planned and real-time protests, parade

routes, and potential helicopter landing areas.

"All activities are recorded into a session database file along with who performed that action, so you have a full audit trail of everything that was placed or indicated on the map at any time," according to Pennywitt. "You can later replay that session file so you can see exactly what happened at each point in time and who did it."

Through early use of the GTVC, it became clear to Pennywitt that one of the biggest challenges posed by a heightened security situation is maintaining effective communication and chain of command: "During the G8 we had mobile field forces staged in both Savannah and St. Simons. So they were separated by 80 miles. They had to reach an understanding that the units that were staged in Savannah would be dispatched from Savannah and the ones in St. Simons would be dispatched from St. Simons. ... A clear understanding of who's responsible for what and who's in charge is one of the biggest things."

Drawing on experiences from the G8 Summit and the requests of potential clients, GTRI is prepping version 2.0 of the GTVC. It will feature better search capabilities, a textual listing of plotted activities, refined buffer capabilities (useful in determining the closest hospital to a given point or similar geographic queries), smoother network configuration, a cleaner user interface, and a system that is generally easier to administer.

While Pennywitt is enthusiastic about the potential for use of the GTVC on a national level, there are many hurdles to overcome first. Faster servers are needed, as are hierarchies to determine who will be involved and how access will be shared. He also concedes that most of the territory on a nationwide GTVC map would be of little interest to agencies such as the FBI and the Department of Homeland Security: "The federal government would have no interest in seeing what's going on in Mayberry 95 percent of the time. But if an agro-terrorism thing happens there, now they're interested."

Sim savvy

Bob Monette, director of marketing for Environmental Tectonics Corp., seconds Pennywitt's assertion that communication and familiarity with the chain of command are essential to effective emergency response.

"The hardest thing is communication," says Monette. On the scene, he says, it's all about who's in charge and how to set up communication processes: what to call for, when to call for it, and who to call to get appropriate responses and resources.

It is that focus on training in procedure and communication in pursuit of a coordinated emergency response that makes the Advanced Disaster Management Simulation an effective tool. Essentially a lifelike portrayal of a range of interactive crisis situations, the simulation can be run in a number of ways.

Through vicarious control of onscreen entities, first responders get a taste of what they will be called upon to do in an emergency situation. Monette describes the experience as similar to being in a movie in which the action onscreen is dictated by the verbal prompting of trainees. "They see icons of other firefighters doing their job, climbing each rung of the ladder to go inside the airplane," says Monette. "We can put a camera on any one of those responders' helmets, so when they go inside the airplane, we go into the airplane with them."

When clients purchase ADMS, ETC will train them to design and run simulations in-house. Alternately, ETC can provide both equipment and technicians. Once trainees are experienced with the software, they can use the intuitive interface to control their point of view in the simulation from a networked workstation. Otherwise, they simply issue verbal commands to ETC operators who run the software.

This kind of training is daunting for some, invigorating for others, according to Monette: "The new guys, the guys who are 20, demand it. The old guys are a little standoffish. So how you integrate the new and the old individuals into a new way of training is always a challenge. Once you get the acceptability of that and they say, 'Wow, this is really great and it adds a new level of interactivity into my training,' then you cautiously expand that trainer."

Fire departments in England use ADMS to certify fire chiefs before each progression in rank. The National Institute for Fire Training in the Netherlands uses it to simulate fires in urban and suburban locales and to train in the use of a turret ladder truck — training that, by law, is not permitted in real life. Baltimore/Washington International Airport is currently employing ADMS to prepare its personnel for a federally mandated live drill, administered every three years at major U.S. airports.

While ETC tries to anticipate the training needs of first responders by providing a range of nuanced scenarios, Monette says much of the detail found in the simulations stems from the requests of clients: "They want to see cloud plumes of a substance. Because our system is fidelity based, the wind effects will affect that cloud plume. It will move it in the direction that the wind is blowing at the rate the wind is blowing. Then the farther you get from where it starts, there's also a dissipation level vis-à-vis distance, time, and environment.

Using a control stick and verbal commands, an incident commander trains as part of an ADMS simulation.

ETC gives customers the option of contracting with ADMS to facilitate simulations or being trained to design and run simulations on their own using an interface like this.

Just as video games have grown gradually more immersive, ETC is constantly trying to up the ante when it comes to portraying realistic emergency situations. Indeed, when Monette describes potential improvements, ADMS sounds as much like a horrifying theme park experience as a training simulation: "They're wanting more chaos, more involvement from bystanders where they will actually run up to you and scream, 'I have two children on the third floor,' or 'I haven't seen Uncle Fred and I think he's in there taking a nap,' or something like that. Then the first responder has to figure out how to get in there. And they want smell. So we broke down five major smells that they want, and we're going to work on a little smell generator. We have a tremendously nice surround system that puts all of the peripheral sounds of a disaster in there. We crank that up as much as the speakers will take."

Currently, ETC is designing a maritime module to simulate a range of crises that might occur in ports. "We live in Florida," Monette explains. "If you take just the map of Florida and you see how many airports are connected to a water port, the only one that's landlocked is Orlando. Every other airport has a seaport and then you put a railroad situation into it. So you have this inter-modal disaster that you can train on."

Every update hones a tool designed to give first responders a chance to confront realistic emergency situations without risking real lives or property. Many of the scenarios would be difficult or impossible to recreate in a live setting. In the polygonal world of the ADMS, it's possible to run a situation again and again, tweaking it on the fly to maximize the learning experience. That way, when a real terrorist attack, chemical spill, or aircraft crash occurs, responding units will be able to approach the situation from a position of experience.

"That's basically the job of a first responder: Taking all of that chaos that is uncommon and turning it back into something that's common," surmises Monette.

Games without frontiers

One of the best ways to prepare for a terrorist attack is to devise ways to prevent one from happening. Based at the University of Southern California, the Center for Risk and Economic Analysis of Terrorism Events (CREATE) is an interdisciplinary think tank created by the Department of Homeland Security. The first university-based Center of Excellence, CREATE brings together experts in engineering, international relations, psychology, policy, and planning in an effort to understand and subvert terrorist strategy. One component of the center's work uses game theory to anticipate terrorist tactics.

"Game theory is the study of optimal defenses against optimal attacks," says CREATE researcher Vicki Bier, Ph.D., a professor of industrial and systems engineering at the University of Wisconsin-Madison. "The basic idea is that if we don't have good enough intelligence to know exactly what a potential terrorist will try to do, it makes sense to try to at least protect against the worst possible scenarios."

Bier says that to make the best use of resources, it is important for the Department of Homeland Security and other agencies to consider a range of contingencies, like a chess player anticipating moves and countermoves three turns ahead. "Depending on how your adversary responds, some types of defenses may not make you better off and may just shift the attack to an equally damaging strategy. You could waste a lot of resources if you don't think that through," she warns.

Difficult-to-defend targets such as oil pipelines offer a prime illustration of this slippery strategic slope. "In that kind of a situation, the attacker can choose where to attack," says Bier. "The

defender has to basically defend all parts of the system equally. For something like an oil pipeline, that's obviously going to be infeasible. We would never be able to defend the entire length of an oil pipeline or an electricity transmission line at anything close to a reasonable cost."

Instead, Bier says the best strategy in this instance is redundancy — a second pipeline, shipping by oil tankers, or other transport — or resiliency — devising a rapid, highly mobile way to repair damage to the line on short notice.

As an example of ineffective defense strategy, Bier points to the inconsistency of airport security workers who thoroughly search backpacks and purses even as they let baby strollers pass through unchecked. "Currently we are spending a lot of effort screening passengers and relatively little effort screening air cargo," she continues. "One of the messages of game theory is that if potential attackers have multiple ways to achieve their goal, we probably ought to equalize or approximately equalize how vulnerable those different routes are. Spending a lot of resources making one possible strategy impossible or virtually impossible while another strategy has not really been dealt with very aggressively might not be a great idea."

Bier says many post-Sept. 11 security measures have more to do with allaying the concerns of politicians and the public than with providing real safety, and this can run counterproductive to the most effective defense strategy: "There's a certain demand to say, 'Well, we ought to be doing something.' But resources are scarce, and if we're going to be spending a lot of money on something, you want to know that it really will improve safety and security, rather than just be window dressing for political purposes."

One of Bier's more controversial conclusions is that resources should be directed toward the most likely targets rather than spread around evenly: "I think one of the problems in defending small towns or less-valuable targets is that there are so vastly many of them. For any individual town, we cannot guarantee that they will not ever be a target. There is some non-zero probability, but the probability is extremely small just because there are so many similar places. So, again, it becomes like defending the oil pipeline. If you can't defend all of those small towns, then you probably ought not be defending any of them."

Though it may not please local governments, Bier says the important thing is to allocate attention and resources to very specific goals. "Every state has a state capital. Even very small, unpopulated rural states are likely to have critical infrastructure like nuclear power plants or dams or whatever we would want to protect. But we ought to focus on which assets we're protecting, rather than which states or which towns."

Setting up and managing a triage center is one of many aspects of a disaster that can be simulated using ADMS.

Vicki Bier, Ph.D., uses game theory to thwart terrorist attacks before they are even planned.

In addition to working with the Department of Homeland Security, CREATE shares the fruits of its labor with local governments and private sector companies. Currently, the Center is researching the implications of dirty bomb attacks, weapon threats to commercial aviation, and attacks on the distribution system for electricity. In the coming year, questions about biological and nuclear terrorism will also be addressed. Bier hopes their work will be of use: "I'm currently working on a project to look at defending commercial airlines against attacks. Even if the detailed mathematical game theory models don't end up getting applied there, I think some of the basic insights about needing to protect against many different types of attacks in a balanced manner will still show up very clearly in our recommendations."