Dr. Tom Altschuler
Advanced Technology Office (ATO)
Self-Healing Minefield

Preston has given you a very good picture of one of ATO's most exciting programs at its embryonic stage. What I would like to do is to provide you with a look at a program at the other end of the development pipeline: the Self-Healing Minefield.

We began work on the Self-Healing Minefield in 1998. In fact, I gave a presentation on it during the 1999 DARPA Tech conference. It was our attempt to merge the capabilities of networked communications and autonomous systems with the tactical needs of modern antitank landmines.

Today, the program is in its final stages. The Army is now looking at how to incorporate our program into an overarching view of tactical obstacles. And while there are certainly more opportunities to build on this concept, we consider the development of the Self-Healing Minefield an ATO success story. It has certainly helped contribute to the Revolution in Communication Affairs that ATO is very much a part of.

So what I would like to do today is update you on the state of the program, provide you with some detail about how the technology works, and then try to explain what process we used to make this program move from concept to testing with relatively few problems.

Our work began by conceptualizing the future opportunities in maneuver denial that exploit advanced technologies. Landmines are a very well established part of the counter mobility component of warfare. Recently, anti-personnel landmines have been the focus of much global debate. Although the U.S is not a signatory to the 1997 Ottawa Convention that bans anti-personnel mines, the Department of Defense has aggressively examined opportunities for anti-personnel landmine alternatives systems.

DARPA has focused on a subset of this problem. We are exploring systems that can continue to provide robust obstacles to disrupt the maneuver of enemy vehicles, without the necessity of incorporating anti-personnel landmines into the system.

When we began our program, we knew what we needed was a new generation of obstacles that could take advantage of novel technology and be compatible with future Army requirements. We began with a few assumptions. We believed this new generation of obstacles would contain integrated networks. They would rely on artificial intelligence. And they would operate autonomously.

The result after 4 years of work is the Self-Healing Minefield. It represents a new kind of anti-vehicle landmine system—one that takes advantage of networked communications. It converts a static munition into a fully autonomous intelligent system that expands the opportunities for counter mobility using mine systems.

In that sense, the Self-Healing Minefield is a killer ap. Its contributions to the transformation of the way land battles are planned and executed are enormous. The traditional concept of a minefield is, of course, something very different. It is a weapon that slows, canalizes, or deters an enemy. But once breached, the field has limited further use.

Our goal is to create a more dynamic system. We envision a fluid minefield that could react to a breach, heal itself by physically reorganizing, and creating new obstacles to be overcome.

The Self-Healing Minefield is deployed like a conventional one. Where it differs is that each of the mines contains a communication subsystem that permits it to monitor the integrity of the minefield autonomously. The minefield knows when and where it has been breached.

Essentially, these mines are a distributed network, each one capable of “talking" to the others, constantly aware of their relative position and health and watchful of the overall integrity of the minefield. Not only do the mines detect a breach in the network, but they are able to react to it. When a breach occurs, they respond by literally hopping themselves automatically to fill the breach.

Imagine a minefield that acts like molasses. No sooner do you run your finger through it than the molasses seals the intrusion. Having swept a path through a minefield, the enemy is now confronted with a new minefield puzzle.

This vision presented many technical challenges. The program is focused on three of these challenges.

First, we needed to create a degree of mine mobility. We needed a mine that could move itself once the minefield had been breached. That would require a hopping system that propels the mine to a new location. It would also need to function in complex terrain, any terrain a tank can move through, and right itself, if necessary, after it had moved to align the warhead for target engagement.

Second, we needed a system of intermine communication. In essence, we viewed a minefield as a self-organizing network. It could contain up to 1,000 mines, each an independent node in a distributed network. Not only did these mines need to "talk" to one another, they needed to recognize the relative battlefield location of the other mines in the minefield. That would allow them to be cognizant of minefield integrity and reorganize themselves once a breach had occurred.

The third technical challenge was to detect and localize a breach, to communicate without disruption from enemy countermeasures, yet remain sensitive enough to distinguish between an enemy breach and a minefield disturbance of another sort.

The program plan was to develop several alternative approaches to each of the key enabling technologies and integrate these into a prototype system to investigate the overall collective behavior of the antivehicle minefield.

Let me provide you with a little detail on the hardware under development. We are developing systems that employ both one-sided and two-sided mobility.

The new mine will be about 12 centimeters in diameter and 7.5 centimeters in height, and weigh less than 2 kilograms. This is similar to the size and weight of the currently fielded scatterable landmine.

The communications unit that is likely to be our standard has two frequency hop spread spectrum radios; an orientation sensor; an optional GPS, which is not necessary for relative location or network synchronization; a processor; and an acoustic communication subsystem with four speakers and microphones.

This unit is integrated into a mine that is able to move by igniting one of the four end-mounted "pancake" rocket thrusters on either side of the mine. These thrusters can propel it up to a range of 9 meters. The most recent testing of the Self-Healing Minefield prototypes involved several different 10-mine systems. These tests were conducted in the spring of this year and were very successful. They demonstrated that a Self-Healing Mine system could both detect a breach and respond with multiple mines hopping.

Here is some video of the tests we recently conducted using the Self-Healing Mine prototype I just described. You can see how, after motor ignition, the mine propels itself up, reconstituting the field.

There are still improvements and refinements we are making to the system. Further testing is underway. At this stage, we are confident in saying that the Self-Healing Minefield is a model of an ATO success.

Let me suggest a few reasons why this research program worked as well as it did.

First, we began with a very clear definition of the problem from a military system viewpoint. As you know, that's not always possible with every advanced technology research and development program.

But here we were able to take a hard look at the way the military was using landmines and what it wanted to achieve. We recognized right away that the military could exploit a very advanced antivehicle landmine system and improve the overall maneuver denial achieved by scatterable munitions. In the current scatterable minefields, we saw a form of distributed technology that hadn't yet exploited the possibilities of networked communications.

From that point, it was easy to give researchers clear objectives. They knew the endgame: a network of intelligent and autonomous mines. They knew the technical hurdles that had to be solved: the communications and mobility hurdles outlined above.

In fact, the goals we set for the program in 1998 never changed. We have always been making progress on the program, solving different problems, expanding our overall technical objectives. But the goals themselves have never changed.

Throughout the process, we insisted on a very synergistic relationship between the researchers and the DARPA team. At every point, the researchers provided us with feedback to enhance our thinking. It is a very strong, two-way relationship.

I believe the Self-Healing Minefield in many ways typifies the ATO mission.

This is a case of bringing enabling technology to a very discrete and definable problem confronting the military. We essentially took the ideas of advanced communications and networked systems and found a very practical application for them. From the very beginning, we knew we were using an unconventional approach to a traditional and critical military mission. It was an approach that worked.

We are now working closely with the Army on the conceptual design to meet the current and future Army requirements. The Self-Healing Minefield Program has achieved significant breakthroughs and successes. The system is on the path to become an integrated part of the Army's array of weapon systems.

Program development has not come to an end. In our most recent tests, we successfully demonstrated the technology using 10 mines. Next, we need to enhance the intelligent communications system and behavioral algorithms and demonstrate scalability to a tactically significant number of mines, between 50 and 100. At that level, we will be able to test the true capability of this type of distributed system.

Beyond this, we are now thinking about how an intelligent minefield could operate at the organic level. We are accustomed to laying mines and waiting for the enemy to respond. But the intelligent minefield could be developed to deploy rapidly for both offensive and defensive maneuvers. The military has already looked into various alternative delivery systems for mines. The added component of intelligent mines opens new possibilities to dynamically shape the battlefield, even in the heat of combat.

This is part of the future vision of ATO. We want to build on the success of the intelligent minefields that we have already attained. We want to work with the private sector and DoD to solve military problems, modernize our forces, and introduce a new shape to the way war is waged.