Bringing SDI Down to Earth

Congress is backing a major thrust to develop a conventional weapons counterpart to SDI; like SDI itself, critics say it will not work and will be unduly expensive

LAST year, in a move that drew little attention outside the military establishment, Congress launched a major initiative to speed up the development of a new generation of weapons that some analysts believe will revolutionize warfare. Just as President Reagan's Strategic Defense Initiative (SDI) is aimed at making Soviet nuclear weapons obsolete, the new congressionally mandated program is aimed, in the words of its chief sponsor, Senator Sam Nunn (D–GA), at "making Soviet armor obsolete."

The principal objective of the new initiative, for which Congress has approved a $300-million budget for this year, is to speed the development of "smart weapons" that would use sophisticated sensors and tiny high-speed computers to seek out and destroy targets without the aid of the human eye or brain.

Such technology, in Nunn's view, would be the West's key advantage if war broke out in Europe. Smart weapons, according to this view, could help neutralize the Soviet Union's most threatening weapons—its army of tanks, which some analysts claim outnumber NATO's by three to one. And they could also play a potentially crucial role in NATO war plans that foresee conducting precision strikes against Soviet reinforcements deep behind the front lines in the early stages of a conventional war.

Experts have talked about such devices, and predicted their imminent arrival, for almost two decades. So far, however, these new weapons have not materialized, and a host of technical problems remain to be solved before they are ready to enter the U.S. arsenal.

Indeed, some critics question whether the promised martial revolution will ever take place, and the likely impact of smart weapons is a matter of sometimes acrimonious disagreement among weapons experts. In a style reminiscent of debates over SDI, critics and advocates of smart weapons have squared off over the fundamental limitations of the underlying technology, its cost, and the ease with which an opponent could counter the weapons.

The smart weapons now under development would represent a major technological leap beyond the present generation of armaments. In essence, they would use sensors, such as infrared detectors or radar receivers to detect potential targets. Tiny computers inside the weapon would check the incoming signals with computerized images, or "signatures," of what the target should look like. If they match, the weapon would then home in on the target.

In contrast to these autonomous weapons, most current guided munitions require a human operator to find the targets before the weapon is fired at them. And, in many cases, such as with laser-guided bombs or artillery shells, a laser beam must continue to focus on the target until the weapon reaches its destination. Some existing weapons can home in on the heat of jet engines and the electromagnetic signals of radars, but the task of detecting less distinctive targets such as tanks and armored vehicles has so far proved frustrating.

"If there's an attribute of a target that makes it different from its surroundings, then you can hit it," says Thomas Amlie, an Air Force engineer with three decades of experience designing missiles and radars. "But these wonder weapons are predicated on attributes that don't exist." According to Amlie, neither infrared sensors, which detect differences in temperature, nor radars can distinguish reliably between tanks and other hot or metal objects, and the sensors are easily confused by simple steps that an adversary may take to disguise the targets. As a result, a weapon that works perfectly in tests against tanks arrayed on an open field may prove worthless on a battlefield filled with smoke and burning equipment.

Others disagree. "We have data on what Soviet tanks should look like (to a sensor), and they make pretty good targets," said James Tegnelia, former deputy director of the Defense Advanced Research Projects Agency (DARPA), now an executive at the Martin Marietta Corporation. According to Jasper Lupo, who oversees DARPA's research in autonomous weapons, "with the computing power that we now have, but haven't packaged yet, we'll do a credible, militarily useful job" against moving and stationary targets, even if the background is littered with metal or hot objects. Compressing the necessary computing power into a package that would fit into a small missile is a challenge, he said, but "that's an engineering problem, and it's time to get on with it."

In contrast to the task of detecting an airplane flying through the sky, the problems associated with identifying targets in the midst of ground clutter still are only


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Senator Nunn. *Chief sponsor of $300-million program to develop smart weapons aimed at "making Soviet armor obsolete."*

partially understood, according to several experts. The weak point is the computer programs, or algorithms, that attempt to match the signals a sensor receives with actual target images. Tests in the field up to this point have served primarily to point out weaknesses that required further work.

Through testing, "we found out that millimeter-wave (MMW) radars need a better set of discriminants than we had when we started out," said Tegnelia. "Hitting the brightest thing is just not good enough."

In fact, until recently, accurate data did not exist on the infrared or MMW radar signature that a tank reflects under various weather and background conditions. During 1985, the Pentagon conducted a series of tests with Soviet tanks at Eglin Air Force Base in Florida to collect this information. The testers placed tanks on a turntable that was mounted on rails, and instruments mounted on a 100-meter tower nearby measured the infrared and radar signal reflected by the tanks as they were rotated and moved back and forth. "We were surprised at the target signatures. Some were much cooler than we expected," said Colonel James Petty, director of the Army Smart Weapons Center in Huntsville, Alabama.

As a result, the Army postponed a decision to proceed with further development of a small artillery-fired smart warhead called SADARM (Sense and Destroy Armor) until the companies building it, Honeywell and Aerojet, had redesigned the weapon. The Army expects SADARM to be the service's first autonomous weapon—it may roll off the assembly line within 5 years—but the service has not yet tested the redesigned version in the field.


Aerojet

The first autonomous weapon? *SADARM submunition firing slug of metal at a tank; critics contend that not enough live-fire tests have been conducted.*

SADARM is an example of the simplest type of autonomous weapon now in development. Shaped like coffee cans, six SADARM submunitions, or miniwarheads, are scattered from a single short-range rocket several hundred meters above the ground, and their descent is slowed by parachutes. As each submunition swings back and forth, it scans the ground below with infrared sensors and a tiny radar transmitter. If it detects an infrared image and a radar reflection that match those that are typical of an armored vehicle, the submunition explodes, firing a slug of metal at 2000 to 3000 meters per second in the direction that the sensor is pointing at that instant.

Submunitions like SADARM can scan within an area only a few hundred meters wide. This simplifies the job of recognizing targets, but makes it less likely that the sensor will detect any at all. A second type of submunition under development, called TGW (Terminally Guided Weapon), is a tiny guided missile that would scan the ground from a distance of a kilometer or more, detecting targets in an area 300 to 500 meters wide and 3 to 5 kilometers deep as it flies. Ground- or air-launched rockets would carry a cluster of TGWs to within a few kilometers of the targets before dropping them toward the target area.

Weapons designers also hope to equip glide bombs and air-to-ground missiles with the ability to recognize and home in on targets from distances of 5 kilometers or more, allowing aircraft and their pilots to stay safe distances from heavily defended areas.

A Defense Science Board report prepared in 1983, however, heaped scorn on efforts to give the Maverick air-to-surface missile this "autorecognition" capability. In the report's cover letter, panel chairman Harold Lewis of the University of California at Santa Barbara wrote that "it is extremely unlikely (I would say impossible) that the current approaches to algorithm development will lead to a target autorecognition system on which one can rely," particularly since data on target signatures were extremely limited. Expectations of reliable autorecognition devices based on then-available algorithms, he said, were "a fantasy." The Air Force, embarrassed by the report, stamped it "For Official Use Only" over the objections of panel members.

Many of the same experts are now preparing an update of that report and expect to finish it before the end of the year. The new report, said Lupo, a member of the group, will note that "quite a bit of progress" has been made on algorithms since 1983. "A set of programs have demonstrated some robust behavior in the presence of a reasonable set of adverse conditions," said Lupo, and new rigor in evaluating computer software has banished some of the "hocus-pocus" from the field.

"You can go to any number of aerospace companies and see a giant computer room and watch these algorithms work," he said. "But packaging them into a credible-looking hardware package—perhaps the size of a beer can—is really one of the big obstacles." But rapid progress in computing technology, said Azriel Rosenfeld of the University of Maryland's Center for Automation Research, means that "what is being done now on a mainframe in a minute will be done 20 years from now in real time on a microchip."

The key factor in improving algorithm reliability, according to Lupo and others, is raw computing power. As computing speed increases by leaps and bounds, a smart weapon can compare the image its sensor is receiving with vastly greater numbers of possible target images, and more accurately decide whether it has found a real target.

Such "brute force solutions," as Rosenfeld put it, will not solve some fundamental problems, say researchers in the field of computer vision and autorecognition. No one knows how to write programs that will recognize subtly different shapes. And detecting objects that are partially obscured remains problematic. "We don't know really deeply how we recognize shape," said the University of California's Lewis.

Although powerful mainframe computers now are successfully identifying targets in simulated tests, prototype weapons such as SADARM and TGW, with more primitive capabilities, have had a spotty record in actual tests. In some instances, testers used bulldozers to grade the surrounding areas, used gasoline-powered tanks that run hotter than Soviet diesel tanks, waited until the cool of the early morning, and even put hot plates on the tanks to help the weapons see the targets.

"In this whole area of brilliant weapons, there has been an unusual amount of success-oriented tests—trying to make them look good rather than finding out what they can do," said James Burton, who retired last year as the Pentagon's director of field testing.

Defenders of smart munitions have pointed to another series of tests, conducted during the past 3 years at Eglin Air Force Base, under an Air Force program called Chicken Little that placed targets in more challenging and realistic conditions. "They really did go out of their way to try to disguise (the targets)" under camouflage nets, among foliage, fires, and other metal objects, said Alan Shaw, who directed a recent study of smart weapons for the Office of Technology Assessment. Such steps can frustrate smart weapons, and are known as simple countermeasures. "We learned that, by golly, smart munitions really do work," said George Kirby, who took over in early 1987 as director of the testing program at Elgin.

Actual live-fire tests were a tiny part of the Chicken Little program, however. Only nine actual weapons were dropped over real targets, and four of them were scattered from one submunition dispenser during a single test. The heart of the program was a series of "captive flight tests," in which each submunition's sensor apparatus was mounted on a helicopter and flown over varied arrays of tanks and other armored vehicles, as instruments monitored the sensor's success in identifying targets, said Kirby. Hundreds of such flights were made, and each sensor had several thousand opportunities to recognize targets.

"They had $30 million, and in the whole series of tests, they only had four or five live warhead firings. That's a crime," said Burton. "And they would not allow this country's best countermeasures outfit, from White Sands Missile Range, to participate." The tanks used in the tests were borrowed from Israel, said Burton, and were spared from live-fire tests because the Air Force "had to give the tanks back."

Despite problems in getting smart weapons into the field, Lupo remains optimistic. "I'm pleased that we're getting a weapon out there that can tell the difference between a tank and a haystack—that's the first step," he said, referring to SADARM. Weapons that will distinguish between tanks and trucks from a few kilometers away are within reach, he said.

Even if the technical difficulties facing the development of smart weapons can be overcome, some analysts question whether the weapons would ever be cost-effective. Indeed, a shroud of uncertainty surrounds cost estimates for smart weapons.

The Army has offered the companies building SADARM a cash reward if they can produce the submunition for $3,000 or less, based on a total purchase of 800,000 weapons. Officials estimated that the TGW minimissile, because it has more sophisticated sensor, signal processing, and guidance systems, would cost ten times that much. "I personally don't think we're going to buy a $1,000 submunition," said Tegnelia. "I think we will buy a $30,000 submunition." Another industry executive, who requested anonymity, said terminally guided submunitions might well come with $50,000 price tags. Lupo, on the other hand, said that he expects eventually to buy submunitions that are able to find targets in an area several kilometers wide for less than $10,000.

"The cost driver in the future is going to be software," said George Kopcsak, director of the Defense Department's Office of Munitions. Algorithms can be enormously expensive to develop, but cheaply reproduced. Therefore, it will be important to buy smart submunitions in large quantities, to drive down unit costs, said Kopcsak. Colonel Petty estimated that sensors and signal processing account for 65% of the cost of current submunitions.

Getting the bugs out of these complex software packages can be expensive as well. "Probably a minimum of 50% of the whole R&D process is associated with validating, testing, and evaluating the stuff," said Lupo.

But of all the unanswered questions that haunt smart weapons, the one that bothers critics most is whether these weapons and their automatic guidance systems will be able to cope with a real adversary intent on finding ways to render them helpless. "I worry that after 3 or 4 days of war, the other guy will figure out a simple countermeasure," said Shaw.

Simple countermeasures might include scattering cheap radar reflectors or flares as decoys. But as algorithms and sensors improve, it will become difficult to fool smart weapons into mistaking decoys for real targets. An alternative, and potentially more effective, approach would be to use chaff or aerosols to hide the telltale signature of armored vehicles and to jam the radar of incoming weapons. "I would much rather suppress the signature than build a decoy," said Tegnelia. Lupo agrees that "no amount of computing power is going to provide a solution if the sensor doesn't provide a signature." He noted, however, that "the enemy will not always have the time, the inclination, or be able to afford countermeasures of the subtlety that you can postulate in your armchair."

According to Tom Carter, former military assistant to the Pentagon's testing chief, the smart weapon that cannot be neutralized will never exist. "With smart weapons, all you're doing is buying time, staying a step ahead in the measure-countermeasure game," he said. And weapons expert Steven Canby pointed out that a weapon based on deterministic algorithms, unlike one controlled by the human brain, is inflexible. If its inherent weaknesses are found and exploited, its usefulness declines precipitously. "It's like an airline schedule," said Canby. "If one small thing goes wrong, it fouls up the whole system." ■ DANIEL CHARLES

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