pense was spared" to build it, he says—but it won't be connected to a telescope until March, when renovation of a 40-inch reflector at the Yerkes Observatory in Wisconsin will be finished. With support from the National Science Foundation, the Kibblewhite group plans to have it ready to observe the collision of a comet with Jupiter in July. Then comes the challenge of building similar systems for other telescopes, something Jacques Beckers, director of the Kitt Peak Solar Observatory, thinks "will take major efforts." Wayne van Citters, who runs the technology support program for astronomy at the National Science Foundation, says, "We are trying to develop something that is affordable to astronomers," but the cost of each unit remains "extremely high."

Eventually, however, many astronomers think the SDI artificial-star technology will prove its value. "By the end of the decade," says astronomer Laird Thompson of the University of Illinois, "this will be a very active field for astronomers—and for the military."

A disputed legacy

These are three of the most successful and best-known technologies for basic research that came out of SDI—a scanty harvest for a $33 billion program. But researchers at the national labs and in the former SDI office insist that's not the end of the story, citing commercial and medical technologies they say were helped along by SDI funding. For example, Science Research Laboratories of Cambridge, Massachusetts—an ex-SDI research contractor—is building a compact proton accelerator that it hopes to sell to hospitals to produce isotopes for PET scanners. Other companies are making SDI-inspired magnetic bearings, nondestructive surface measuring instruments, and sophisticated infrared cameras. Dwight Duston, director of the former SDI office of innovative science and technology, says that a decade ago it would have cost $1 million to buy a large infrared camera; now, thanks to SDI, he claims, you can buy one with superior sensors for about $80,000. Meanwhile, Livermore is trying to interest companies in developing a digital mammography device based on software developed for the x-ray laser program. And others have adapted military x-ray microscopes into tools for studying industrial composite materials.

The list of spinoffs is long, but it's difficult to sift out the contributions of Star Wars from those made by other weapons programs and by civilian research. It's also hard to find agreement in the research community on the significance of any particular SDI-inspired gadget. As the battleground of the Cold War's last great ideological clash, SDI and all that sprang from it remains contentious territory.

–Eliot Marshall

CULTURAL SHIFTS

Ex-Defense Scientists Come in From the Cold

For many researchers who have spent their careers working on military projects, the end of the Cold War has brought an end to an era of secure funding. Uncertain new priorities such as "technology transfer" and "economic competitiveness" now determine whether their work will continue to be supported–and at what level. As a result, thousands of researchers who depended on defense money in national labs and universities are struggling to make the transition to civilian science in a research culture very different from the closed world of secret research. Many of them have found some seemingly unlikely uses for their skills: The computer algorithms developed to detect incoming missiles can also identify errant cells in the human body, and the plasma physics vital to understanding the detonation of a hydrogen bomb can also be applied to pollution control. But these gentler research goals don't always mean a gentler research environment, say some ex-military scientists. Cold War veterans are finding that the civilian research world, rife with the struggle for funds and the search for "spinoffs," can be a pretty cold place itself.

Target Recognition Goes From Tanks to Tumors

The software algorithms developed to help identify tanks in the jungle wouldn't seem to have much future outside the military. But University of Missouri computer scientist James Keller has hit upon a novel use for them. He has repackaged the basic research that occupied him during the Cold War—and found that it's equally relevant to civilian concerns. After 12 years developing algorithms for target recognition for the Air Force and a defense contractor called Emerson Electric, he's applying the same strategies to automated cancer screening.

James Keller

"Separating target objects from the things around them is a big problem for target recognition, and it's the same kind of problem in medical imaging," says Keller. Keller's algorithms rely on a strategy called fuzzy logic. Fuzzy logic, he explains, is designed to deal with the imprecision and vagueness of the real world. An ordinary program designed to find a tank in a jungle, for example, might classify every point in the scene as either tank or tree. Fuzzy logic would instead define ambiguous points as, say, 30% tank and 70% tree—then wait until all the points are tallied before finally deciding whether or not a tank is hiding in the scene. That strategy boosts the amount of data needed to describe a scene, but in the end, Keller says, it enables a computer to simulate the mix of intuition and judgment that humans use to solve complex problems.

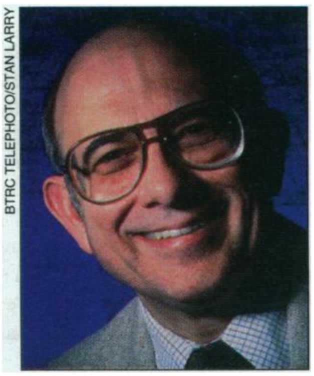
Doctors face such problems each time they interpret a tissue slide or x-ray image. Generally, human beings are much better at such tasks than computers, says Keller, but he's convinced fuzzy logic can endow machines with a much closer approximation to good medical judgment. He and colleagues at the University of Missouri medical school are working on a project to apply fuzzy logic to mammography. Their system, they hope, will be able to give mammograms a preliminary screening and alert doctors to suspicious patterns. Meanwhile, other researchers are looking into fuzzy logic programs based on Keller's algorithms to help them identify abnormal cells in biopsied tissues.

Keller says he's happy working in this new environment; it enables him to keep pursuing his real enthusiasm, which is computer algorithms. "A lot of what we do is very basic research, and we want to apply it to problems of current interest," he says. The trick to defense conversion, he adds, is to listen to what other people want. "All we've got to get is someone at the funding agencies to agree with us and we're in."

Military Electronics Follows a Rougher Road

Applied physicist William Youngblood spent 11 years at Georgia Tech Research Institute working on "electronic warfare"—developing sensors to help military aircraft detect enemies and jam the enemy's own sensors. But by 1990, he says, he "could see the writing on the wall." The communist world was collapsing, and funding for his brand of military work was bound to dry up. So he decided to take his electronics skills on the road by adapting the same sorts of sensors that can warn fighter pilots of approaching enemies to alerting drivers of obstacles or automatically averting collisions.

With funding from the Department of Transportation (DOT) through a federal project known as the Intelligent Vehicle Highway System, Youngblood has been able to tackle some problems even more challenging than those he faced in the military. "In the air you just have clouds," he says. "The highway has curves and bends—it's not nearly so simple." But he has also found a less welcome challenge: getting money.



BTRC TELEPHOTO/STAN LARRY

William Youngblood

"The biggest thing we defense-oriented people have to learn [in the civilian world] is that money isn't nearly as free flowing," he says. He says he used to get grants of about a million dollars. With DOT the average grant is much smaller—around $100,000. What's more, he says, the civilian sector runs with a certain "lean and mean" efficiency. "The transportation world wants more for its money," he notes. For example, the military was willing to pay for an elaborate, structured management system. "We typically did a very careful job of tracking progress—we had charts and computer programs to measure progress against expectations," he says. There's no room for that kind of overhead anymore. "The DOT looks at that as excess baggage."

A Physicist Comes Halfway in From the Cold

Plasma physicist Norman Bardsley is living in the borderlands between defense and civilian work, and it's not always a comfortable place to be. His office sits inside a classified "green" area within the fence of the Lawrence Livermore National Laboratory, and much of the research he's done has been under wraps because of its applications to the nuclear weapons program. But for the past 3 years he's also been cooperating with industry to develop commercial applications for the lab's plasma technology. Bardsley is enthusiastic about the Department of Energy's effort to push nondefense applications at the national laboratories, but he says that in practice, mixing the classified and the commercial gets complicated.

Norman Bardsley

While the restrictions apply officially only to certain areas of research, some aspects of the security system slow down other work at the lab. Bardsley says he needs to keep classified and unclassified work rigorously separate by, for example, using different computer systems for each. He still has to write to Washington before inviting foreign researchers to come to work with him, and his office is off-limits to a colleague who is from the Philippines and lacks a clearance. And bringing new people on board can take ages. "Right now, for example, I need to hire people, and I have some qualified people who were born in mainland China. For us to consider hiring such a person we end up with months of paperwork." That's more than an inconvenience, he adds: What would be an acceptable security burden in defense work could be fatal in the fast-paced competition of industry.

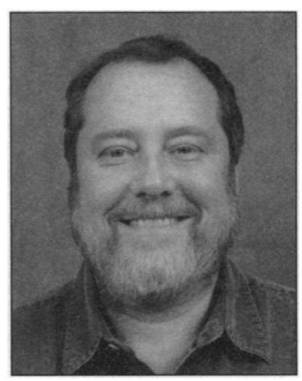
Despite the obstacles, Bardsley says he's started several joint projects with companies. In one of them, he and colleagues have devised a way to run smokestack and other exhaust fumes through a plasma in order to break down toxic chemicals into simpler, more benign constituents. He's also working with AT&T and IBM to apply low-pressure plasmas to the delicate craft of etching fine structures in layers of silicon. He's finding ample challenges in the work. "Taking a good idea and turning it into a project that will make money is more complex than working on weapons," he says.

And ironically, he says, he deals with just as much secrecy in the private sector as he did in his secret lab. "This is the way a lot of industry makes their living—by getting an idea and keeping it secret until they have manufactured a saleable product.... Industry can be a very closed society." But the brand of secrecy found in private industry is streamlined, he says, unlike the rigid procedures of the military. "Their security system is similar to ours except they don't have to document their procedure the way we do," he says. "In industry, it's just the act [of keeping secrets] that counts."

A New World Beckons for Neural Networks

Computer scientist Scott Fahlman says he and his colleagues at Carnegie-Mellon University feel some of the same funding anxieties as other veterans of defense work. But the neural-network researcher likes to emphasize a happier side of the transition: the freedom to explore a broader universe of applications.

During the Cold War, he says, "everything had to be cast in military terms to get more funding. Almost everything we do has a number of uses, but we had to single out the military applications," such as navigation or detecting targets. That was when he and his colleagues were funded largely by the Defense Advanced Research Projects Agency (DARPA). Now DARPA has dropped the "Defense" to become ARPA, and as the name change implies, the agency encourages commercial applications as well as military ones. "We still end up doing the same research," he says, "but there's a wider range of applications we can call on to justify what we are doing."



Scott Fahlman

Fahlman, who is now funded by the National Science Foundation, is trying to take the computational techniques developed for military target recognition and apply them to three-dimensional imaging of moving systems, such as cell movement or embryonic development. Doing so takes computational tricks similar to those in target recognition, he says, because both goals require processing torrents of data in real time. In another aspect of the project, he says, he's aiming to display cells and tissues as "virtual reality" images—computer-created images that can be turned around and explored from different angles in such a realistic way that they give the illusion of being solid objects.

Still, the freedom to set such goals comes at the expense of another kind of freedom: While the civilian sector offers more research possibilities, he says, he has to specify each one before getting money for it. "We used to get broad packages with the freedom to pick and choose what research to do," he says. Now, "we've chopped things up into smaller programs," funded with incremental grants. And that means Fahlman finds himself spending more time trolling for funds. "About half of our time is spent raising the money instead of doing the work," he says. "You've hardly got going before you have to turn around and start fighting for the next one."

–Faye Flam