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Still in the lead?

Half a century after its creation, the Pentagon's Defense Advanced Research Projects Agency is considered a paragon of government innovation. But some question whether it is still relevant. **Sharon Weinberger** reports.

G. BLEVINS/REUTERS

Last year's DARPATech conference could not have been held at a more fitting place than a Disneyland hotel in California. Run by the Pentagon's research arm — the Defense Advanced Research Projects Agency (DARPA) — the August meeting was meant to tout the agency's unparalleled record of far-out technological innovation. Next to the theme park, which features Buzz Lightyear Astro Blasters and elaborate virtual-reality displays, DARPA's message — military technology meets science fiction — took on a positively surreal form.

On display were a robotic dog that can traverse rugged terrain and advanced human prosthetics that could someday be controlled by the brain. One presenter talked of putting micromechanical systems into larvae to create cyborg insects, and the agency's director, Anthony Tether (pictured, right, with flag), touted its upcoming robot car race, a competition that promised US$2 million to the team whose vehicle could drive itself fastest through a 97-kilometre 'urban challenge' course. Meanwhile, meeting organizers passed out chocolates emblazoned with DARPA slogans and jostled past the pink-clad army of Cookie Lee jewellery saleswomen attending their own conference elsewhere in the hotel.

The event was in stark contrast to the buttoned-down DARPA of the early years. Since its creation in 1958, the agency has been a major player in science and technology challenges facing US national security. During the cold war, its experts worked on everything from the space race to the Vietnam conflict. Most famously, it created Arpanet, the precursor to the Internet. Today, in an era when federal agencies talk about becoming more like the private sector, DARPA is uniquely regarded as a model of success. "It is the jewel in the defence-department crown," says former defence secretary William Perry, who served as the Pentagon's director of defence research and engineering — a position that oversees DARPA — in the 1970s.

But now, as DARPA turns 50, observers are asking whether the agency is still as relevant as it once was. The question is particularly pressing as other parts of the US government look to launch their own DARPA spin-offs, in fields from intelligence to homeland security to energy (see 'DARPA: the next generation', overleaf).

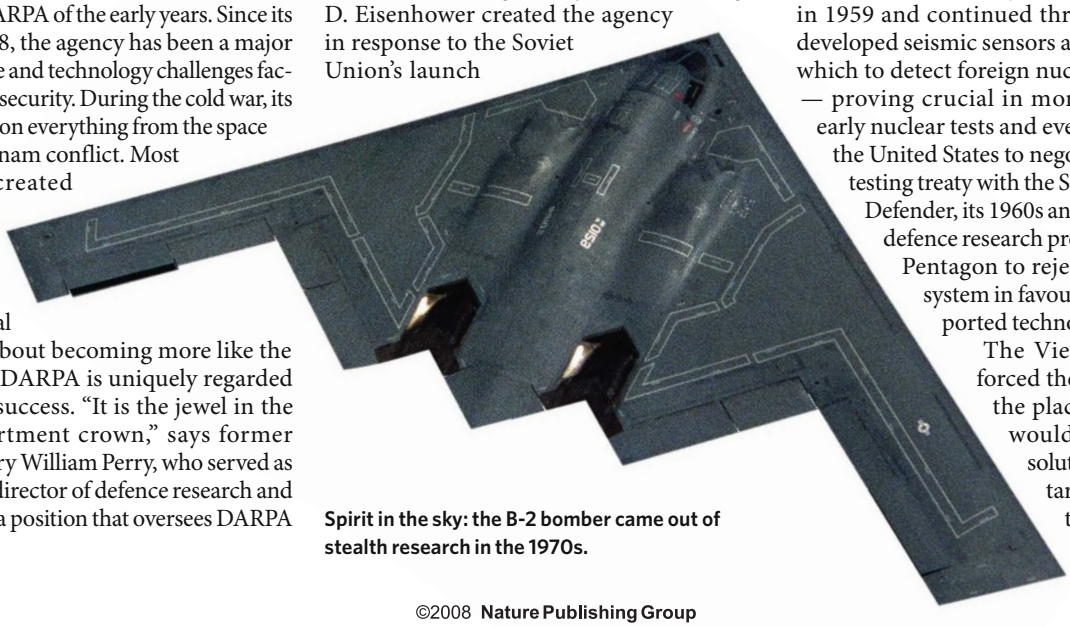
A lean, mean machine

With just 250 employees, most of whom serve a term of 4 to 6 years, DARPA is everything the federal bureaucracy is not: lean, innovative and dynamic. Its approximately $3-billion budget is directed at high-risk projects designed to provide the Pentagon with revolutionary advances. Unlike the military services, DARPA projects don't have to be tied to a specific need, and unlike grant agencies such as the National Science Foundation, it can fund risky ideas without going through peer review. That high-risk approach can lead to high payoffs: the agency counts satellite navigation, unmanned aerial vehicles and radar-evading aircraft among its major accomplishments. But it's also had some flops: laser weapons are still elusive, and a decade-long strategic computing initiative never reached its goal of artificial intelligence.

Even in its early days, DARPA struggled for purpose and legitimacy. President Dwight D. Eisenhower created the agency in response to the Soviet Union's launch of Sputnik. The aim was to jump-start space programmes by bypassing the traditional rivalry among the military services that had been developing competing and overlapping satellite technologies. But within a year, the Advanced Research Projects Agency ('Defense' was added to its name in 1972) lost its major mission when Eisenhower created the civilian space agency NASA. The defence department eventually transferred the remaining military space programmes back to the military services.

But DARPA soon found its niche in other defence work. Its Project Vela, which began in 1959 and continued through the 1960s, developed seismic sensors and satellites with which to detect foreign nuclear detonations — proving crucial in monitoring China's early nuclear tests and eventually enabling the United States to negotiate a weapons-testing treaty with the Soviet Union. And Defender, its 1960s anti-ballistic missile defence research programme, led the Pentagon to reject an army-built system in favour of DARPA-supported technology.

The Vietnam war reinforced the agency's role as the place senior leaders would go looking for solutions. As US military involvement in the war escalated throughout the



NORTHROP GRUMMAN

Spirit in the sky: the B-2 bomber came out of stealth research in the 1970s.

Anthony Tether waves the chequered flag at Grand Challenge 2005 — DARPA's competition to develop fully automated vehicles.

1960s, DARPA became a focal point for counterinsurgency work through its Project Agile. The project incorporated an array of research efforts and experimental technologies from the serious — the now-infamous Agent Orange, a defoliant widely used by the US military — to the retrospectively silly — a jet belt designed to propel individual soldiers on the battlefield.

Jack Ruina, DARPA's director from 1961 to 1963, says that he never liked the Agile projects, calling them "gimmickry and gadgetry". But Charles Herzfeld, who served as director from 1965 to 1967, says that he embraced the agency's mission in Vietnam. DARPA's 'systems approach' to counterinsurgency has included finding ways to spot tunnels in Vietnam, tracing relationships between families in the Middle East and developing radar to patrol Iran's borders.

Broad scope

At the same time, the agency continued its forays into areas such as computer and materials science. It fostered relationships with academia by funding long-term university research and by its sponsorship of the JASONs, a group of mostly university scientists that provides advice on national security. After a dispute over who got to choose JASON members, DARPA dropped the JASONs contract in 2002, and the group's sponsorship shifted to the director of defence research and engineering (see *Nature* **416,** 353; 2002).

Historically, DARPA directors also facilitated the agency's cooperation with universities and industry; they have all been engineers or physicists, many with close links to academia. As the director typically has sole discretion to fund or cancel a particular programme, the head of DARPA has great power to shape the agency's direction. Tether, an electrical engineer with a doctorate from Stanford University in California, spent much of his career in defence jobs in the private sector, working at companies such as Science Applications International Corporation in San Diego, California, one of the top Pentagon contractors.

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> — Anthony Tether

Tether says that the key to steering the agency is hiring creative managers "who can generate ideas, unfettered sometimes by hard data" to direct its research programmes. "I believe strongly that the best DARPA programme managers must have inside them the desire to be a science-fiction writer," Tether says. H. G. Wells, he adds, would have been good at the job.

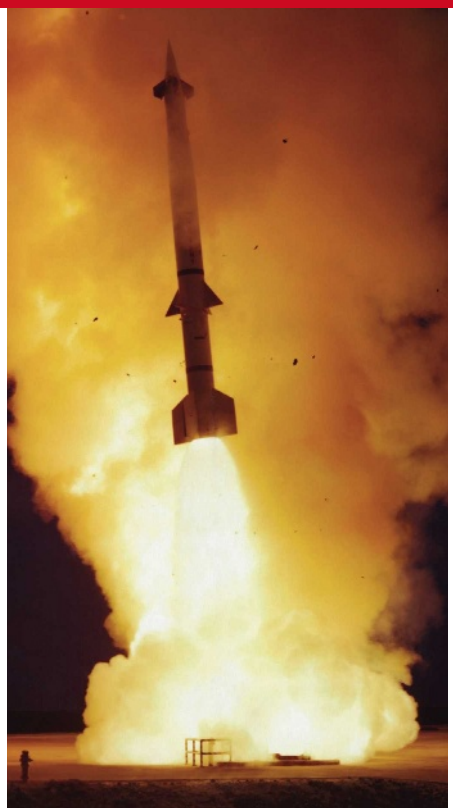
And Tether thinks that this approach is working. Today, DARPA "in all of its organizations is banging at the door of highly innovative ideas", he says. "I think anyone who attended DARPATech 2007 in Anaheim would agree." Others aren't so sure that DARPATech is really the best reflection of that, however. The tightly scripted event excludes questions from the audience, and features little detailed discussion of current programmes. Stephen Lukasik, who was DARPA's director from 1971 to 1975, says he worries that DARPATech is now light on substance. "It used to be a technical meeting," he says, where programme managers and attendees had a forum to learn and argue about specific technologies.

And the conference's penchant for Hollywood-style fantasy also underscores the differences between DARPA in the Vietnam era and today. In Vietnam, the Pentagon turned to DARPA to lead counterinsurgency research. But as violence ramped up in the Iraq conflict, it divided up counterinsurgency tasks among other organizations, such as the Joint Improvised Explosive Device Defeat Organization, an office established to fund technologies to defeat the ubiquitous homemade bombs seen in Iraq. Today, DARPA says that the closest thing it has to the Vietnam-era Project Agile

is Persistent Operational Surface Surveillance and Engagement, a software system designed to track insurgents by integrating sensor data. Other DARPA technologies are being used in Iraq, such as unmanned aerial vehicles, translation devices and an anti-sniper system.

Privacy issues

DARPA's highest-profile counterterrorism effort, though, proved politically disastrous. After the 11 September 2001 terrorist attacks, Tether — then in his first year of the job — created a new Information Awareness Office under the leadership of John Poindexter, a former national-security adviser and a key figure during the 1980s Iran–Contra scandal. Poindexter and his office proved to be more polarizing than expected; its Total Information Awareness programme (later changed to Terrorism Information Awareness), which aimed to sift through huge amounts of data to track terrorists, was attacked on privacy grounds, and Congress eventually cancelled it. "That was a dishonest misuse of DARPA," says Hans Mark, a former director of defence research and engineering now at the University of Texas at Austin. For its part, DARPA concedes that the office could have been created with more caution, but says that Tether believed that the right technology could have prevented 9/11, and that data mining could prevent similar events in the future.



BETTMANN/CORBIS

DARPA's early focus on detecting missile launches has faded somewhat.

Although former agency directors and senior defence-department officials agree that DARPA is still highly innovative, they don't agree on whether it is as important as it once was to the Pentagon. In one early significant shift at the end of 1969, leaders moved DARPA out of the Pentagon building to make way for Vietnam analysts; DARPA's offices are now located in nearby Arlington, Virginia. Herzfeld calls the move the loss of "a great gift", breaking the immediate link between DARPA and senior Pentagon leadership.

The agency also shifted, in the early 1970s, from issues directed by the president to more self-directed work, although Herb York, one of the agency's founding leaders, notes that the shift was more a product of the time than a change in DARPA's role. "The fact that ARPA moved away from the White House," he says, "is not because of anything ARPA did — it's because of the way the whole scene changed."

Some directors from DARPA's earlier era suggest that later agency directors have tended to choose more conservative projects, leading to less high-impact pay-offs. George Heilmeier focused during his tenure on projects such as radar-evading aircraft and acoustic detection of submarines; the maiden flight of the first stealth aircraft, a project managed and funded by DARPA, took place on Heilmeier's final day as director in 1977. "Then things changed," he says. "Compensation became much less competitive with the outside high-tech world, and DARPA, without the

DARPA: THE NEXT GENERATION

At Bolling Air Force Base in Washington DC, Steven Nixon's office is filled with management theory books such as *The First 90 Days: Critical Success Strategies for New Leaders at All Levels* and *The Innovator's Solution: Creating and Sustaining Successful Growth*. Nixon, who is director of science and technology in the Office of the Director of National Intelligence, is studying management culture as part of his plan to do what many people say is impossible: create an organization that replicates the successes of the Defense Advanced Research Projects Agency (DARPA).

In preparing to set up the Intelligence Advanced Research Projects Activity (IARPA), Nixon has consulted with previous DARPA heads, as well as former office directors and programme managers. He thinks that copying the management structure of DARPA will be the best route to IARPA's success — in particular, limiting employees' contracts to four to six years. "That's the key attribute that we plan on borrowing," Nixon says.

IARPA is one of three ARPAs to be proposed or set up since 2002. The others are the Homeland Security Advanced Research Projects Agency (HSARPA) and the newly authorized, but not yet established, Advanced Research Projects for Energy (ARPA-E). Each is meant to bring the sorts of revolutionary breakthroughs made by DARPA to their fields. But it's not clear that a technological solution is what's really needed in each case. Stephen Lukasik, a former DARPA director who was consulted on setting up IARPA, half-jokes that the best model for creating a DARPA-like agency is if an asteroid impact were threatening Earth. "It would be universally understood, the impact would be universally disastrous and it would be scientifically challenging," he says.

MEHAU KULYK/SPL

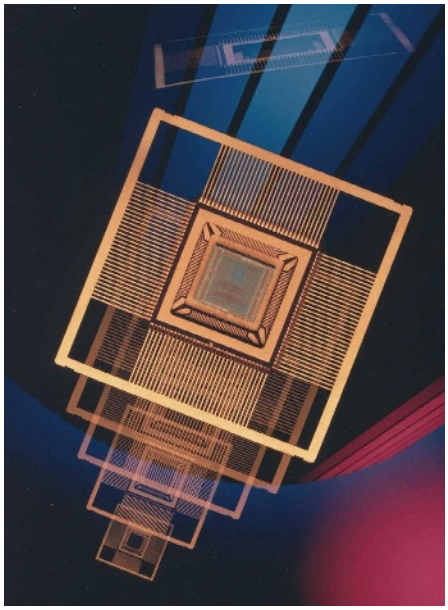
In fact, the first of the new ARPAs — the homeland security one — is already distancing itself somewhat from the original DARPA model. Programme managers at HSARPA do serve limited terms, but so far none of them comes from academia, as many DARPA managers do, says its director Roger McGinnis. The biggest difference, however, is the nature of the projects that HSARPA supports — driven mainly by customers such as the Secret Service and the Transportation Security Administration. "They come to us, we look at the money, and together we choose," says McGinnis. That means that HSARPA tends to focus on specific technologies — for example, miniaturizing biological and chemical sensors to fit in a hand-held device. HSARPA

close connection to the secretary of defence, became more conservative in its selection of new, technology-driven initiatives. To many, DARPA was losing its passion and excitement and seemed to be moving in the direction of a bureaucracy."

While Heilmeier questions DARPA's current commitment to bold research, others accuse the agency of moving away from supporting basic research in universities. In 2005, DARPA became the subject of a congressional hearing to discuss concerns that the agency was cutting off long-term support for universities and, in particular, computer-science departments. "That simply is not correct," Tether told the panel, saying that there had been no decline in support, merely a shift in priorities to interdisciplinary research. One DARPA-supported researcher attributed the change to the director's management style.

"DARPA is the jewel in the defence-department crown."
— William Perry

DARPA's leader today doesn't agree that the agency is in decline. Tether points to a host of projects developed in the 1980s and later, such as unmanned aerial vehicles, as well as lesser-known advances such as research on solid-state photon detectors, which enabled night-vision goggles, and integrated circuit research that helped lead to modern mobile phones. Tether also points to miniature global-positioning system receivers and DARPA's funding of gallium arsenide research (for use in semiconductors at a time when the commercial industry viewed such an investment as too risky). Today, he says, nanotechnology is a key research area.



NORTHROP GRUMMAN

Very-high-speed integrated circuits are used in airborne warfare equipment.

Former directors, such as Lukasik and Herzfeld, also credit Tether for starting the Grand Challenge robot races that encouraged younger scientists and engineers to compete for a cash prize to develop a fully autonomous vehicle. The first two competitions were held in the California desert; the third, in November 2007, required the robots to operate in an urban area, obeying traffic laws and avoiding collisions.

Although he hails that accomplishment, Lukasik warns that without presidential challenges, DARPA is in danger of working on problems that are technologically interesting but not important to the nation. "Once you move in that direction," he says, "you move in the direction of more detail, and if that's the case, you run the risk of becoming irrelevant because your measure of survival is political adroitness rather than technical excellence and solving important problems." ■

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also differs from DARPA in another key area: its budget is $60 million a year rather than $3 billion.

A separate challenge for the ARPA spin-offs is whether they have enough access to key leadership in their areas. "For any organization to have a chance to be as successful as DARPA, it has to report to the very top of the organization," says current DARPA director Anthony Tether. That's not the case at the intelligence or homeland-security ARPAs. "I don't think people understand just how important it is for the director to report directly to the top and have the flexibility to make key decisions and execute bold, new, technology-driven initiatives," adds George Heilmeier, a former DARPA director.

Another issue for the new ARPAs is deciding what to fund. Citing classification issues, Nixon can speak only broadly on this subject, but he points to cyberspace and biology — particularly synthetic biology and biometrics — as key subjects for the intelligence community. "These are areas that are going to be transforming science and will have a huge impact one way or the other on intelligence," he says. Still, he notes, "if we have an intelligence breakthrough, my fervent hope is that people won't know about it, at least for a while."

Nixon, however, does say that IARPA will be a new source of funding for the academic community, calling it the "next big game in town" for basic research. Of course, how much money that will be is hard to quantify—IARPA's budget, like most aspects of the US intelligence budget, is secret. "I would think it's in the hundreds of millions of dollars," speculates Jeffrey Richelson, a fellow at the National Security Archive in Washington DC and a long-time expert on the intelligence community's science and technology programme. Although it might be too early to know how academics will view IARPA, the University of Maryland in College Park has agreed to house it, as part of the agency's bid to foster academic collaboration. And this month, IARPA named Lisa Porter, a well-regarded physicist and senior NASA official, as its first director .

The energy ARPA is proving the most polarizing of the new ARPAs (see *Nature* **447,** 130; 2007). Although the legislation creating the agency says that it is meant to "support revolutionary and transformational energy research where risk and pay-offs are high," ARPA-E has no obvious customer. DARPA has the Department of Defense, IARPA has the intelligence community, but ARPA-E faces a complex maze of private-sector industries.

The idea for ARPA-E emerged from a report by the National Academy of Sciences and found support last year in Congress, which passed a bill to create the new agency. But the Bush administration didn't support the proposal, and energy secretary Samuel Bodman expressed concerns about additional bureaucracy and draining money from basic research. Funds for ARPA-E have still not been appropriated, and it's unclear where the money will come from. Martha Krebs, a former head of the Department of Energy's Office of Science, expresses grave doubts about the proposal. "I believe ARPA-E has been born out of a misconception that the defence model can and should work for energy," she says.

Politics, not technology, could eventually prove the downfall of the new ARPAs. DARPA emerged from the extraordinary atmosphere that surrounded Sputnik; six years have passed since the 11 September 2001 terrorist attacks, and the bureaucracy is entrenched, notes John Foster, a former director of defence research and engineering. "The important thing is to recognize what it took to start DARPA and sustain it for 50 years. Do we have those conditions in energy, do we have it in intelligence, in homeland security?" he asks. "No." **S.W.**