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DARPA AT 50

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BLUE SKY THINKING

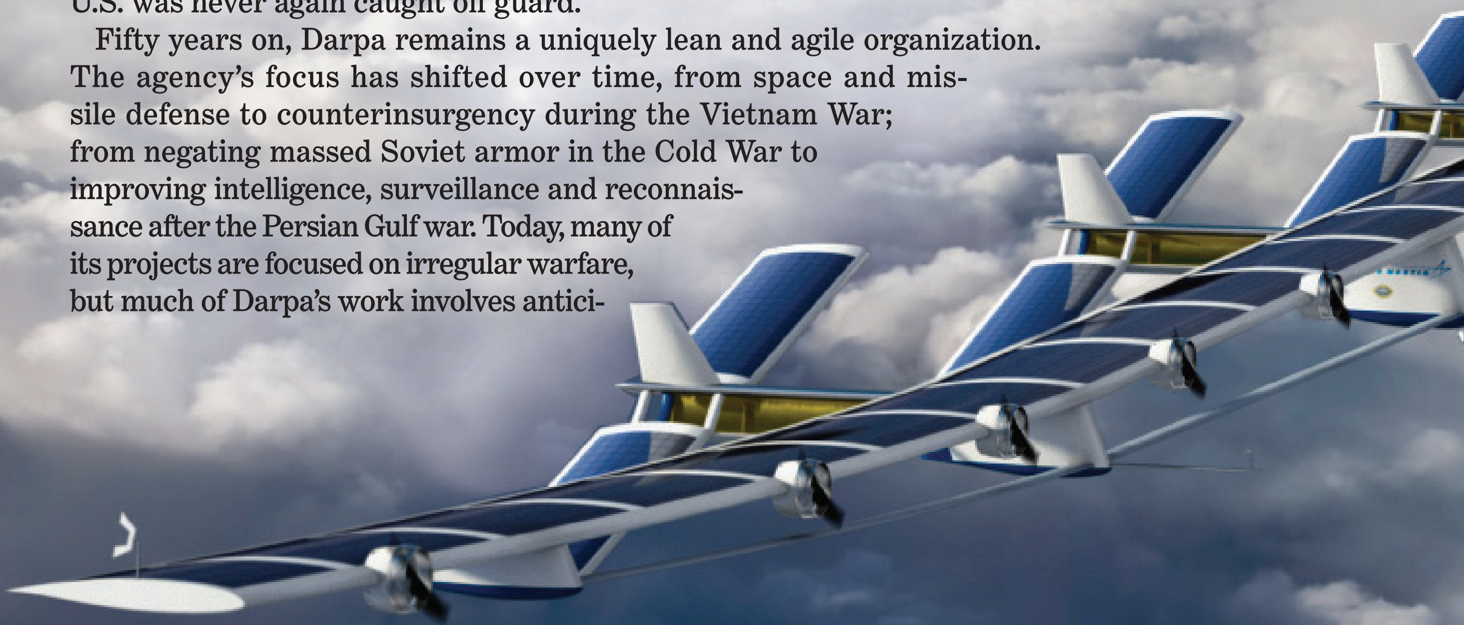
Darpa is 50 years old and still looking 20 years into the future

GRAHAM WARWICK/WASHINGTON and GUY NORRIS/LOS ANGELES

As it enters its sixth decade, the U.S. Defense Advanced Research Projects Agency faces challenges in seeing ahead at a time when the U.S. military's focus is firmly on the present and on fighting two wars.

Established in February 1958 in response to the Soviet Sputnik launch in October 1957, the Advanced Research Projects Agency, as it was originally known, was chartered with "preventing technological surprise." Its initial task was to reorganize U.S. military space programs, but Darpa was also charged with looking into the future to ensure the U.S. was never again caught off guard.

Fifty years on, Darpa remains a uniquely lean and agile organization. The agency's focus has shifted over time, from space and missile defense to counterinsurgency during the Vietnam War; from negating massed Soviet armor in the Cold War to improving intelligence, surveillance and reconnaissance after the Persian Gulf war. Today, many of its projects are focused on irregular warfare, but much of Darpa's work involves antici-



Intended to stay aloft for five years, the Vulture unmanned aircraft exemplifies Darpa's "far side" thinking.

LOCKHEED MARTIN

pating the military's needs for the war after next.

Some of Darpa's ideas can seem crazy, like unmanned aircraft or airships that stay aloft for five or even 10 years, but it's difficult to see 20 years ahead. "If you look at how we use UAVs today in conflict, they are all dreams of Darpa in the mid-1990s," says Stephen Welby, former director of the agency's Tactical Technology Office. "Global Hawk and Predator were born here, but UAVs are still at the Wright brothers' stage. There are new domains and new missions to be explored."

As U.S. operations in Afghanistan and Iraq place heavy demands on military budgets and tight constraints on research and development

The Have Blue stealth demonstrator led to one of Darpa's most successful technology transitions.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY/LOCKHEED MARTIN

spending, Darpa's role in funding science and technology (S&T) work is taking on greater importance. This creates tension between those who want Darpa to solve today's problems and those who recognize the agency does its best work when given the freedom to think about the future.

Darpa responds to perceived needs rather than validated requirements, and this creates tensions with the customers. "We are not captured by the services; we hold the status quo at risk," says Welby. He defends Darpa against criticism that its ideas can be too far-fetched. "We get criticized when we engage stovepipes with new ways of doing things that threaten their way of doing things," a process he describes as "creative destruction."

As Darpa's customer, the U.S. Air Force is aware of the tension. "We are always talking about the difference between requirements pull and technology push. Should we be essentially governed by either?" asks Mark Lewis, Air Force chief scientist. "There was never a requirements document for laser, or even the light bulb for that matter. [But] sometimes there is a need for a reality check."

Darpa's role is not to develop and procure systems, but to "take the technology question off the table" through demonstration, so a concept can be an option to meet a requirement. "We don't do the heavy lifting of delivering a system to the field," says Welby. "You can't go out and buy an aircraft by duplicating a Darpa bird, but you will have the database to design one."

LOCKHEED MARTIN

Blackswift program will demonstrate reusable air-breathing hypersonic technology for the first time.

Darpa casts a wide net for ideas, talking to "anyone, everywhere" from military operators about missing capabilities to laboratory researchers about emerging technologies. Project ideas can arrive as full-blown proposals or one-page white papers—"the envelope someone has drawn the future on," says Welby.

Many project proposals are rejected because they are not "Darpa hard." In talking to operators and researchers, the agency looks for the core technology that's lacking, but too risky for the service laboratories or industry to take on alone.

If projects can be started quickly, they can be stopped just as quickly when results disappoint or a better idea comes along. "We start a lot of things, but we also ruthlessly kill them," says Welby. "It's acceptable to fail as long as we have learned from it. If it succeeds, we get the data; if it fails, we find out it's a path not to take."

The key word in Darpa's name is "projects," says Welby. "A project is something with a defined start, defined finish and clearly defined objectives. Something that can be written on a single piece of paper." The goal is to "prove the feasibility of a concept and take the specific technology risk off the table."

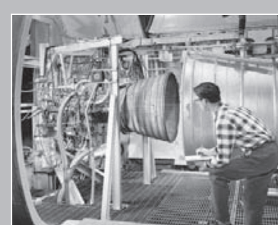
Darpa's strength as an organization is in its structure, or lack thereof. The agency owns no facilities and has no infrastructure that needs long-term programs for support. Instead, it pursues high-risk, high-payoff research through short-term projects with aggressive technical goals. Project managers stay for only four years.

"They are all temporary hires," says Welby, "They are here to get something done. The clock is ticking, and there is personal pressure to advance the state of the art on very aggressive timelines." Welby left Darpa at the end of July after an unusually long 11 years at the agency—first as program manager, then later as office director.

"You can change rapidly and move quickly when

50 YEARS OF DARPA 1958

After the Soviet Union launched Sputnik into orbit in October 1957, the U.S. responded by establishing the Advanced Research Projects Agency (ARPA) in February 1958 to coordinate and accelerate its military space programs. One of ARPA's first actions, in August 1958, was to start development of a large launch vehicle, the Juno V, designed by Wernher von Braun's rocket team. Renamed Saturn I, the clustered-engine booster was almost canceled before it was transferred to the newly created National Aeronautics and Space Administration to become the forerunner of the Saturn V Moon rocket. Also in August 1958, ARPA authorized development of the Centaur liquid oxygen/hydrogen upper stage. This, too, was transferred to NASA when it took over the nonmilitary space program, but Centaur remains in service today as the upper stage on the Atlas V.



25% of your people change out every year," he says. "You would never want to run a business this way, but for preventing technological surprise and being the engine of innovation—it's perfect."

Some Darpa-watchers criticize the short-term project-by-project approach for preventing the agency from staging larger-scale demonstrations of integrated systems, as it has in the past. Such demonstrations have helped transition technology to the services—the metric by which Darpa's performance is often measured, particularly by Congress.

The agency's success in transitioning technologies has varied over the years. Successful transitions include stealth technology, precision-guided weapons and unmanned aircraft, but not all followed a direct path to the customer.

Stealth is the success story most often cited. Darpa began studying low-observable technology in 1974, Lockheed's Have Blue demonstrator flew in December 1977, and the F-117 entered service in 1982. Darpa also funded Northrop's Tacit Blue stealth demonstrator, which flew in 1982 and influenced the design of the B-2 bomber.

In 1982, the Assault Breaker program showed that airborne radars could guide ground-launched missiles to rain precision-guided submunitions on to formations of tanks. But the technology did not transition as an integrated system. Instead, separate service efforts produced the Joint Stars airborne radar, Army Tactical Missile System and Sensor Fuzed Weapon.

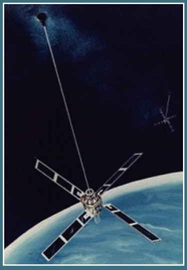
"How well technologies transition has a tremendous amount to do with what the secretary of Defense and President want from Darpa," says Richard van Atta of the Institute for Defense Analyses. Both Have Blue and Assault Breaker had top-level Pentagon support as responses to the Soviet buildup in Europe, he says, with then-Defense Secretary William Perry overseeing the four-year program to develop the F-117.

NORTHROP GRUMMAN

High-level Pentagon support helped ensure that the Global Hawk UAV moved from Darpa to the Air Force.

The story was different for unmanned aircraft, which had no constituency to champion them. While Darpa had demonstrated by the mid-1970s that small UAVs could be used for reconnaissance and targeting, the Army badly fumbled the transition

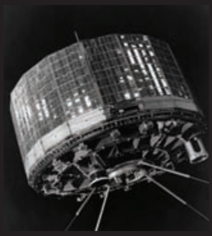
1959



In December 1959, as the U.S. sought to monitor and eventually outlaw atmospheric tests, ARPA took on the Vela program to detect nuclear explosions. The Vela Hotel satellites to detect high-altitude explosions were launched beginning in October 1963 just days after the Partial Test Ban Treaty took effect. The companion Vela Uniform program to detect underground explosions provided a massive funding boost for U.S. seismologists.

ARPA's role as the lead agency for U.S. space programs was brief, but productive. Analysis of Sputnik's signals led the Johns Hopkins University Applied Physics Laboratory to propose the concept of navigation by satellite. Funded by ARPA, the first Transit satellite was launched in 1959; the U.S. Navy operated the system until its retirement in 1996. ARPA also began development of the first weather satellite, Tiros 1, which was transferred to NASA before its launch in April 1960.

1960



ARPA, with the Central Intelligence Agency, jointly funded the classified Corona program to develop a film-return photo-reconnaissance satellite. Operating under the cover of ARPA's Discoverer test program, Corona successfully returned the first spy-satellite photographs in August 1960, and launches continued until 1972.

Ballistic-missile defense was another of ARPA's initial responsibilities. For a decade, under Project Defender, the agency explored advanced BMD capabilities, including space-based interceptors and directed-energy weapons. ARPA's work led to the development of phased-array and over-the-horizon radars.

and canceled its massively overbudget Aquila program, setting back U.S. tactical UAVs by 20 years.

The Darpa-funded Amber medium-altitude endurance UAV flew in 1986, but was not picked up by the military. The design did not evolve into today's Predator until after Desert Storm had highlighted the ISR gap and the Office of the Secretary of Defense had launched an advanced concept technology demonstration program to accelerate the UAV into Air Force service.

The same mechanism successfully transitioned the Global Hawk high-altitude endurance UAV from Darpa to the Air Force. But despite the successful demonstration of the X-45 unmanned combat air vehicle in 2005, the Air Force pulled out of the follow-on Joint Unmanned Combat Air System program, forcing its cancellation.

But flight demonstrators such as Have Blue and Global Hawk are only a small part of the technology Darpa has handed over. "As a measure of merit, transition has been relatively constant," says George Muellner, former president of Boeing's Advanced Systems and Phantom Works units. "A lot of Darpa activity is at a subsystem level, or in the black world, and we are not aware of it."

But Darpa has "had its ups and downs," Muellner acknowledges. Sometimes technologies were not embraced because they were out of step with the need. "Assault Breaker came at the right time, was mature enough, and there were a couple of conflicts it could be applied to," he says. "You have got to have the right environment."

Muellner believes a lot of technologies transition to industry and show up for the first time in a system for which Darpa gets no credit. "I think almost everything we do transitions. Even those that fail leave behind an industrial base or an aerodynamic database that can be used," says Welby.

Advancing S&T work to the next stage is an issue bigger than Darpa. "In the Defense Dept., we have the transition "valley of death" and all the organizations face this issue—how do we transition a useful product?" says Lewis. The valley of death is the 3-5-year funding gap before a capability gets picked up by the services.

Darpa Director Tony Tether has described technology transition as a "contact sport" that requires program managers to build constituencies within the services. "Program managers have to be evangelists," says Welby.

Now Darpa is trying to forge agreements with the services before building a demonstrator. An increasing number of projects are covered by memorandums of understanding that document the transition path. "We'll invest to the point of demonstration if the service will put dollars in its out-year plan to take the technology forward," says Welby. The service laboratories play a key role. "They are the flywheel that keeps us going."

As Darpa looks ahead, "there are lots of opportunities still out there," says Welby. Among them are technologies for the dismounted soldier, precision weapons for UAVs, space architectures, robotics, long-endurance propulsion and environmental power capture. "There is lots of interesting work left for Darpa to do."

To see photographs of demonstrators past and present, visit Darpa's 50th anniversary gallery at:
aviationweek.com/photos

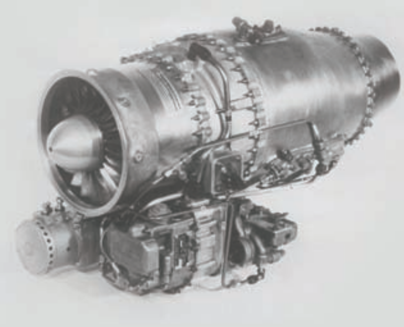
50 YEARS OF DARPA

1961

In 1961, as U.S. involvement in Vietnam escalated, ARPA began Project Agile to develop and test technologies for counter-insurgency warfare. This included field tests of the AR-15 rifle, which became the U.S. Army's M16 assault rifle. ARPA also developed the Camp Sentinel foliage-penetration radar and funded Lockheed to convert two Schweizer sailplanes to QT-2 quiet night surveillance aircraft.

1965

Beginning in 1965, under a joint effort with the Army to extend the range and endurance of the Bell Rocket Belt, the agency funded development of the WR19 small turbofan by Williams Research. This engine was further developed to power the AGM-86 Air Launched Cruise Missile and BGM-109 Tomahawk.



Expanding the Envelope

Darpa's research is pushing the speed, endurance and size limits on air vehicles

GRAHAM WARWICK/WASHINGTON

Supersonic flying wings with variable sweep, rotors that slow or stop in flight, aircraft that maneuver by changing shape, vehicles that cruise hypersonically or loiter indefinitely—all are taking shape as Darpa pushes the edge of the envelope in aeronautics.

Over the years, the agency has helped reshape aviation—literally, with programs such as the Have Blue and Tacit Blue stealth demonstrators changing the way aircraft are designed. Darpa helped initiate X-planes that flight-tested aerodynamic, structural and flight-control innovations including the forward-swept-wing X-29, post-stall maneuvering X-31, supersonic vertical-lift X-35 and tailless X-45 unmanned combat air vehicle.

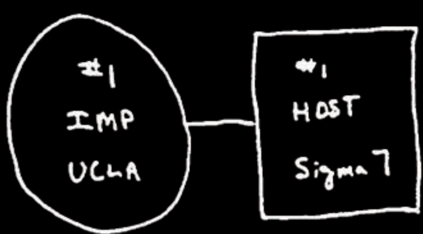
The Oblique Flying Wing (OFW) program has the potential to introduce another new shape. The OFW increases sweep as it accelerates, so the leading edge always stays behind the shockwave and supersonic wave drag is reduced. The aircraft is designed to move seamlessly from low sweep in a subsonic loiter to high sweep in a supersonic dash. But the configuration is tailless and unstable, and flight control is a key challenge.

After completing wind tunnel tests, Northrop

NASA

Advanced composites and flight controls allowed Grumman's forward-swept-wing X-29 to achieve high maneuverability.

1969

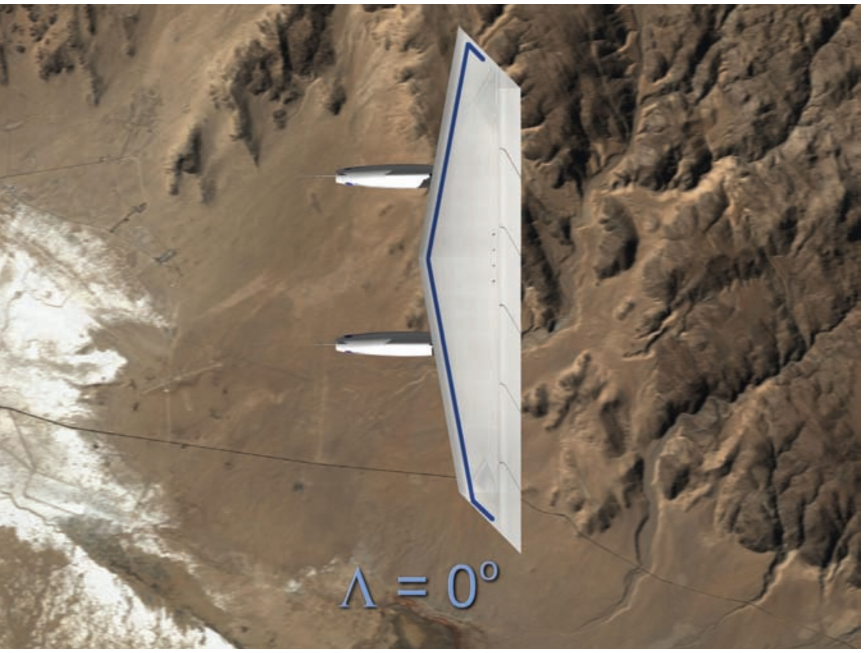


In 1968, ARPA approved plans for a "resource-sharing computer network" to be called ARPAnet. In December 1958, BBN was awarded the contract to build the interface message processors–the first routers–for the packet-switched network, and ARPAnet became operational in 1969, linking four computer research laboratories. As ARPAnet grew and was upgraded, it became known as "the Internet."

1973

After experimenting with remotely piloted vehicles in Vietnam, ARPA in 1971 began the Mini-RPV program to develop small, low-cost unmanned aircraft for reconnaissance, target acquisition and laser designation. Weighing 75 lb. and powered by a modified lawn-mower engine, the Praerie I first flew in 1973. This led to the U.S. Army's Aquila RPV program, which was abandoned in 1987 after costs had spiraled almost four-fold.

Grumman is waiting to hear if Darpa will approve an unmanned demonstrator to fly around 2010. The 56-ft.-span X-plane would be designed to achieve Mach 1.2 with 65-deg. sweep.



DARPA/NORTHROP GRUMMAN PHOTOS

Northrop Grumman's Oblique Flying Wing sweeps seamlessly from 0 deg. (above) to 65 deg. (opposite) as it accelerates to Mach 1.2.

The agency plans to begin another program to evaluate the Adaptive Morphing Super-Maneuver Aircraft (Amsma), which would combine long loiter endurance, high dash speed and maneuverability by making radical configuration changes in flight. Asymmetric wing sweep, fore and aft wing translation and hingeless aeroelastic controls are all key enablers, says Darpa.

Amsma follows an earlier project that demonstrated inflight shape changing. In late 2006, NextGen Aeronautics' MFX-2 UAV proved it could change the area, chord, sweep and aspect ratio of its flexible-skin morphing wing in flight.

On the high-speed front, Darpa's involvement in hypersonics predates its classified Copper Canyon studies of the early 1980s, which led to the X-30 single-stage-to-orbit demonstrator program. Since the X-30's cancellation, U.S. hypersonics research has focused mainly on expendable missiles. "When I came to Darpa, Director Tony Tether told me to start a reusable program," says Stephen Walker, deputy director of the Tactical Technology Office and manager of the Falcon program. "In the Darpa tradition, that's the harder challenge."

Falcon is one of Darpa's longer-running programs, and has changed significantly since it began in 2003. Aimed at developing technology for a prompt global strike capability from the continental U.S., Falcon had three elements: a small launch vehicle (SLV), common aero vehicle (CAV) and hypersonic cruise vehicle (HCV).

The plan was to demonstrate technology for the CAV and HCV by flying a series of unpowered hypersonic test vehicles (HTVs). The intent was to provide a near-term (2010) global strike capability with the SLV and CAV, and a far-term (2025) capability

50 YEARS OF DARPA

1977

Darpa initiated the study of manned stealth aircraft in 1975, awarding contracts to Northrop and Lockheed to design the Experimental Survivable Testbed (XST). After pole-model tests, the program was transitioned to the Air Force and Lockheed was awarded the contract to build two Have Blue demonstrators. First flight was in December 1977, and led to the F-117 stealth fighter.

1978

One of Darpa's most successful efforts began in 1978 with the Assault Breaker program to integrate airborne radar, ground-launched missiles and self-guided submunitions to provide the capability to detect and destroy second-echelon armored forces at standoff range. The program's Pave Mover ground moving-target indication radar evolved into the Air Force/Army E-8 Joint Surveillance Target Attack Radar System, while the missile became the Army's ATACMS and the munition the Air Force's Sensor Fuzed Weapon.

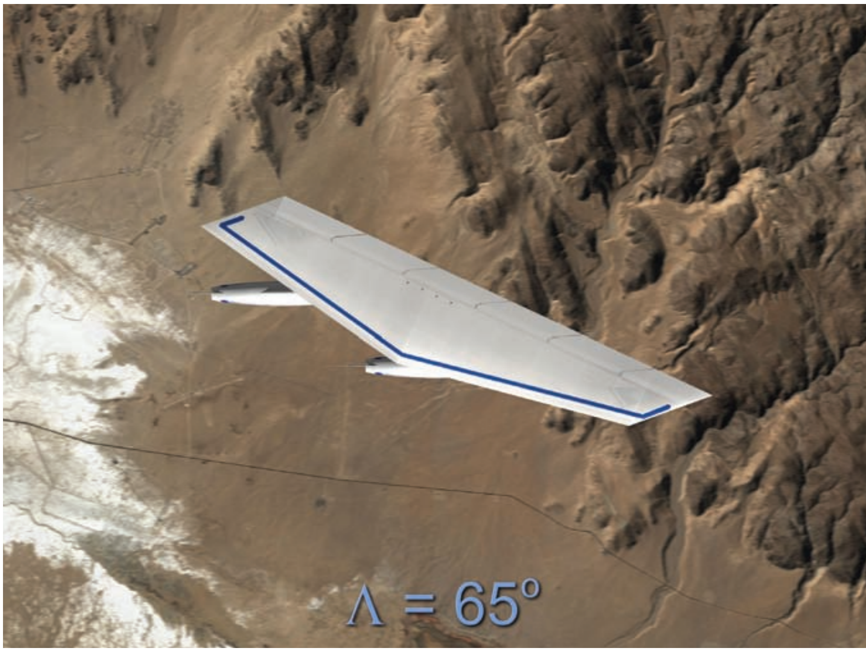
using the unmanned, reusable HCV and CAV. Political and technical challenges intervened. Congress ordered Darpa to stop work on the CAV; the initial HTV-1 proved unproducible; and NASA canceled all its hypersonic propulsion work. Falcon was refocused around flight tests of the unpowered, expendable HTV-2 and design of a new powered, reusable demonstrator, the HTV-3X.

Falcon prime contractor Lockheed Martin plans to fly two HTV-2s in 2009, boosted by Minotaur IV rockets. The Skunk Works is completing conceptual design of the HTV-3X and subscale ground tests of its propulsion system, in which a high-Mach turbojet and dual-mode ramjet/scramjet combine to power the vehicle from the runway to a Mach 6 cruise then back to the runway.

Late in 2007, HTV-3X became a joint program with the U.S. Air Force and morphed into the Blackswift hypersonic testbed. Lockheed Martin, teamed with Boeing and ATK, is believed to be the only bidder for Blackswift, with a contract expected in September leading to a first flight in 2012.

Slightly larger than the Have Blue demonstrators, Blackswift will be powered by high-Mach turbojets developed by either Rolls-Royce or Williams International, and dual-mode ramjets developed by Pratt & Whitney Rocketdyne, with shared inlets and nozzles. Propulsion mode transition is a key challenge, particularly combining the flowpaths over the Mach range during which both turbojet and ramjet are operating.

Separately, Darpa is starting a project to look at how to accelerate a full-scale hypersonic vehicle to scramjet speed. A full-size high-Mach turbine engine would be expensive to develop, so the Vulcan program aims to integrate a current production fighter engine with a constant-volume combustion (CVC) powerplant, such as a pulse-detonation engine. The turbine would operate from rest to its upper speed limit, above Mach 2,



where the CVC would take over and accelerate the vehicle to Mach 4-plus. Under Vulcan, Darpa plans to ground test an integrated turbine/CVC engine with shared inlet and nozzle.

Although the Falcon HCV remains the "vision vehicle," Blackswift could spin off technology for

1981

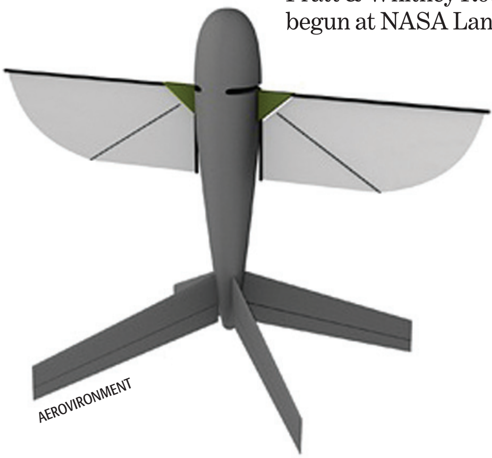
With funding from Darpa, Hughes Helicopters flew an OH-6 modified with its No Tail Rotor (Notar) anti-torque system in 1981. Notar uses circulation control over the tail boom to counteract rotor torque and remains a feature of MD Helicopters aircraft.

1982

The Air Force and Darpa began a program to develop a stealthy battlefield surveillance aircraft with a low-probability-of-intercept radar, and in 1977 Northrop was awarded a contract to build the Tacit Blue demonstrator. First flown in February 1982, Tacit Blue contributed to development of the B-2 bomber. Later, Darpa's Teal Dawn program would develop key technologies for the stealthy AGM-129 Advanced Cruise Missile.

a high-speed missile—an area Darpa is investigating under several other programs. These include the Navy/Boeing HyFly, a Mach 6 air-launched missile demonstrator powered by a dual-combustion ramjet. The two planned tests failed, but Darpa has agreed to fund a third flight in 2010.

Darpa is also supporting the Air Force/Boeing X-51A WaveRider rocket-boosted, hydrocarbon-fueled scramjet demonstrator. Ground tests of the Pratt & Whitney Rocketdyne SJX61-2 engine have begun at NASA Langley, aiming for a first flight in 2009. The missile-size X-51 is designed to demonstrate scramjet operation from Mach 4.5 to 6.0-plus.


AEROVIRONMENT

AeroVironment's 3-in.-span Nano Air Vehicle will weigh less than 10 grams, including its 2-gram payload.

Both HyFly and X-51 technologies could be contenders for Darpa's new Long-Range Anti-Ship Missile program, which aims to demonstrate a next-generation vertical-launch weapon to replace the Harpoon. The Darpa/Navy project aims to flight-test a prototype within three years.

Over the years, Darpa has returned to the challenge of a high-speed rotorcraft. One of the earliest efforts was the stopped-rotor X-Wing, begun by Lockheed in the mid-1970s and continued by Sikorsky. The project was canceled in 1988, before the demonstrator flew, because of the complexity of the X-Wing's circulation-control rotor. A later attempt fared little better; both of Boeing's X-50A Dragonfly canard rotor/wing (CRW) demonstrators crashed during hover tests. The CRW's reaction-drive rotor was designed to stop in forward flight to form a wing. This effort was terminated after control issues caused crashes in 2004 and 2006.

Undaunted, the agency is funding another high-speed rotorcraft, Heliplane. This aims to demonstrate a 400-mph. gyrodyne—an aircraft in which the rotor is powered for vertical flight and autorotates in forward flight. Challenges include controlling the rotor at high speed—and the noise generated by the rotor blade tip-jets.

Heliplane developer Groen Brothers Aviation was given more time to solve the noise issues, but hit financial problems. So Darpa is to transfer the program to the Georgia Institute of Technology, which had provided much of the analytical horsepower to solve the noise problem.

While it works toward a Heliplane flight demonstrator, Darpa is also looking at the disc-rotor compound helicopter. This has a rotating circular wing with blades that extend for vertical takeoff and landing (VTOL) and retract for forward flight at up to 300-400 kt. The agency plans a subscale demonstrator.

After playing a pivotal role in the development of unmanned air vehicles, including Global Hawk and Predator, Darpa is pushing the envelope for autonomous aircraft to extremes of endurance, speed and size. Key programs are Vulture, designed to stay aloft in the stratosphere for five

50 YEARS OF DARPA

1984

Darpa and the Air Force funded a program to demonstrate that a highly unstable aircraft with forward-swept wing and close-coupled canard could be flown to extreme angles of attack. Grumman was awarded the contract to build two X-29 demonstrators, the first flying in December 1984. The X-29 demonstrated advanced digital flight controls and aeroelastic tailoring of the wing using composites.

1985

Copper Canyon was a classified Darpa program that ran from 1982-85 and led to the X-30 National AeroSpace Plane (NASP). The X-30 was to be an air-breathing, single-stage-to-orbit demonstrator powered by airframe-integrated ramjet/scramjet engines burning liquid hydrogen fuel. The X-30 was transferred to the Air Force, but runaway costs led to its cancellation in 1995.

years; Rapid Eye, a gap-filler UAV to be rocket-deployed anywhere in the world within hours; and Nano Air Vehicle—a 3-in.-span flapping-wing VTOL UAV for urban operations.

The "infinite endurance" Vulture is an example of how Darpa's stretch goals can sometimes strain credulity. "We started out rolling our eyes, but further into it we became convinced it's doable," says John Langford, president of Aurora Flight Sciences, one of three companies working on Phase 1 of the program. Challenges include closing the solar-electric energy cycle through the short days and long nights of winter.

"It's a fundamentally new concept," says Derek Bye, Vulture program manager for the Skunk Works. "It combines aircraft-like operations with satellite-like persistence and reliability." Lockheed Martin, like Boeing, has opted for a launch-once, stay-aloft, ultra-reliable aircraft with greater than 300-ft. wingspan. Aurora's concept has three smaller, modular aircraft that take off separately, then link up. They can be swapped out in flight, easing the reliability requirement.

Darpa sees an autonomous aircraft on station in the stratosphere for five years as a "compelling concept," says program manager Daniel Newman. But the three-month and one-year endurance UAVs planned to be flown as subscale demonstrators in later phases of the program could prove useful in their own right. "In itself, each demonstrator will give residual tactical capability," he says.

Whereas Vulture would act as a relocatable satellite, Rapid Eye will take a different approach, packaging a long-endurance UAV into the nose cone of a rocket and launching it from the U.S. at short notice to fill a coverage gap anywhere in the world within 1-2 hr. Challenges include deploying an inflatable or folding UAV after reentry and powering the vehicle at very high altitude.

Darpa has pushed the size of UAVs ever smaller with AeroVironment's 14-in.-span flying-wing Wasp and Honeywell's 13-in.-dia. ducted-fan MAV micro air vehicles; but the Nano Air Vehicle (NAV) program seeks to shrink UAVs to a scale where birds and insects are the inspiration, not aircraft. At this scale, aerodynamics work differently, and propulsion, navigation, structure and payload must be tightly integrated in a vehicle able to perch like a bird and fly indoors. AeroVironment is to fly a prototype 3-in. flapping-wing NAV.

"We started out rolling our eyes, but further into it we became convinced it's doable"

Other projects are developing enabling technologies. The BioFuels program is demonstrating processes to produce affordable, sustainable alternatives to JP-8 jet fuel from crop oils as well as cellulosic and algal feedstocks. The materials thrust is working to establish a low-cost titanium production capability; develop higher-performing "metallic glass" aluminum alloys with noncrystalline microstructures; and apply nanotechnology to improve carbon fiber, engineer surfaces and heal damage.

To see photographs of demonstrators past and present, visit Darpa's 50th anniversary gallery at:
aviationweek.com/photos

1986

Under the Teal Rain program, Darpa developed the first medium-size endurance UAV. Designed by Abe Karem, the Leading Systems Amber first flew in November 1986 and in June 1988 set an endurance record of 38 hr. The Amber did not transition to the military, and Leading Systems was acquired by General Atomics, which ultimately evolved the vehicle into the Predator UAV.

1988

Darpa awarded Orbital Sciences a contract for up to six Pegasus launches in 1988, and the air-launched booster made its first flight in 1990, becoming the first privately developed launch vehicle. Darpa subsequently sponsored development of a ground-launched variant, the Taurus, as a small satellite launcher, with its first flight in 1994.

Guided by the Light

Research aims to overcome the challenge of fitting a high-energy laser weapon in a tactical aircraft

GRAHAM WARWICK/WASHINGTON

Having played a pivotal role in the development of smart weapons, Darpa is now targeting high-energy lasers for their ability to deliver ultra-precise lethal and non-lethal effects in both defensive and offensive operations.

The challenge the research agency has set is to demonstrate a complete laser weapon system packaged to fit in the bomb bay of a B-1 bomber and have it ready to fly by 2012. This will be the first demonstration of a compact, robust solid-state laser weapon outside the laboratory.

Darpa has had a long involvement in advanced weapons. In 1982, the Assault Breaker program demonstrated a standoff precision strike capability using an airborne radar to locate and track targets and guide a ground-to-ground missile to dispense terminally guided submunitions over an array of tanks.

> **"Precision-guided munitions took the target area from a city block to a single building. Lasers are the next step."**

Twenty years later, the Affordable Moving Surface Target Engagement (AMSTE) program demonstrated the ability to engage vehicles with low-cost standoff precision weapons. AMSTE fused the information from multiple airborne radars and sent real-time target updates to the seekerless weapon in flight via data link.

Darpa's involvement in high-energy lasers goes back even further, and initially focused on developing weapons to shoot down intercontinental ballistic missiles. These included a pair of carbon dioxide electric lasers, Humdinger and Thumper, both powerful but massive and firmly ground-based.

A laser weapon compact and robust enough to fit in a tactical aircraft was originally conceived as part of Darpa's Unmanned Combat Armed Rotorcraft (UCAR) program. UCAR was a follow-on to the agency's successful Boeing X-45A unmanned combat air vehicle demonstration, and was aimed at developing an autonomous rotorcraft able to cooperate with manned helicopters.

Because of the technical challenges, the laser weapon became a separate program— the High Energy Liquid Laser Area Defense System (Hellads)—but UCAR set the weight and volume

50 YEARS OF DARPA

1990

The first international X-plane program began in 1984, when Darpa, the Navy and the German government began the X-31 Enhanced Fighter Maneuverability project to demonstrate the use of thrust vectoring for control beyond the stall. Rockwell and MBB built two X-31s, the first flying in October 1990. In addition to advanced flight controls and thrust vectoring, the X-31 featured a cranked-delta wing and close-coupled canard.

1997

In 1997, Darpa began a program to develop micro air vehicles (MAVs). Several designs were tested, including AeroVironment's flying-wing Black Widow. This led, via the Hornet, to the Wasp MAV, developed versions of which are now operational. Darpa also funded Honeywell's ducted-fan MAV, which has been selected as the Class I "backpackable" UAV for the Army's Future Combat Systems.

constraints on the system, says Don Woodbury, Hellads program manager. He was also the program manager for UCAR, which was canceled in 2005 when the U.S. Army lost interest.

Hellads has faced its own challenges. "When we started in 2003, we expected to finish in four years," says Woodbury. "The vendor base proved very shallow. We have had to spend time developing and maturing components to get the reliability and performance, but we are nearing the end of the road." A ground demonstration is now planned by 2011.

The objective is to demonstrate a 150-kw. laser weapon system packaged to fit in one of the B-1's three weapons bays. Requirements include a weight of less than 5 kg. (11 lb.) per kilowatt and volume less than 3 cu. meters (106 cu. ft.). This size will allow the B-1 to carry conventional weapons in the other two bays while adding the laser's defensive and offensive capabilities.

An electric laser, Hellads consumes only aircraft power and ambient air. The weapon is designed to be small enough to be installed on a tactical aircraft and still allow the platform to perform its other missions. It could be carried on a gunship, tanker or command-and-control platform "and take up just a corner of the aircraft," says Woodbury.

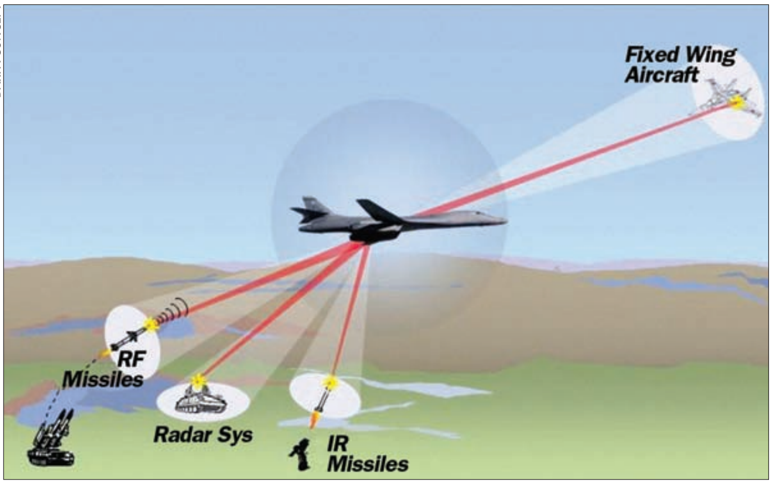
Under Hellads, General Atomics and Textron are developing competing designs for the unit cell laser modules that form the building blocks of the system. Subscale tests have demonstrated unlimited run time, and laboratory tests of full-scale modules are building up to full power-level tests in 2009.

"If we demonstrate the modules, we reduce the risk. Then we can replicate additional modules to produce the laser," says Woodbury. General Atomics uses two 75-kw. modules, while Textron uses three 50-kw. modules. In each case, they plug together to produce a single 150-kw. laser resonator. "There is no beam combining," he says.

Plans call for one of the two designs to be selected for a laboratory demonstration of the full-scale 150-kw. laser in the third quarter of 2010. The laser will then be delivered to the U.S. Air Force Research Laboratory for integration with the rest of the weapon system.

Lockheed Martin is designing the weapon sys-

DARPA CONCEPT



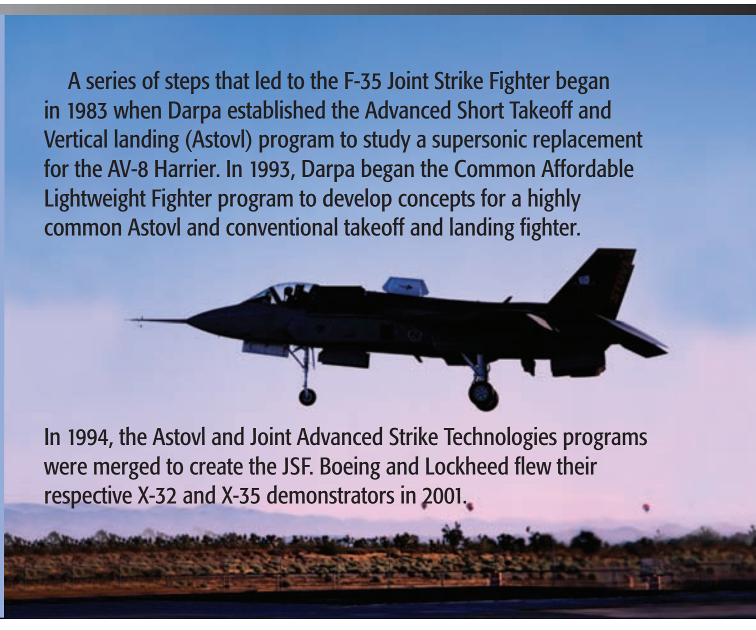
Mounted in one weapons bay, Hellads would allow the B-1 to engage air and ground targets with lethal and non-lethal effect.

1998

Under the Teal Rain program, Darpa funded flight tests of Boeing's Condor high-altitude endurance (HAE) UAV beginning in October 1988. Despite exceeding 67,000 ft. altitude and flying for 58.2 hr., Condor did not proceed, but it proved the concept. In 1995, Teledyne Ryan won the Tier II+ HAE UAV contract to develop the single-turbofan RQ-4 Global Hawk. First flight was in February 1998, and the demonstrators were rushed to Afghanistan in late 2001. The Lockheed Martin/Boeing RQ-3 DarkStar, selected as the Tier III- low-observable HAE UAV, flew in March 1996, but crashed. Flying resumed in 1998, but the program was canceled.

2001

A series of steps that led to the F-35 Joint Strike Fighter began in 1983 when Darpa established the Advanced Short Takeoff and Vertical landing (Astovl) program to study a supersonic replacement for the AV-8 Harrier. In 1993, Darpa began the Common Affordable Lightweight Fighter program to develop concepts for a highly common Astovl and conventional takeoff and landing fighter.



In 1994, the Astovl and Joint Advanced Strike Technologies programs were merged to create the JSF. Boeing and Lockheed flew their respective X-32 and X-35 demonstrators in 2001.

tem, which includes the beam director, targeting subsystem, power supply and thermal management. Darpa's goal is to simplify the overall weapon system, avoiding the complexity of targeting lasers and producing a reliable and compact weapon.

Risk-reduction testing on the weapon system is planned for 2009, in parallel with development of the laser modules. They will come together in 2010, ready for ground tests in 2011. These will include a defensive demonstration of the system's ability to shoot down two SA-10-class surface-to-air missiles in flight simultaneously.

Lethal and non-lethal offensive capability against a range of ground targets will also be tested. "We will demonstrate the ability to disable or destroy a vehicle by dialing in a power level or dialing in an effect," says Woodbury.

The Darpa program will end with the ground demonstration, but the laser weapon system is designed for flight testing. "The Air Force has agreed to fund an airborne demonstration, which we will be ready to do in 2012. Current funding will not allow that, so it will be a later date," he says.

An integrated laser weapon system will require continuous, high power generation and heat rejection, but that is outside the scope of the Hellads program. For the demonstration system, power will be provided using an electrical battery and heat removed using a thermal battery. Sized for a number of shots, the electrical battery will be recharged from aircraft power at the same time as heat stored in the thermal battery is dissipated.

Hellads will be able to run continuously for as long as power and cooling are available. "We have demonstrated the capability in the laboratory to run as long as we want," says Woodbury.

Operationally, this "deep magazine" capability could allow a non-stealthy aircraft like the B-1 to penetrate and operate in defended airspace until the enemy runs out of missiles or the aircraft runs out of fuel. Darpa believes the laser weapon's capability could provide a path to more affordable platforms that require less stealth and speed.

"Precision-guided munitions took the target area from a city block to a single building. Lasers are the next step," says Woodbury. "We will be able to put a spot a few inches across on a target a long way away with lethal through non-lethal effect. It will be the same kind of revolution in military affairs as PGMs."

LOCKHEED MARTIN

Assault Breaker proved missiles could destroy massed tanks at long range by dispensing precision-guided submunitions.

50 YEARS OF DARPA

2003

Under Darpa's Quiet Supersonic Platform program, Boeing, Lockheed Martin and Northrop Grumman in 2000 began studying a long-range aircraft with low sonic boom allowing unrestricted supersonic flight over land. In August 2003, Northrop's Shaped Sonic Boom Demonstrator, an extensively modified F-5, proved that an aircraft could be designed to shape its shockwave signature and so reduce the sonic boom.

2005

Instrumental in the development of UAVs, Darpa took the next step in 1998 when it began the Unmanned Combat Air Vehicle (UCAV) program. Boeing's Phantom Works was awarded a contract to build two tailless X-45A UCAV demonstrators, the first flying in May 2002. In July 2005, the two X-45s demonstrated the preemptive destruction of enemy air defenses, autonomously detecting and avoiding threats and replanning and coordinating attacks. The follow-on Joint Unmanned Combat Air Systems program was canceled in 2006, but the Navy is continuing with a carrier-based UCAS demonstration.

Seeking the Unseen

Sensor research is focused on finding and tracking elusive and evasive targets

GRAHAM WARWICK/WASHINGTON

A review of Darpa's research portfolio suggests its ideal sensor has the range of radar and resolution of electro-optics, can see through trees and walls to track vehicles and people and is small enough to fit into an unmanned aircraft.

Within Darpa, the search for better sensors has taken over from the development of new platforms. That work is largely behind it. In the mid-1970s, under its Mini-RPV program, the agency demonstrated small unmanned air vehicles could be used for reconnaissance and targeting, although it would take the intended customer, the U.S. Army, two decades to field a tactical UAV.

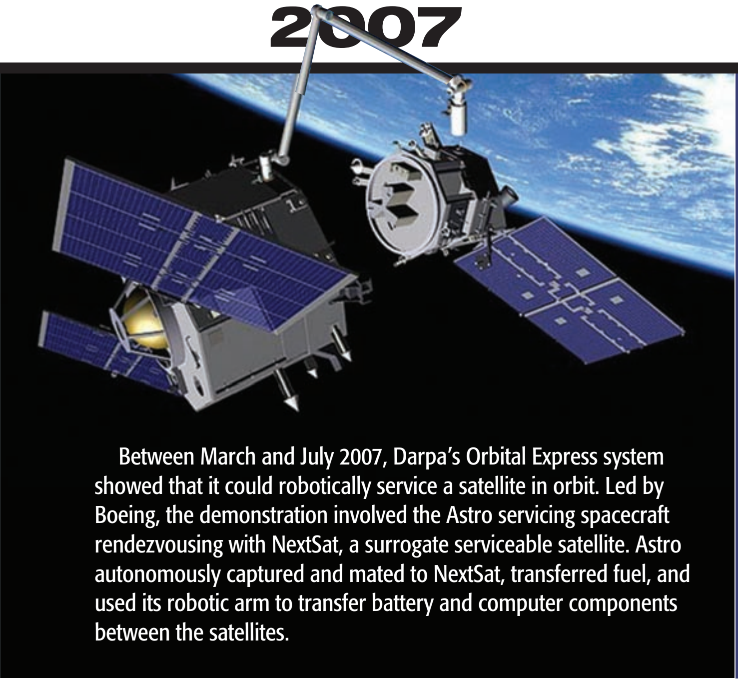
Darpa then developed the long-endurance UAV, the Leading Systems Amber, which flew in 1986 and eventually led to the General Atomics Aeronautical Systems Predator. A decade later, the High Altitude Endurance program produced the Northrop Grumman Global Hawk. Most recently, the agency demonstrated the first long-endurance unmanned rotorcraft, Boeing's A160T Hummingbird, which stayed aloft for 18.7 hr. Much of Darpa's research is aimed at developing better sensors for these platforms, to exploit their potential for persistent surveillance and tracking.

LOCKHEED MARTIN CONCEPT

ISIS would integrate a massive radar array into a stratospheric airship able to stay aloft for 10 years.

The Affordable Adaptive Conformal ESA Radar (Aacer) is a small, K_a-band, active electronically

2007



Between March and July 2007, Darpa's Orbital Express system showed that it could robotically service a satellite in orbit. Led by Boeing, the demonstration involved the Astro servicing spacecraft rendezvousing with NextSat, a surrogate serviceable satellite. Astro autonomously captured and mated to NextSat, transferred fuel, and used its robotic arm to transfer battery and computer components between the satellites.

2008

Amber designer Abe Karem approached Darpa in 1998 with a concept for a long-endurance unmanned rotorcraft with a rigid optimum-speed rotor able to vary its speed to minimize fuel consumption. The A160 Hummingbird first flew in January 2002. Boeing acquired its developer, Frontier Systems, in 2004 and in May 2008 the turbine-powered A160T demonstrated an 18.7-hr. endurance with a 300-lb. payload.

scanned array (AESA) aimed at the A160. Developed by Raytheon, the 110-lb. sensor provides targeting-quality synthetic-aperture radar (SAR) imaging and ground moving-target indication (GMTI) with dismount detection, while also using the array for wideband communications. Aacer is to fly on a Black Hawk helicopter.

Designed to be carried under the wing of a Predator-class UAV, the Vehicle and Dismount Exploitation Radar (Vader) is a podded SAR/GMTI radar capable of tracking vehicles and individuals and detecting the planting of roadside bombs. Developed in 18 months by Northrop Grumman, and packaged into a Hellfire missile-sized pod, the AESA is being flown on an Islander testbed and could be deployed to Iraq for operational testing (AW&ST July 28, p. 62).

While Aacer and Vader can track moving targets, Darpa's Foliage Penetration Reconnaissance, Surveillance, Tracking and Engagement Radar (Forester) has the task of denying concealment to people and vehicles moving under tree cover. The UHF-band radar can penetrate foliage and, when mounted under a hovering helicopter, can track slow-moving targets. With the aircraft flying into the wind to maintain near-zero ground speed, the goal is to detect people under foliage at 30-km. (18.6-mi.) range.

Built by Syracuse Research, the 21-ft.-long antenna has been flown on a Black Hawk, but pilots found it hard to maintain a low ground speed. Boeing is preparing to fly Forester on the A160, which has the advantage of being unmanned, with long endurance and retractable landing gear. The latter feature will allow the radar to stay pointed at the target area as the aircraft keeps aligned with the wind.

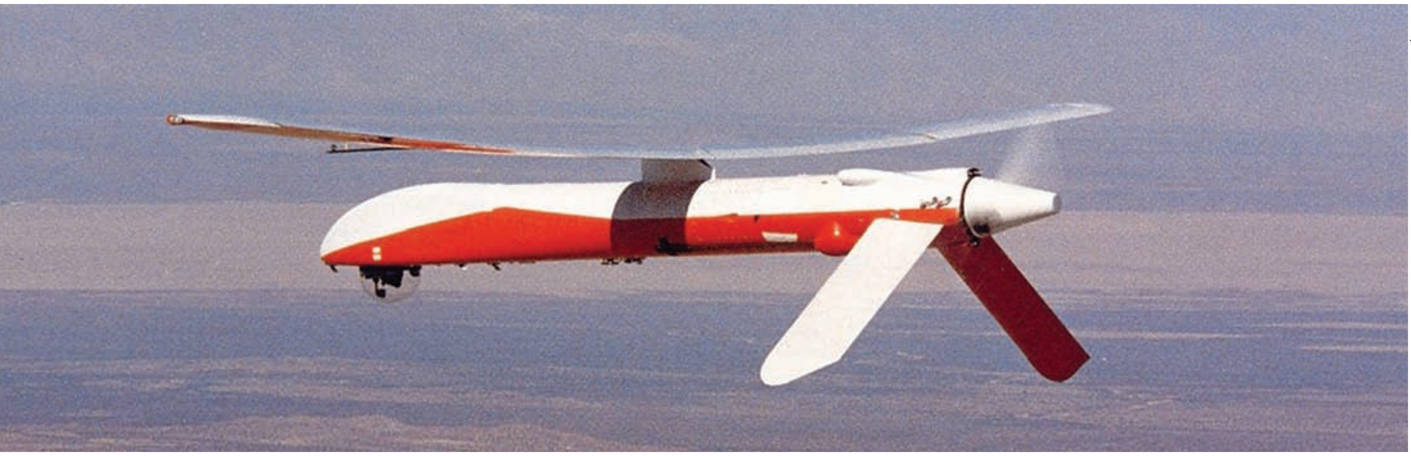
Darpa's Jigsaw program is demonstrating the capability to see through foliage and camouflage using high-resolution laser radar (ladar) to produce three-dimensional images of hidden targets. After imaging the target from multiple angles using a flash ladar, Jigsaw software can remove the concealing cover. The system has been test-flown on a UH-1 helicopter, but the objective platform is a small, vertical takeoff and landing UAV.

Finding targets hidden underground, such as in bunkers and tunnels, is the focus of other programs. Airborne Tomography using Active Electromagnetics (Ataem) aims to find and map underground facilities by illuminating the ground with electromagnetic energy and looking for distortions of the electric and magnetic fields. BAE Systems is to demonstrate the sensor towed behind a helicopter.

The Low-Altitude Airborne Sensor System (LASS) program is developing passive sensors that could be carried by manned or unmanned aircraft to detect and map hidden or underground facilities both before and after strikes. The acoustic, electromagnetic and gravity gradiometer sensors require extremely low-noise platforms and Darpa is looking at a UAV or a manned helicopter towing a payload.

Electro-optical sensors with radar-like tracking and targeting capabilities are another area of Darpa research. Programs include Standoff Precision Identification in 3D (SPI-3D), a laser imaging sensor designed to provide optical-quality geolocation of ground targets at radar stand-off ranges. Under development by General Atomics for integration into the Predator's MTS electro-optical/infrared sensor, SPI-3D provides laser ranging to every pixel in the sensor image, to perform 3D imaging at ranges exceeding 10 km. for target identification and geolocation. Flight tests are planned for 2009.

With the Global Hawk as the objective platform, the Synthetic Aperture Ladar for Tactical Imaging (Salti) program is demonstrating the electro-optical equivalent of synthetic-aperture radar. SAR can operate at long range and in all weathers, but interpreting the radar imagery requires specialist skills. Salti produces photo-real-



DARPA/LEADING SYSTEMS

Amber pioneered the long-endurance unmanned air vehicle and provided the basis for today's Predator.

istic imagery with the high resolution and ease of interpretation of an electro-optical sensor. Also, unlike SAR, synthetic-aperture ladar can work in urban areas.

Under previous phases of the program, Northrop Grumman and Raytheon flight-tested different sensor designs, producing the first airborne synthetic-aperture ladar images. While Raytheon tested a 1.55-micron wavelength ladar using off-the-shelf fiber laser technology, Northrop Grumman tested a 9.11-micron carbon dioxide laser that was less mature, but less sensitive to platform vibration and atmospheric turbulence. Work is underway to increase ladar power and performance for long range, and to shrink the system into a pod for flight testing.

One drawback to Salti is the ladar's narrow field of regard, which requires it to be cued by another sensor. Under other programs, Darpa is working on wide field-of-view electro-optical sensors that provide a search-and-surveillance capability similar to radar.

The Autonomous Real-time Ground Ubiquitous Surveillance-Imaging System (Argus-IS) is designed to provide persistent video surveillance over a large area using a gigapixel sensor and ultra-fast processor to generate multiple high-resolution windows within its wide field of view. The BAE Systems sensor can produce at least 65 windows at a 12-Hz. video rate while also providing image chips of vehicle-sized moving targets across its full field of view—which from 20,000 ft. covers around 40 sq. km.

The airborne portion of Argus-IS will be carried in a pod under an A160 for the demonstration. The video sensor has four sets of optics and a total of 368 5-megapixel focal-plane arrays, connected by fiber optic cables to 16 image-processing modules. Ground users trying to find and track targets will send requests for windows to the airborne processor, which will generate and downlink the video streams in real time.

The Large Area Coverage Optical Search-while-Track and Engage (Lacoste) program aims to provide continuous tracking of moving vehicles in urban areas using a high-altitude airship or long-endurance UAV equipped with a lensless wide-angle infrared sensor. This uses a technology known as coded aperture imaging. An array of pinhole apertures is electronically controlled to vary the direction and resolution of the sensor. Lacoste's 90-deg. field of regard can be scanned rapidly to track up to 10,000 vehicles in search-while-track mode, while providing precision tracking of around 100 targets. Lockheed Martin and Qinetiq are working toward rooftop sensor tests in 2009.

While Argus-IS and Lacoste will allow unmanned aircraft and airships to provide long-duration surveillance and tracking, Darpa's Integrated Sensor Is Structure (ISIS) aims to demonstrate perhaps the ultimate in persistence.

DARPA/BOEING

Designed to track moving targets through foliage, Forester will be flown under an A160 unmanned helicopter.

ISIS is an autonomous, solar-powered airship able to stay aloft in the stratosphere for years, with extremely large, ultra-lightweight radar arrays integrated into its structure providing simultaneous air and ground surveillance. The massive UHF- and X-band arrays would provide the capability to track stealthy cruise missiles out to 600 km. and moving soldiers out to 300 km.

Lockheed Martin and Northrop Grumman are competing to build a subscale demonstrator. A cross between a satellite and a UAV, ISIS is intended to be launched from the U.S. to stay aloft unattended for at least 10 years, after which it would be discarded.

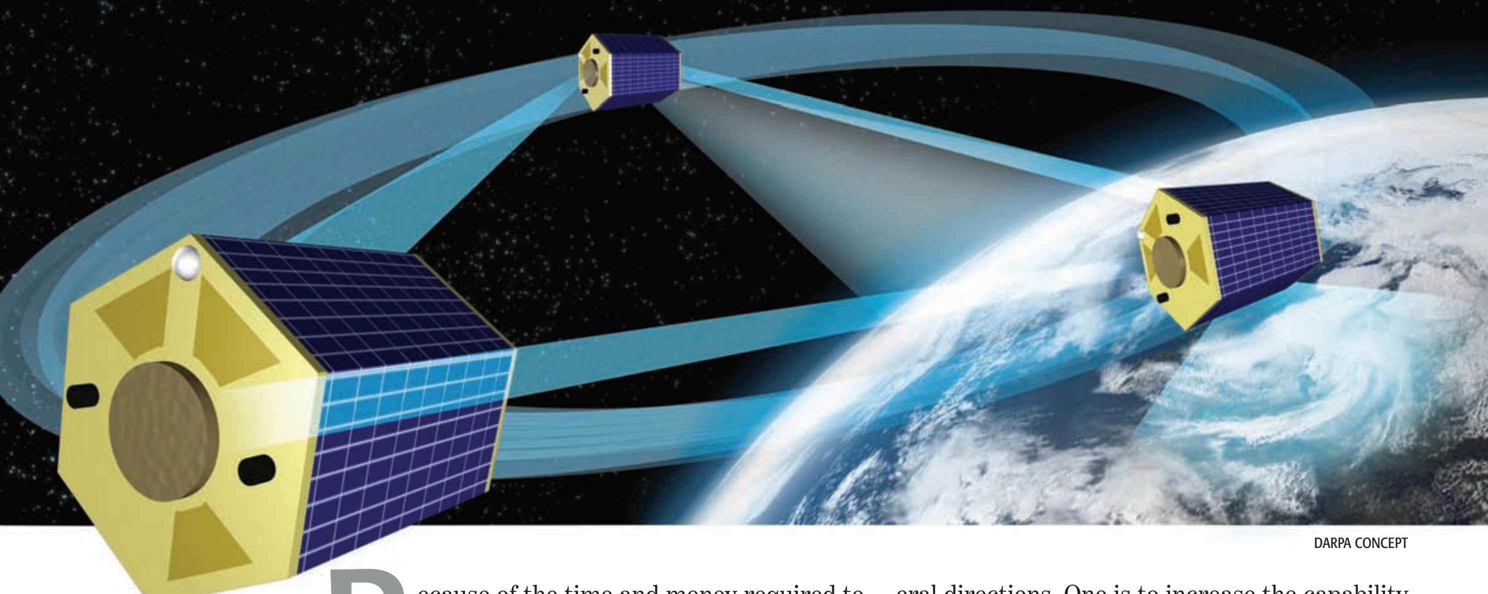
In addition to new sensors, Darpa is developing ways to network sensors to provide new capabilities. The NetTrack program is developing the capability to share vehicle "signatures" between networked radars. By exchanging radar features between sensors, the system will be able to compare signatures before and after a confusing event to keep track of target vehicles, providing long-term tracking to analyze their behavior and re-engage them hours later. Real-time networked radar demonstrations are planned for 2009.

The Multipath Exploitation Radar (MER) program seeks to extend the range of airborne sensors by using the radar energy reflected off buildings into the streets to track moving targets in the shadows of urban canyons. Exploiting these multipath bounces could extend the area coverage of an airborne radar by a factor of 10 or more over line-of-sight limitations and allow a large city to be covered by a handful of platforms. A demonstration is planned for 2009.

Rethinking Space

To make space systems more flexible, Darpa wants to change their design

GRAHAM WARWICK/WASHINGTON



DARPA CONCEPT

Because of the time and money required to develop satellites, and the costs and risks in launching them, Darpa is trying to change the way we think about space. The agency is focusing on demonstrating technology for quicker, cheaper launches of smaller satellites that can cooperate in orbit.

Darpa was on the starting line for the space race sparked by Sputnik's launch, and its few months as lead agency for U.S. space programs saw the start of the Saturn launch vehicle and Centaur upper-stage programs, and development of the first navigation, reconnaissance and weather satellites. Now it is trying to break the mold it helped create.

"Darpa was born from a crisis in the use of space," says Stephen Welby, outgoing director of the agency's Tactical Technology Office. "Now we are rethinking how we do space—how we can deliver capabilities in a cost-effective, responsive way." This involves reconsidering the fundamental architectures and capabilities of space systems, he says.

Today most military satellites take years to develop, cost hundreds of millions of dollars to build and launch and must operate unattended in orbit for years, their operational lives often determined by fuel exhaustion rather than component failure. They represent a huge investment that can be lost on a single launch or destroyed by an anti-satellite weapon.

Darpa is approaching the problem from several directions. One is to increase the capability of smaller, cheaper satellites with bigger payloads and more power. Another is to service satellites on orbit, refueling, repairing and updating them in space to extend their lives. Yet another is to replace large, monolithic satellites with constellations of simpler, free-flying microsats launched and replaced quickly and inexpensively.

Through the small launch vehicle (SLV) part of its larger Falcon program, Darpa has sponsored development of lower-cost boosters with quicker turnaround times by start-up companies Space Exploration Technologies (SpaceX) and AirLaunch. The SLV program has the goal of delivering 1,000 lb. to low Earth orbit (LEO) within 24 hr. for $5 million.

The agency funded SpaceX's first two Falcon I launches, both of which failed but were judged to have met the objective of demonstrating responsive launch operations. AirLaunch has drop-tested a model of its QuickReach booster from a C-17 and is now preparing to ground-test its second-stage propulsion system.

Looking for even faster and less costly launches, Darpa plans to demonstrate that modified missiles, like the AIM-120 Amraam, can boost 1-10-kg. (2.2-22-lb.) "nanopayloads" into LEO within hours for a target cost of $100,000 per sortie. The NanoPayload Delivery program aims to develop high thrust-to-weight microscale liquid rocket engines for the first and upper stages of launchers based on modified air- or surface-launched missiles.

System F6 aims to create a virtual satellite by wirelessly networking formation-flying microsats.

Nanopayloads are only intended to remain in orbit for weeks or months, but the concept of replenishing a satellite to extend its life on orbit was proved by Darpa's Orbital Express program. Between March and July last year, Boeing's servicing satellite, Astro, demonstrated it could autonomously rendezvous with, approach, capture and mate to Ball Aerospace's surrogate serviceable satellite, NextSat, then transfer fuel and components between the spacecraft.

Although Orbital Express demonstrated the feasibility of on-orbit replenishment and repair in low Earth orbit, it used special interfaces that have to be designed into both the servicing and client spacecraft. Because of the lead times for building and launching satellites, it is expected to be at least five years before an operator can adopt the technology.

Darpa, meanwhile, is taking the next step and developing means to service existing satellites not designed for the purpose, particularly in higher orbits. This involves the Front-end Robotics Enabling Near-term Demonstration (Frend), which is devising a prototype manipulator able to grapple a satellite using launch interfaces found on all spacecraft, such as adapter rings and bolt holes.

Frend is demonstrating the "front end" for a spacecraft able to autonomously capture a GEO satellite for repair, rescue, repositioning, reboosting or retirement. Stereo imaging and a robotic arm provide the "hand-eye" coordination. With ground testing of the Alliance Spacesystems-developed robotic manipulator complete, Darpa and the U.S. Navy are looking for a demonstration mission late this decade.

Operations in geosynchronous orbit are of particular interest to the military, and the focus of Darpa's Fast Access Spacecraft Testbed (FAST) program. This aims to demonstrate the power generation system for an electrically propelled satellite able to move rapidly around the GEO belt, and within the super-synchronous "graveyard," to inspect, repair or reposition spacecraft.

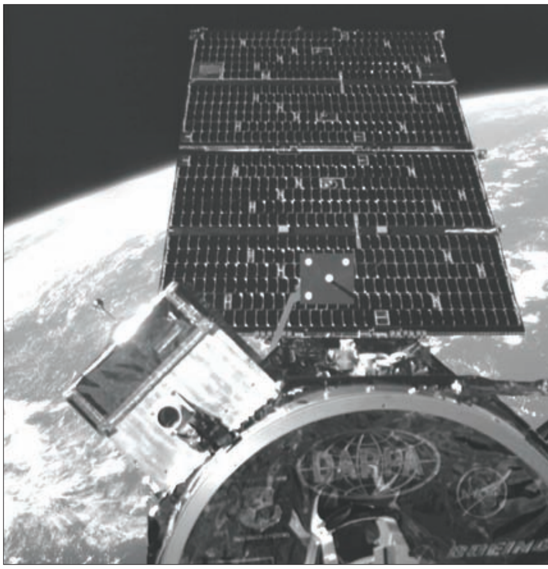
Boeing and Hamilton Sundstrand have received contracts for the six-month first phase of the FAST program, involving preliminary design of a high-power generation subsystem using large deployable arrays to concentrate the Sun's energy onto small solar panels. Darpa's goal is a specific power of 40 watts per kilogram for the spacecraft—more than 10 times that of current satellites and enough for a spacecraft to lift itself from LEO to GEO in 30 days and move halfway round the GEO ring in seven days.

Darpa sees several "compelling" missions for FAST, including using Orbital Express or Frend technology for GEO satellite servicing and repositioning. The spacecraft would have the mobility to reach objects of interest in high orbit and investigate them at standoff range using high-power radar or lidar. It would also have the capability to maneuver rapidly in orbit to respond to and diagnose satellite anomalies.

Maneuverability is also a theme of the agency's High Delta-V Experiment (HiDVE) program to demonstrate a small, light, solar thermal propulsion engine for satellites weighing about 15 kg. The system would increase nanosatellites' orbital range and allow them to be moved from less-than-optimal insertion points to their intended orbits.

A solar thermal rocket uses the Sun's energy to directly heat the propellant. Pratt & Whitney Rocketdyne is to ground-test the engine under a six-month contract awarded in June, while SpaceDev is continuing with design of the nanosat bus.

Many of these technologies come together in one of Darpa's most challenging space programs, System F6, which aims to prove that a traditional satellite can be replaced by wirelessly networked modular spacecraft flying in formation, each launched and replaced individually to repair and upgrade the "virtual satellite" in orbit.



DARPA/BOEING

Orbital Express demonstrated the ability to refuel and service a specially designed client satellite.

F6 stands for "future, flexible, fast, fractionated, free-flying spacecraft united by information exchange" and is a fundamental rethinking of how space systems are structured. "F6 would replace monolithic satellites with constellations of simpler, free-flying microsats that could be maintained, fueled and serviced on orbit, which would change the reliability requirement," says Welby.

The microsats would be launched separately to rendezvous autonomously in orbit and form wireless data and power networks connecting the physically separate elements into a virtual satellite. Darpa believes this will reduce costs through modularity, reduce risks by spreading the elements over several launches and reduce vulnerability by making the clusters adaptable—able to disperse when threatened, then reform.

In March, Darpa awarded contracts to four teams for the preliminary-design phase of System F6, aiming for a year-long on-orbit demonstration within five years. The program's goal is to produce open interface standards to enable design of future space systems using the fractionated approach.