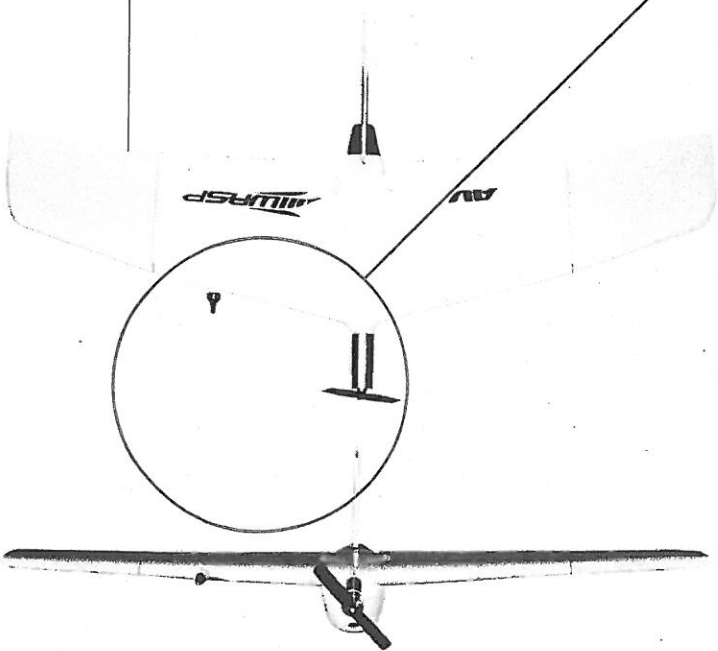


Flight of the Warbots

How a save-the-earth maker of solar-powered aircraft became the world's most prolific manufacturer of military drones



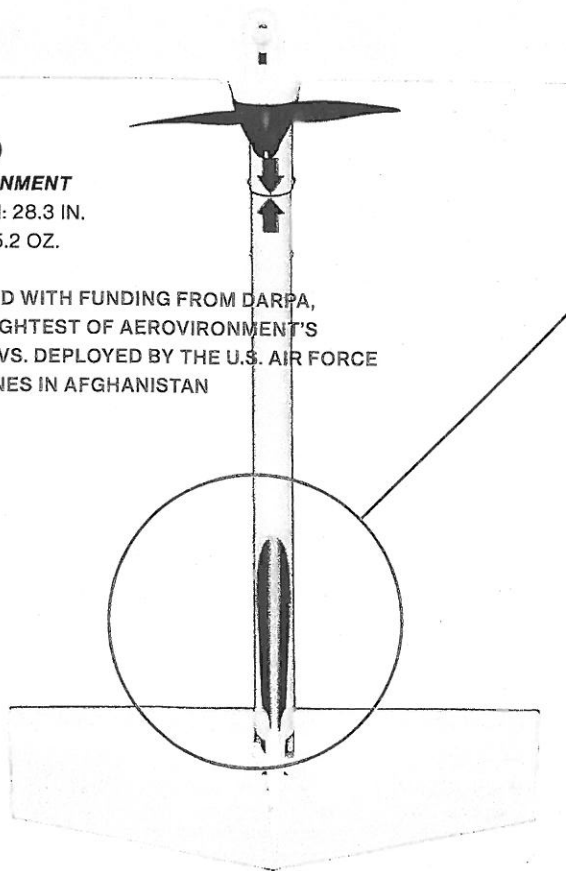
Made from lightweight composites



Wasp

AEROVIRONMENT
WINGSPAN: 28.3 IN.
WEIGHT: 15.2 OZ.

DEVELOPED WITH FUNDING FROM DARPA, IT'S THE LIGHTEST OF AEROVIRONMENT'S ACTIVE UAVS. DEPLOYED BY THE U.S. AIR FORCE AND MARINES IN AFGHANISTAN



By Brad Stone Photographs by David Clugston

Infrared and
electro-optic
cameras

Lands by going
into deep stall

Raven-B

AEROVIRONMENT
WINGSPAN: 4.5 FT.
WEIGHT: 4.2 LB.

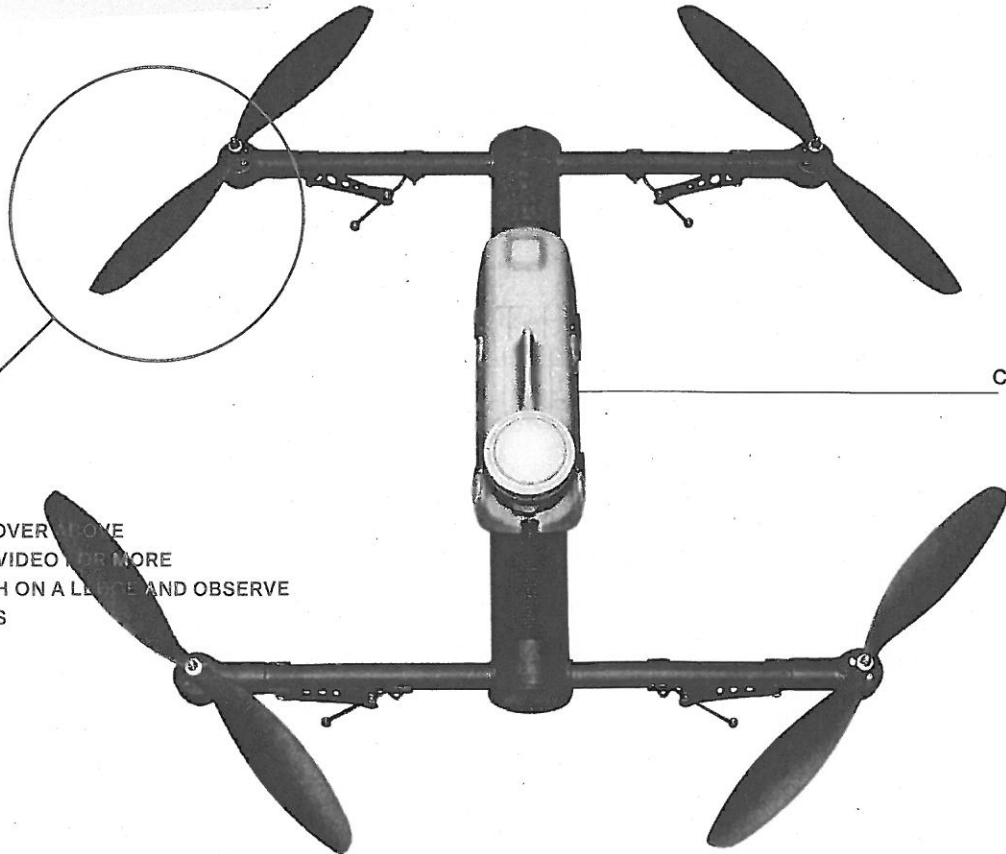
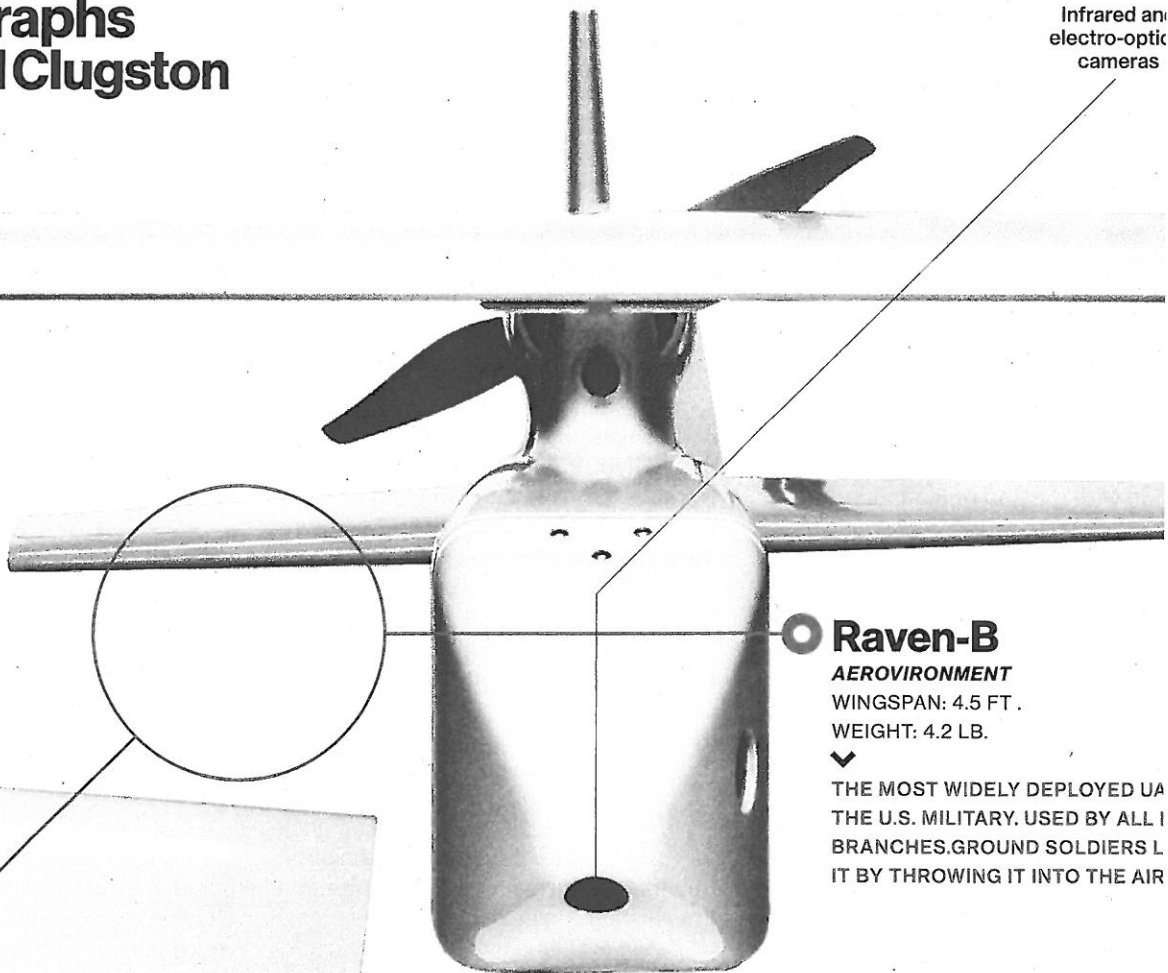
▼
THE MOST WIDELY DEPLOYED UAV
IN THE U.S. MILITARY. USED BY ALL
BRANCHES. GROUND SOLDIERS
LOCATE IT BY THROWING IT INTO THE AIR

Shrike

AEROVIRONMENT
WEIGHT: 2.5 LB.

▼
THE "QUAD COPTER" CAN HOVER TO
FOCUS ON A SCENE AND STREAM LIVE VIDEO FOR MORE
THAN 40 MINUTES OR PERCH ON A LEDGE AND OBSERVE
UNOBTRUSIVELY FOR HOURS

Can travel
30 knot



THE MEMBERS of Apache Troop couldn't see a thing.

It was August 2010, 0200 hours. About 120 U.S. and Iraqi soldiers were silently spreading out over a remote farm in northwestern Iraq. Their objective: a mud hut where, according to intelligence reports, two suicide bombers were planning an attack on a checkpoint to coincide with the end of Ramadan. But the allied soldiers, even wearing night vision goggles, couldn't locate the hut; eight-foot-tall sunflowers obscured their view.

As the troops searched for their target, two U.S. cavalrymen set up on the edge of the squadron, reached into their packs, and withdrew the components of a 4-lb. miniature airplane called the Raven-B. They assembled it in seconds, revved its motor until it buzzed like an angry bee, and threw it into the air. With a handheld control unit, the soldiers put the aircraft into automatic orbit a few hundred feet above the field. Watching the video transmission from the Raven-B's infrared camera, they spotted the hut and directed the plane to light up the roof with an infrared laser, which guided the team through the sunflowers to their target. Without firing a shot, they arrested the saboteurs, who were sleeping inside. The suicide vests were buried nearby in a vegetable garden.

When civilians think of the new class of mechanical warriors aiding troops in places like Iraq and Afghanistan, the high-priced, high-tech airplanes that come to mind have names like Predator and Global Hawk, made by General Atomics and Northrop Grumman, respective-

ly. These unmanned aerial vehicles, or UAVs, operate over the Middle East, conducting in-depth surveillance of potential targets. Some of them are armed. In September, senior al-Qaeda leader Anwar al-Awlaki was killed in Yemen by two CIA-controlled Predators launching Hellfire missiles. On Dec. 4, Iran claimed it recovered a RQ-170 Sentinel, the top-secret stealth drone that was used in the May raid on Osama bin Laden's compound.

But aircraft such as the MQ-1 Predator, which has a wingspan of 49 feet and costs up to \$30 million, constitute only a sliver of America's expanding drone fleet. The rest are portable, far less expensive models like the Raven-B. Made with durable composites and packed with electronics, these smaller devices serve as binoculars in the sky for soldiers on the ground. Small UAVs "provide ground commanders with intelligence that five years ago was only available as a general-officer or corps-level asset," says U.S. Army Captain Keith Benoit, who commanded Apache Troop's assault through the sunflower field. "They in essence saved the lives of my soldiers because we were able to stage the operation covertly."

In 2002, U.S. ground forces brought only a few prototype UAVs into Afghanistan. They allowed soldiers to see around the next village block or over the next hill without having to call up the chain of command for air support. As of July of this year, according to the Defense Dept., nearly 7,000 small UAVs were deployed in Afghanistan and Iraq. "Any time you

Quiet motor

Fold-out wings

empower an individual soldier, seaman or airman with the ability to gather a little bit of reconnaissance information that I control, you empower him to make decisions quickly," says Jeffrey Kline, program director of maritime defense and security research programs at the Naval Postgraduate School in Monterey, Calif. Even as the U.S. military budget declines in the face of ballooning deficits and the wind-down of two wars, spending on unmanned systems has grown from near nothing two decades ago to a projected \$6.2 billion in 2012. Not surprisingly, defense contractors have refocused their efforts. They're preparing for warfare waged by unmanned vehicles—robot controlled by a combination of artificial intelligence and remote human input.

An unlikely industry leader of this explosion of flying robots, and maker of the Raven-B, is a small Los Angeles-area company called AeroVironment. It produces 85 percent of the unmanned aerial systems used by U.S. forces in Iraq and Afghanistan, according to the Defense Dept. Measured by number of units deployed, AeroVironment is America's top maker of surveillance drones. The Army is also funding production of AeroVironment's newest UAV, called Switchblade. Like the Raven-B and AeroVironment's other systems, Switchblade, which is still in development, will fit in a soldier's backpack. But rather than merely spy, this toy-size



A U.S. soldier in Kandahar Province, Afghanistan, launches a Raven drone.

Switchblade

AEROVIRONMENT
WINGSPAN: UNKNOWN
WEIGHT: UNKNOWN

STILL IN DEVELOPMENT. THE KAM DRONE WILL POP OUT OF A TUBE, CONVERT INTO A MISSILE. THE U.S. HAS PLACED A \$4.9 MILLION ORD

Fly,
Find,
Destroy

Fire from tube,
mortar-style

Operator watches
live video

Sees target;
Switchblade
locks on

Drops
bomb

drone can kill: When its operator spots an enemy, Switchblade locks on, turns into a missile, and blows up the target. "I think Switchblade, like our other small UAVs, is going to plug a hole in [the military's] arsenal," says Tim Conver, chief executive of AeroVironment.

In the 12 months ended in April, AeroVironment had revenue of \$292 million, and 85 percent of it came from UAV sales and services. Despite being dwarfed by Boeing or Lockheed Martin, the company has become an important military supplier—although its executives prefer not to put it in those terms. "We think of ourselves as a technology solutions provider, not a defense contractor," says Steve Gitlin, AeroVironment's chief spokesman. Considering where the company came from, that reticence is understandable. AeroVironment got its start in the 1970s developing, of all things, earth-friendly pedal- and solar-powered aircraft. Its 40-year journey from free-spirited eco startup to maker of weaponized UAVs is one of the more radical transformations in corporate history.

AeroVironment was founded in 1971 by Paul MacCready, a legend in aerospace engineering and meteorology. MacCready, who died four years ago, was obsessed with unconventional planes that flew without conventional fuel. In 1977 he created the *Gossamer Condor*, a pedal-

powered craft made of piano wire, Mylar, and old bike parts. An amateur cyclist piloted the contraption through a mile-long figure-8 course and won the \$100,000 Kremer prize, awarded by the Royal Aeronautical Society for achievements in human-powered flight. (A 1978 documentary about the project, *Flight of the Gossamer Condor*, snagged an Oscar.) MacCready's 1979 follow-up, the *Gossamer Albatross*, made it across the English Channel. Both planes hang in the Smithsonian.

While building MacCready's human-powered aircraft on the side, AeroVironment's engineers conducted wind-profile investigations that helped cities and states build the most efficient freeway systems and wind farms. In the '80s, MacCready devoted himself to creating unmanned, sun-powered airplanes such as *Solar Challenger*, which weighed only

205 lb. and repeatedly set altitude a distance records. In 1986 he teamed with Imax to build the first successful wing-flapping airplane—a contraption made to resemble a pterodactyl. "It certainly was a save-the-world type," says his son, Tyler MacCready, who works at AeroVironment and is now a constant to the company, helping it identify new technologies to pursue. "His concern was not wasting resources, especially with something like aerodynamic drag on a vehicle. All you needed to do was change the design of a car, and it could run on less power."

In the 1990s, AeroVironment was a major supplier of technology for General Motors' electric vehicle program. During the recession of the early '90s, when GM lost money and retrenched, MacCready and Conver had to offer their homes as collateral to preserve AeroVironment's line of credit. The relationship was scuttled back after GM produced the Impact concept car, a predecessor to the ill-fated L-Series (later recalled, and made famous in the other award-winning documentary, *Who Killed the Electric Car?*) AeroVironment turned its technology into a line of fire-charging stations that it still sells to industrial customers.

The company had long toyed with parlaying its expertise in electric vehicle and airplane design into miniature surveillance planes for the military.

"We think of ourselves as a technology solutions provider, not a defense contractor"

From a workshop in Simi Valley, 45 minutes northwest of L.A., AeroVironment developed the concept for almost two decades, at times drawing funding from the Marine Corps and the Special Operations Command. "We never ran across a current or former forward observer that didn't think it was a good idea," says Conver, "even though we couldn't quite get the concept sold."

That changed in the years after 9/11. The Pentagon, embroiled in two wars, became much more interested in battlefield robotics. AeroVironment was ready. Digital cameras now weighed a few ounces rather than pounds, and lithium batteries allowed its planes to stay aloft for hours and cover more territory. Special forces brought a few of AeroVironment's Pointer Systems to Afghanistan to spot enemy positions. When commanders visited the deployed U.S. forces, according to Conver, the troops pulled out their Pointers and said, "We need more of these."

Over the next few years the Army, Marines, Air Force, and Special Operations Command conducted bakeoffs among contractors to build small UAVs. AeroVironment won all the major competitions. In 2003 the Army deployed a few hundred Raven-A systems, which came with three planes, two base stations, and a \$400,000 price tag. By 2007 the upgraded model was logging 150,000 annual combat hours, and the price had fallen 40 percent. Two years later, AeroVironment introduced a relative heavyweight, the 12-lb. Puma, which can fly autonomously, land on water as well as ground, and has an infrared and electro-optical camera with a 360-degree view. In August, the Special Operations Command put in a \$65 million order. All AeroVironment planes work with the same ground-control units.

Soldiers returning from battle zones describe using small UAVs to probe enemy positions and ensure convoy routes are clear. U.S. Army Major Noma C. Martini, who commanded a brigade near Mosul, Iraq, says his company flew Raven-Bs at extremely low altitudes to deter insurgent attacks. "The enemy was probing us con-

stantly," he says. "If they could see and hear our Ravens, they knew we had the ability to take action on them."

For more than a decade, Jeffrey W.

Bray served in the Air Force as a member of the elite Special Tactics Squadron, part of the Joint Special Operations Command. He saw action in Panama, Haiti, and the first Gulf War and was a member of the team whose attempted arrest of a Somali warlord was depicted in the book and movie *Black Hawk Down*. Four years ago, Bray joined AeroVironment—about 10 percent of its 800 employees are ex-military—and today he trains war fighters to operate the company's UAVs.

On a sunny November day in Simi Valley, Bray brought a much weaker creature, a journalist, onto a farmer's field of red peppers for a demonstration. He had just returned from a year in Afghanistan, teaching soldiers the mechanics of the new Puma. "These are being flown on an almost daily basis," he says. "At forward operating bases, where they don't have the assets for manual reconnaissance, they help to make sure nothing will surprise us."

Bray and a half-dozen colleagues launch and land each plane on a dirt strip amid the pepper plants. They also show off a new vehicle, Shrike, a remotely operated four-rotor helicopter that, unlike fixed-wing planes, can hover and stare from one spot. It competes with similar rotary UAVs from Boeing, Honeywell, and Northrop Grumman. Shrike, like the planes, is fast, maneuverable, and surprisingly resilient. Upon landing, AeroVironment's aircraft often break into several large pieces, which is part of their design. They reassemble easily.

Then it's my turn. Bray hands me a Raven-B and steps away. He helpfully adds that several Congressmen have botched their inaugural toss, and that it took cable-TV host and retired Marine Colonel Oliver North eight tries before getting a plane airborne. As the engine whirs to life, the UAV violently vibrates in my hand; because of the 4½-foot wingspan and backward-facing propeller, I have to hold it awkwardly away from my body. "You throw it like

it's a javelin, you don't throw a curveball," advises Dan Stone, a retired U.S. Navy rear admiral who's now an AeroVironment executive. I throw the plane, and it immediately sinks toward the ground before miraculously gaining lift and buzzing into the sky. Behind me, Bray and his colleague exchange money, settling their bets on the outcome of my throw.

At AeroVironment's Simi Valley complex, American flags adorn the entrance and visitors need to present a U.S. passport. "It used to be a much more informal place," Tyler MacCready recalls, marveling at the change. "It was a little like a workshop for model airplane enthusiasts."

With an 85,000-square-foot production facility, the company can produce 80 UAVs a day, up from two a week when the company first started making them. A testing area in the center of the floor is enclosed by a Faraday cage, a structure that blocks out extraneous electromagnetic signals. In another part of the building, workers repair broken UAVs that have come back from the battlefield. Some are riddled with bullet holes.

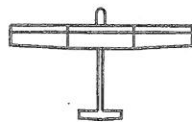
AeroVironment went public in January 2007, raising \$114 million to expand its UAV business and line of vehicle recharging stations. Paul MacCready was 81 at the time and still working every day. He joined Conver in New York for the initial public offering and recorded video interview about the company's unusual history. He died seven months later, of brain cancer.

Since then the ride for AeroVironment investors has been unpredictable. The company once hoped to diversify by selling its planes to private companies that might want to check on assets in the field and to local law enforcement, which could use them to monitor high-crime areas and pursue fleeing suspects. That was quashed in 2007, when the Federal Aviation Administration instituted rules that severely restrict the use of UAVs in domestic airspace. (Special clearance required for testing in places like the red pepper field.) The agency is worried that pilotless aircraft could cause midair collisions and that the technology could be coopted by terrorists and drug traffickers. The FAA has promised it will issue new UAV guidelines by mid-2013.

Conver says the company will pursue those new opportunities vigorously, but for now, he admits, "I see our business operating in a boundary layer between stability and chaos." In the meantime, AeroVironment has been trying to anticipate the needs of its primary customer, the Pentagon. In February the company i-

Shrinking Birds of Prey

(shown to scale)



Raven-B



Nano Hummingbird

← Predator C Avenger

The High and the Mighty

RQ-170 Sentinel

LOCKHEED MARTIN
WINGSPAN: UNKNOWN

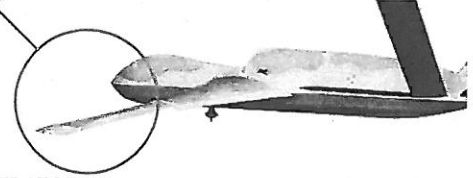
STEALTH DRONE. THE IRANIANS JUST RECOVERED ONE



Predator Avenger

GENERAL ATOMICS
WINGSPAN: 66 FT.
WEIGHT: UNKNOWN

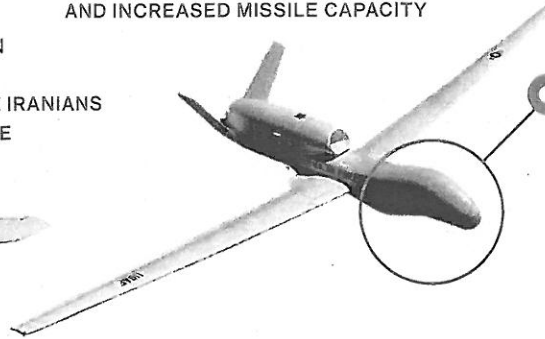
THIRD VERSION OF THE PREDATOR.
REDUCED RADAR SIGNATURE
AND INCREASED MISSILE CAPACITY



RQ-4 Global Hawk

NORTHROP GRUMMAN
WINGSPAN: 116 FT.
WEIGHT: 8,490 LB.

HIGH-ALTITUDE SURVEILLANCE



roduced the Nano Hummingbird, a hovering, two-winged birdlike machine with a wingspan of 6½ inches that transmits live video from a camera in its neck. The project was funded by the Defense Advanced Research Projects Agency, which wants to create robots capable of surveillance both indoors and outdoors in an urban setting. It's years from deployment.

On the other end of the size spectrum is the Global Observer, a liquid-hydrogen-powered drone with a 175-foot wingspan that's designed to fly in the stratosphere for up to a week at a time. Such a craft offers tantalizing benefits in the post-Space Shuttle era: It would be much cheaper than launching satellites into space, and its payloads could be constantly changed and upgraded. Last year, AeroVironment began testing at Edwards Air Force Base in California. In April, 18 hours into the ninth such test, one of the two Global Observer prototypes crashed. That week the company's stock tumbled 16 percent. (It's up 18 percent for the year.) AeroVironment has determined the cause but won't release its findings until the Air Force makes its report public. Tim Conner says work has paused on the project until the company can find new funding.

An Army truck convoy tears down a lone desert road, with dramatic, action-movie music blaring in the background. A sniper's bullet rings out, and one of the trucks skids to a stop amid a cloud of smoke. Soldiers scatter onto the ground to retaliate but are forced to take cover under heavy automatic weapons fire from a turbaned enemy, hiding behind a far-off ridge. There's only one thing to do. "Launch the bird! Launch the bird!" one soldier yells.

The music swells. Another soldier takes a tube from his backpack and leans it on two retractable legs. A small, thin

UAV pops out, sprouts tandem wings, and soars into the air. The soldier monitors the video feed on a hand-held control unit, until his comrades yell, "We can't hold them. Do it!" He locks Switchblade onto the target, and it rockets into the enemy's position with an explosion. "Got him!" the soldiers cheer.

That's the plot of a Switchblade demonstration video produced by AeroVironment for a recent UAV conference in Las Vegas, and it's as specific as the company will get in describing how the new kamikaze drone works. AeroVironment initiated the project five years ago and in September announced it had received a \$4.9 million contract from the Army to start making operational systems for deployment. In the press release, AeroVironment emphasized that the explosive payload is delivered "with precision while minimizing collateral damage" and that soldiers will have the "ability to call off a strike even after the air vehicle is armed."

The decision to produce Switchblade did not come without self-examination. At the beginning of the program, Conner organized all-hands meetings to discuss the project. Employees were supportive. One executive stood up and recalled how such a weapon might have saved him from severe injuries sustained in battle during his service in Vietnam.

Not all of AeroVironment's rivals are enthusiastic about arming portable UAVs. Waterloo (Ont.)-based Aeryon Labs makes the Scout, a small, unmanned surveillance helicopter. It recently sold units to the Libyan rebels that overthrew the regime of Muammar Qaddafi. Dave Kroetsch, the company's founder, says Aeryon has backed away from packing any kind of munitions on its aircraft. "We just think it's a slippery slope," he says. "We know there will come a day when someone will strap a grenade to the bottom of it, but we'll just leave that to

them. We want to keep our hands clean.

Ronald Arkin, a professor and director of the mobile robot lab at the Georgia Institute of Technology, says the real challenge will be building safeguards into new weaponized UAVs, to make sure their use complies with the rules of war. While Predator operators make a decision from hundreds or thousands of miles away whether to fire on a particular target, they consult with a military attorney. Even so, it's an open question whether drone strikes in countries such as Yemen or Somalia, where the U.S. is not engaged in armed conflict, conform to international law. Unless Army lawyers get deployed into battles along with the new system, an unlikely prospect—weaponized surveillance UAVs will pose an even greater challenge to laws that govern the use of force.

The issue is just one aspect of a larger debate over the future of robots in war. Most drones today have autonomous capabilities and can operate without the input of their human minders. Should they be able to independently deploy force, and take the lives of enemy combatants? How will U.S. forces defend themselves when adversaries deploy their own agile Switchblade-style robots, which can evade traditional air defenses? What happens when the robots attack each other?

Toward the end of his life, Paul MacCready spoke of the perils that humans pose to the planet, and how humans have grown in "population, technology, and intelligence to a position of terrible power. And yet, according to Conner, MacCready knew about the Switchblade program in its early stages and was in favor of it.

Tyler MacCready, too, says he's pleased with the transformations at the company his father founded. "We're saving lives," he says. "That's a pretty amazing thing, and way beyond what we used to do. We certainly didn't save the world with the perodactyl." **B**