SPECIAL REPORT

UNMANNED AIRCRAFT:

BIGGER, SMALLER, SMARTER AND DEADLIER

By David Carr

Unmanned aircraft are taking to the skies in unprecedented numbers as new designs and technical capabilities are offering the military a widening array of options for surveillance, communications and combat missions. The growing demand for specialized aircraft has in turn created an explosion of shapes, sizes and applications tailored to specific tasks. The result is a new generation of unmanned aerial systems that are smarter, faster, stealthier and deadlier.

Northrop Grumman's X-47B robotic fighter jet takes off and lands on Navy ships.

The most famous unmanned aircraft is the General Atomics Predator, which started as a reconnaissance craft but has become better known for its ability to launch Hellfire missiles at targets in Iraq, Afghanistan and lawless regions of Pakistan. The success of the Predator begat a family of related craft, including the Air Force's Reaper and Army's Sky Warrior.

The biggest aircraft so far is the Northrop Grumman Global Hawk, a spy plane with a wingspan of almost 131 feet, making it a little bigger than its manned counterpart, the U-2. Then there are micro-air vehicles (MAVs), such as the hand-launched Wasp, which has a wingspan of 16 inches, and the T-Hawk MAV, a flying cube about the size of a milk crate, which packs a ducted fan takeoff and landing system in a 15-inch casing. Meanwhile, the Navy is testing a demonstration model of an unmanned fighter jet, the X-47B, being developed by Northrop Grumman, that can launch from aircraft carrier, presaging an age when robotic fighters might combat enemies' manned fighters – and perhaps emerge victorious by executing high G-force maneuvers that would make a human pilot black out.

Global Hawk, developed by Northrop Grumman, with a 131-foot wingspan and weighing 32,250 pounds, is among the largest unmanned aerial systems approved to fly regular flights within U.S. airspace.

Overlapping with this proliferation of designs is a push to establish technical standards for control of unmanned aerial vehicles (UAVs). This includes innovations not only in the crafts but also in ground control, data analysis and related systems that make up the broader unmanned aircraft system (UAS).

The frontiers in UAS design and use are:

- **Autonomy** – the trend toward UAVs that function more as independent-minded robots and less as radio-controlled aircraft.
- **Teaming** – developing technologies and techniques for using UAVs with manned aircraft. The Army is applying this trend by sending Shadows and Sky Warriors as advance scouts for Apache helicopter crews, who can watch the video feed and might eventually be able to take control of an unmanned aircraft.
- **Increased weapons and combat capabilities.** Many UAVs that started as surveillance aircraft are being armed, and the military is also starting to design UAVs for combat roles and weapons specifically for UAVs.

"In FY 2008, DOD flew just under 400,000 flight hours with unmanned aircraft, and 80 percent of that was operational."

Dyke Weatherington, DOD

Overall, the demand for more and better UAVs has spiked dramatically, said Dyke Weatherington, deputy director of unmanned warfare at the Defense Department. In 2003, the year that the United States invaded Iraq, Weatherington said DOD hoped to increase its UAV inventory to about 350 by 2010, but it surpassed that number far sooner. Today, the Army has about 250 Shadows, while the Air Force has 110 Predators and 30 Reapers. That's only the start of the story.

"In FY 2008, DOD flew just under 400,000 flight hours with unmanned aircraft, and 80 percent of that was operational," Weatherington said. That figure doesn't include the less-measured use of small UAVs, such as the Army's Raven and the Marine Corps' Dragon Eye, which individual soldiers can fly with handheld control units to see what's over the next hill. Overall, UAV use has risen exponentially since 2001 *(see chart on Page 22)*.

Even with new budgetary pressures stemming from the economic decline, UAV purchases are the last thing the military will cut back on, said Lindsay Voss, research analyst at Frost and Sullivan. However, she said she sees some change in how DOD will spend the money. The department will spend less on whole new systems, or platforms, and more "on what the platform can do for troops on the ground," Voss said. "I see money flowing in for replacements for aircraft that are lost and for upgrades and increased capabilities." That includes new software, sensors and weapons that can be mounted on existing aircraft. Money for new UAV designs won't disappear, "but it's going to be harder to come by," she said.

Meanwhile, the United States is facing more competition in UAS development from other nations, including potential adversaries. In February, Iran announced that it had developed a UAV with a range of 620 miles, giving it the ability to conduct reconnaissance or attack any U.S. base in the Middle East by remote control. Iran also has

sold previous generations of its UAVs to terrorist groups, such as Hezbollah.

UPGRADING AUTONOMY

The military services have mostly used the UAS technologies that have proliferated during the past decade to fly missions without putting pilots at risk. Most Predator missions are flown by Air Force crews operating from bases in the United States, working with maintenance and support teams based in Iraq and Afghanistan. But the personnel requirements have not necessarily diminished: Every Predator is flown by a two-man team of a pilot and sensor operator, backed up by additional support personnel who help analyze sensor data.

That might start to change with technologies that allow for greater autonomous operation of UAVs.

For example, the Air Force has started deploying a multi-aircraft control system (MAC) that allows a single crew to control as many as four Predators or similar aircraft, and the next version of MAC will allow simultaneous control of twice as many planes. The goal is for the planes to become smart enough to fly with less supervision, using software-based pattern recognition techniques to identify potential threats or targets. The crew will provide looser supervision for operations that don't require more active control, such as judging surveillance data and firing weapons.

The unmanned aircraft pilot and sensor operators will be on hand "to jump in each one of those cockpits as needed and handle dynamic situations as they arise," said Col. Eric Mathewson, director of the Air Force UAS Task Force. "In the future, this is something we will increasingly move toward," he said, and the ratio of aircraft to crews "could be numbers in the tens, potentially."

Until now, the Air Force often has been criticized for being slow to recognize the potential of unmanned aircraft systems. Another criticism is that when the service has supported UAS, it insists on direct joystick control by officers trained as pilots rather than taking maximum advantage of the flying robots' autonomous capabilities. In contrast, the Army has been pulling UAV operators – pointedly not referred to as pilots – directly from the enlisted ranks and pushing manufacturers to make the aircraft operate as autonomously as possible, following a mission plan established by computerized point-and-click commands.

"We optimize the system so the operator is concentrating on the mission, not on keeping the aircraft aloft," said Tim Owings, the Army's deputy UAS project manager. "We rely heavily on software products to simplify the operation of these systems." In particular, because the Army insisted on fully automated takeoff and landing for UAVs such as the Shadow and new Sky Warrior, "we're seeing a fraction of the incidents with takeoff and landing than we see with either externally or internally controlled aircraft," he said.

At the time Shadow manufacturer AAI won the Army contract for a new UAV in 1999, its designers did not counsel the Army to avoid training Shadow operators as pilots but rather advised the service "to make a firm commitment to the technology," said Steve Reid, vice president of unmanned aircraft at Textron Systems, which bought AAI in 2007. Otherwise, the designers figured there would be a tendency to revert to direct remote control whenever something went wrong with the automation, he said. It was a gutsy decision at the time because the targeted level of autonomy was not proven, he said, but it has paid off.

"In the Air Force, the way Predators are flown and landed is with a pilot who has a joystick," Reid said. "They're trying to recreate the sensation of being the pilot. But 84 percent of all Predator mishaps occur during that landing process."

Northrop Grumman's Fire Scout, a helicopter-type UAV that the Army and Navy plan to deploy, follows a similar philosophy. Once a mission is programmed in, "the air vehicle operator is more of an observer than anything," said Mike Fuqua, the company's business development manager for the craft. The operator can intervene with mouse clicks and keystrokes, but the intention is to limit such actions to changing mission requirements rather than micromanaging the flight, he said. "And the computer takes much better direction than I ever did as a pilot," he said.

The T-Hawk MAV wouldn't be able to fly if the operator had to manage its every move. Like a helicopter, it lifts straight in the air and tilts in the direction it wants to fly, but it lacks the stability a helicopter gets from having broad rotors and a tail.

> **"The computer takes much better direction than I ever did as a pilot."**
>
> **Mike Fuqua, Northrop Grumman**

"It's an inherently unstable vehicle, so we had to develop extremely robust flight controls," said Dan Fouts, business development manager at Honeywell, the prime contractor for T-Hawk. What the military gets in return is a craft small enough to be carried in a warfighter's backpack and sent ahead as a scout, with the helicopter-like ability to hover and stare but without the danger posed by large spinning rotors. "If you get a helicopter in too close to a building and touch that building, you're going to crash the helicopter. But we've done tests where the T-Hawk has bumped into buildings and cars and things like that, and the vehicle continues to fly," he said.

While a small UAV such as the Raven might be ideal for peering over the next hill, the T-Hawk is designed to maneuver through urban settings similar to what soldiers encounter in Iraq. A soldier can operate it with a tablet computer, tapping the screen to indicate where he wants the vehicle to fly or focus its gimbaled camera. There also is a fully autonomous mode in which the T-Hawk can follow a preprogrammed mission and then return.

Mathewson said the Air Force will use autonomous systems when appropriate, and the allegation that the service is dragging its feet on the technology is more stereotype than reality. "Personally, I think we're at a revolution in military affairs right now, and the revolution is not UAS – it's the application of automated technologies," he said.

However, autonomy is not all or nothing. Almost every UAV takes advantage of some robotic capabilities to simplify the operation of an aircraft from a distance. Tom Cassidy, president of aircraft systems at General Atomics, maker of the Predator, said his company's aircraft have always been capable of autonomous operation. At a minimum, they need to be able to drop into an autonomous mode in which they fly according to preprogrammed parameters if they lose their satellite data feed. But customers must decide how far to push those autonomous capabilities, he said.

UAV fleet classifications

LEVEL 0

Operating altitude: **less than 1,200 feet**

Current systems (projected by 2014):
Hornet, BATCAM, Wasp (pictured)
Description:
- Systems less than 2 lbs.
- Airspeed: Less than 250 knots
- Within line-of-site control
- Operating in unregulated airspace

LEVEL 1

Operating altitude: **less than 3,000 feet**

Current systems (projected by 2014):
Raven, Dragon Eye, FPASS, Pointer, BUSTER, MAV
Description:
- Systems 2-20 lbs.
- Airspeed: Less than 250 knots
- Operating below Visual Flight Rules airspace

LEVEL 2

Operating altitude: **less than 18,000 feet**

Current systems (projected by 2014):
Silver Fox, FINDER, AEROSENDE, MARTS, ScanEagle, Neptune, OAV-II, Tern, Mako, Shadow, Pioneer, REAP
Description:
- Systems 21-1,320 lbs. fall under light sport aircraft standards
- Airspeed: Less than 250 knots

LEVEL 3

Operating altitude: **less than 18,000 feet**

Current systems (projected by 2014):
Maverick, Snow Goose, Dragonfly, Hunter A, Hunter B, I-Gnat-ER, Eagle Eye, ER/MP, Firescout, BAMS, Hummingbird, Predator
Description:
- Systems less than 1,320 lbs.
- Airspeed: More than 250 knots
- Operating below Class A airspace

LEVEL 4

Operating altitude: **less than 18,000 feet**

Currently no DOD UAS fall into this category (Killer Bee)
Description:
- Systems operating below 10,000 feet Mean Sea Level.
- Airspeed: More than 250 knots

LEVEL 5

Operating altitude: **less than 18,000 feet**

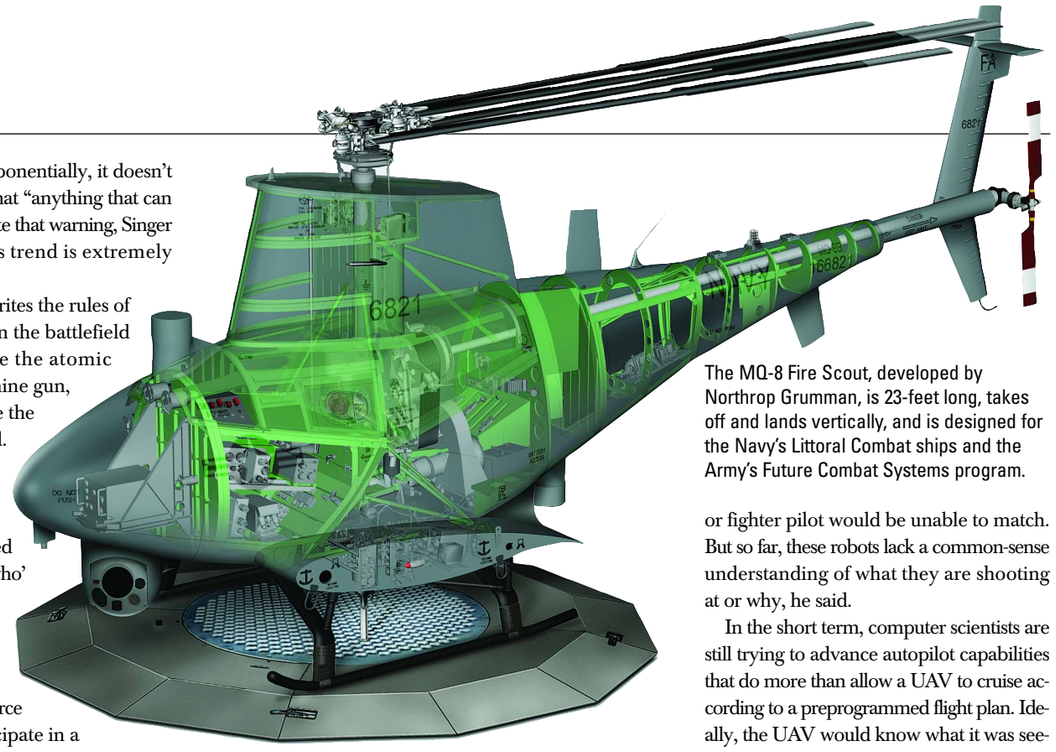
Current systems (projected by 2014):
Reaper, Global Hawk, N-UCAS, HAA, NSMV
Description:
- Systems operating at or above 18,000 feet Mean Sea Level fall under Class A airspace standards.
- Airspeed: Variable

Deciding how much to leave to robotic control, rather than human judgment, is not an easy question. In his book "Wired for War: The Robotics Revolution and Conflict in the 21st Century," Brookings Institution defense analyst P.W. Singer argues that the capabilities of unmanned systems are advancing faster than military culture, doctrine, law and ethics are adapting to the new realities. He wrote that he believes the day will soon come when UAVs are capable of identifying targets and firing at them without human intervention, and some of them will be able to fly, turn and return fire faster and more precisely than a manned aircraft. On one hand, the military risks ignoring these capabilities because of the biases of officers who rose from the fighter-jock ranks. On the other hand, there is the risk of putting too much trust in automated systems that wind up misfiring, as an automated Navy anti-aircraft system did in 1988 when it shot down an Iranian airliner that it mistook for an approaching fighter jet.

"Just because we're seeing the benefits of Moore's Law, that doesn't mean Murphy's Law has been repealed," Singer said. That is, even though computing power continues to increase exponentially, it doesn't dispel the principle that "anything that can go wrong will." Despite that warning, Singer said he believes this trend is extremely important.

"I believe this rewrites the rules of the game not only on the battlefield but in society – like the atomic bomb, like the machine gun, like the airplane, like the longbow," Singer said. "Where those earlier revolutions mostly changed the 'how' of warfare, unmanned systems change the 'who' of warfare at the most fundamental level." Robots already are allowing military personnel, such as Air Force UAV pilots, to participate in a conflict from thousands of miles away. And in time, unmanned systems are likely to operate with less human supervision.

Automatons are already showing they can push beyond human capabilities for some military tasks, Singer said. For example, the Swords ground robot "can hit an apple at 800 meters with a machine gun, let alone a sniper rifle," he said. In other words, when it comes to precision, robots are likely to achieve feats that even the best trained sniper or fighter pilot would be unable to match. But so far, these robots lack a common-sense understanding of what they are shooting at or why, he said.



The MQ-8 Fire Scout, developed by Northrop Grumman, is 23-feet long, takes off and lands vertically, and is designed for the Navy's Littoral Combat ships and the Army's Future Combat Systems program.

In the short term, computer scientists are still trying to advance autopilot capabilities that do more than allow a UAV to cruise according to a preprogrammed flight plan. Ideally, the UAV would know what it was seeing with its camera and other sensors rather than just relaying the data. The more the UAV can autonomously identify a threat or recognize disturbed earth where insurgents might have planted an improvised explosive device, the less time human operators will waste watching hours of uninteresting video. So far, such technologies are more at the level of decision-support tools for UAV crews than anything that would allow them to take their eyes off the screen, let alone delegate the authority to fire weapons to the machine.

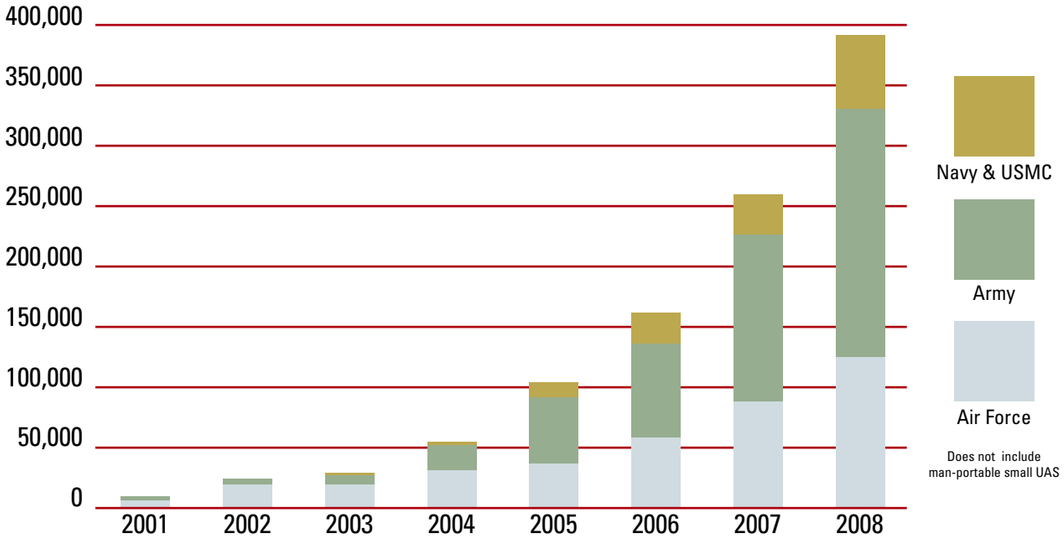
"There's a lot of work on improving the ratio of operators to aircraft, and we're going to continue to see improvements in autonomy, but we still have to ensure we have positive control of every weapon," Weatherington said.

Another reason for the drive to greater autonomy is that direct radio control of so many unmanned aircraft is starting to strain the capacity of military communications systems.

"The unmanned systems community must wean itself from the telecommunication bandwidth," states the unmanned systems road map that DOD released at the end of 2007. "Autonomy will certainly be required in order to accomplish this goal."

NORTHROP GRUMMAN

Unmanned aerial system flight hours climb sky high



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WEAPONS AND TEAMING

Even though more UAVs are carrying weapons, surveillance and reconnaissance remain their primary missions, Weatherington said. In the chain of military decision-making and action, UAVs are part of the process of "find, fix and finish, where 'finish' is typically the weapons piece, and 'fix' is identifying the individual or activity and monitoring it for as long as it takes to figure out how you want to finish."

The reason Predators were armed in the first place, back in 2001, was that their operators complained of spotting high-value targets, only to watch them escape because of the time it took to call in an air strike. Those stories started accumulating during operations in Bosnia and culminated with missed opportunities to kill Osama bin Laden before the 2001 terrorist attacks. By the time of the U.S. invasion of Afghanistan, the arguments against arming UAVs had been brushed aside.

Still, with the exception of the Navy unmanned combat air system prototype, UAVs are not being designed with the kind of performance characteristics associated with fighter jets. The most combat-oriented craft fielded to date, the Reaper, has a turboprop engine, and smaller models are propeller planes powered by gasoline, diesel or electric engines. These designs are optimized less for speed than the ability to loiter over a potential target and study it for an extended time. That's one reason it still makes sense to leave some UAVs unarmed, "because we tend to take a pretty severe performance hit from arming these systems," Weatherington said.

He said arming UAVs makes the most sense "in scenarios where the unmanned aircraft is typically operating by itself and the potential targets are not observed for long periods of time. Then, it gives us a significant ability to strike very rapidly."

This combat method is evolving with the addition of smaller, lighter, more precise weapons that can hit a target with a minimal potential for collateral damage, Weatherington said. The Predators were initially armed with Hellfire missiles, but not every situation calls for that kind of firepower, he said.

The MQ-1C Sky Warrior was developed by General Atomics Aeronautical Systems for Army reconnaissance, communications relay and attack missions, and is 28-feet long.

GENERAL ATOMICS

Another approach is to leave UAVs unarmed, but team them more closely with manned aircraft. For example, the Army is equipping the Shadow to do reconnaissance and laser-target identification in coordination with Apache helicopters. "The Shadow can pump video into the back seat of an Apache, so that the Shadow does the find-and-fix piece," Weatherington said. "The Apache can then do that finish piece better than a Predator can."

A whole formation of UAVs could spread out ahead of an Apache "like a bunch of hunting dogs out in front of the hunter," said the Army's Owings. The Apache crew will be able to watch video and take target designation from the UAVs, which will also include Sky Warriors as they are deployed in greater numbers. "In the future, we will also be doing limited command and control so that the Apache will be able to not only fire his own weapons but also launch Warrior weapons that might be 50 or 100 miles from where he is," Owings said.

Although the Army has only started deploying equipment and training personnel for this mode of operations, it plans to train some Apache crews in every brigade. Initial tests have shown that Apache crews can be considerably more effective and lethal with this assistance from unmanned craft, Owings said.

"There are many ways to force multiply by using UAS as an augmentation to the manned fleet," Mathewson said. The Air Force is exploring the possibility of flying mixed manned and unmanned formations, so that an F-22 might go into battle with a team of UAV wingmen carrying additional weapons, he said.

Owings said he isn't sure whether it makes sense to develop a UAV capable of a one-on-one dogfight with another manned or unmanned. For the conflicts in Iraq and Afghanistan, air-to-air combat isn't a factor. Meanwhile, UAVs might start to take over other tasks, such as cargo, airborne refueling and even Airborne Warning and Control System-type warning and control, Mathewson said. "There is no mission that's off the table." ■