Artist's conception by Erik Simonsen

Tomorrow's Combat Ad

With technologies like these, USAF will sharpen its fighting edge.

Above is an artist's conception of a long-range, unmanned high-speed strike aircraft. New technologies make such an aircraft possible.

The United States Air Force may well be in the first stages of yet another technological great leap forward.

Today, service leaders say that they see prospects for startling advances in propulsion, stealth, sensors, computation, and unmanned flight, to name a few areas. The new technologies could start working their way into systems within a decade.

When that happens, Air Force officials suggest, it will radically alter the way the service fights its wars, much as the revolutions in stealth, precision, and reliability in the 1980s transformed USAF operations of the past two decades.

vantages

By **John A. Tirpak,** Executive Editor

As was the case then, the new revolution will bestow on the Air Force some dramatic combat advantages.

Today, USAF's individual aircraft are optimized for range, speed, or payload but do not feature all three attributes. Future technological gains could blur the distinctions; the prospective engine and airframe concepts could blend all three capabilities into a single machine.

Moreover, such aircraft could feature powerful sensors similar in concept to those used by insects; indeed, they might be at least partially organic in composition.

In the future, aircraft probably will be equipped with potent directed energy weapons able to neutralize all electronic devices in a target area without harming humans or physical structures such as hospitals or offices. They will also be superaccurate and instantaneous in their effect.

Future aircraft might be substantially stealthier than those of today, even able to make in-flight changes to their shape and appearance.

These glimpses of the future are offered by Gen. Bruce Carlson, head of Air Force Materiel Command at Wright-Patterson AFB, Ohio. In that command, Carlson oversees USAF research and development efforts.

Protecting S&T Funding

Carlson, in an extensive interview with *Air Force* Magazine, said that he is satisfied with the service's level of spending on science and technology and believes the Air Force's effort will yield necessary advances at a manageable rate.

"Of course," said the general, "we can spend as much money as our senior leaders want to give us." However, he went on to say, "I am happy with our S&T funding. ... I think the Air Force and the Department of Defense have done a remarkable job over the last few years, especially as we're in a wartime environment, protecting the S&T budget."

In its Fiscal 2007 budget presented in February and now being weighed by Congress, the Air Force sought $2.1 billion for science and technology work. Roughly $1.7 billion of that amount would be expended on broad research efforts. The rest is needed to fund classified programs and high energy lasers.

The requested spending level, if approved, would represent a one-year jump of 11.5 percentage points. However, USAF officers say that fact should be kept in perspective; last year's outlay was much lower than that of the previous year. Over the three-year 2005-07 period, the "composite real growth" in S&T funding is 2.6 percent, they note.

USAF's goals are ambitious. Terry J. Jaggers, the Air Force's deputy assistant secretary for science, technology, and engineering, said the service believes that it should commit not less than 15 percent of its S&T money to basic research. These efforts are "game changing opportunities for technological superiority," he told a House Armed Services Committee panel.

Another goal, said Jaggers, is to spend not less than 30 percent of S&T funds on advanced technology developments, which are short turnaround projects aimed at directly assisting American forces in the field.

Carlson credited his predecessor, Gen. Gregory S. Martin, with developing an Air Force "vision" for S&T efforts that sharpens the focus on solving the service's real-world problems and developing capabilities that would dramatically enhance its effectiveness. Programs deemed not having any direct bearing on the service's missions have either been reduced or discarded.

Research projects have to match some aspect of the Air Force's new desire to be able to "anticipate, find, fix, target, track, engage, assess, anytime, anything, anywhere," Carlson said.

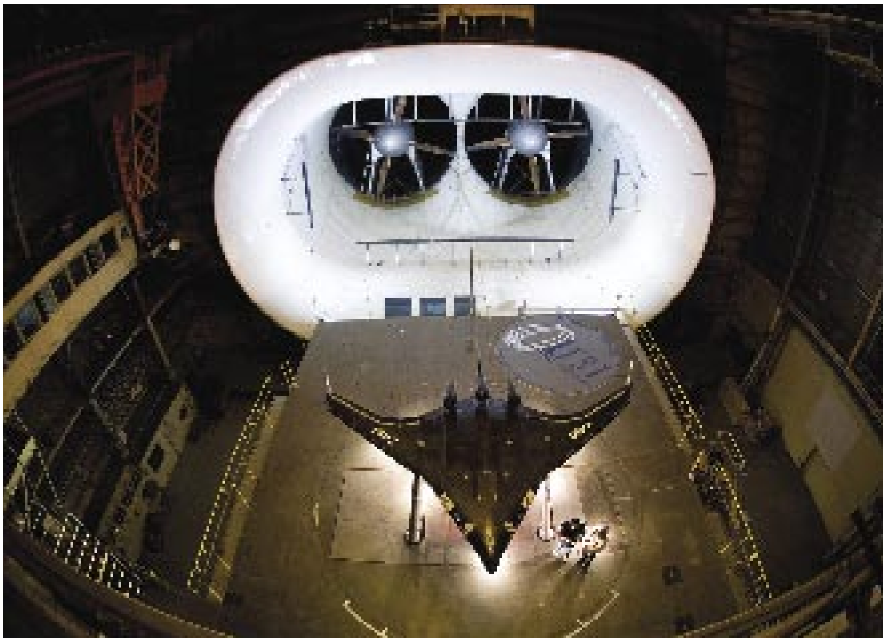
As a result, all programs have been evaluated with an eye toward whether they fit in any of those categories. If a project did not further any of those capabilities, said Carlson, "we got rid of it."

The major commands and users set the priorities, and that has made it easier to prevent the addition of features and tasks the users didn't intend.

Eight Challenges

The requirements of "the kill chain" have been translated into eight "focused long-term challenges," Carlson said. The eight S&T investment areas have been given highly descriptive titles, which are:

- Anticipatory command, control, and intelligence
- Unprecedented proactive surveillance and reconnaissance
- Dominant difficult surface target engagement/defeat
- Persistent and responsive precision engagement
- Assured operations in high threat environments
- Dominant offensive cyber-engagement
- On-demand theater force projection, anywhere



Boeing photo

Wind tunnel engineers test the X-48 blended wing body shape. New engines, fuels, and "morphing" technology could lead to a wide variety in aircraft shapes in the next decade. Some may even change shape in flight.

■ Affordable mission generation and sustainment

The re-stacking of research priorities has allowed AFMC to form "a lot closer partnership with the using command," Carlson said. The logic of the challenges, he noted, is that they allow technical problems to be identified.

"If you know what the technical challenges are," said the AFMC chief, "you can say, 'OK, we want to attack this one four or five different ways because there's high risk, while [another] one we might want to attack only one or two ways, because it's lower risk.' "

He added, "We're essentially able to map everything we're doing in the labs back to this vision."

Even as it sharpens its focus on these few areas, the Air Force is plugging in with other service and government research agencies, all with a goal of eliminating duplicative projects or picking up and developing promising ideas those other agencies aren't pursuing, Carlson explained.

"We have a little better situational awareness on what's going on out there in the S&T world," said Carlson. "The key is to figure out what others are doing, and then how you can piggyback on what they're doing, [and] focus your [research and development] dollars on those things that then provide you the highest payoff."

Asked to identify some of the biggest payoff efforts, Carlson pointed to propulsion projects with enormous potential for the service.

The X-51A project is an effort to develop a vehicle that can achieve a speed of Mach 7 using standard jet fuel, Carlson noted. The vehicle uses a scramjet—a supersonic combustion ramjet—which will fly within the next three years.

"This connects right back to our vision," Carlson said. A vehicle that can operate at Mach 4.5 to Mach 6.5 can go "about 600 miles in 10 minutes" and would likely affect the choice and design of the next long-range strike system. Another project is in the works, using hydrogen fuel, that could propel a vehicle at speeds of up to Mach 12, he said.

Asked why USAF would want to travel within the atmosphere at such speeds, rather than simply perform a suborbital ballistic maneuver, Carlson noted that "there may be policy or legal implications of going to space, so we're working hard to get us to do greater than Mach 7 without going into orbit."

Fast Reaction

The Pentagon is contemplating mounting conventional warheads on some Minuteman or Trident ballistic missiles, as a way to obtain a very quick precision strike on a time-sensitive target thousands of miles away. However, Russian President Vladimir Putin warned in May that the launch of such a weapon could easily be misinterpreted as a nuclear strike and trigger a "full retaliatory response." (See "Washington Watch: Back to the Future Cold War," July, p. 12.)

Aside from the propulsion challenges, Carlson pointed out that materials have yet to be invented that can withstand the multithousand-degree

Next, the One-Size-Fits-All Engine

Next generation engines will be able to reconfigure themselves in flight to adapt to demands of the mission, at some times having the high-bypass characteristics of a big airliner engine and at others the low-bypass characteristics found in the power plant of a fighter.

High speed, long range, long loiter—one engine may be able to do it all.

The research is being done under the Versatile Affordable Advanced Turbine Engines, or VAATE, project. It's a follow-on to the Integrated High Performance Turbine Engine Technology, or IHPTET, program that ran from 1987 until just a few months ago. The goal of IHPTET—to double the power of the F100 and F110 series engines that equip the F-15 and F-16—was never reached, although those engines and their derivatives gained 20 percent more thrust and efficiency, achieved through improved rotor, fan blade, and fluid dynamics technologies. The program also solved early teething problems with those engines in high cycle fatigue.

Under VAATE, the Air Force will look beyond just the engine and incorporate inlets and exhausts, as part of an overall, holistic approach to propulsion. Stealth considerations also will be an intrinsic part of the project.

There will be little that the F-15 and F-16 can gain from VAATE—their engines are close to being "maxed out" in performance—but the F-22, F-35, and future aircraft will benefit substantially. The Air Force is also partnering with engine companies on the project, sharing knowledge and expenses. Materials, fan blade design, cooling systems, fuel efficiency, flow control, and the big trick of altering the engine's configuration will be the early focus of the program. Some of these initiatives have already gained the F135 engine—which powers the F-35 Joint Strike Fighter—a single-digit increase in power.

Program officials report that a VAATE variable engine could be ready in 2013—soon enough to be available to power a new long-range strike aircraft, which is to be fielded by 2018.

temperatures caused by air friction at sustained high Mach speeds.

"When you get up above Mach 7, you either have to have an ablative coating, something that will just burn off, or you've got to come up with some new materials," he said.

He reported that the Air Force Research Lab is pursuing the goals of developing resilient materials that are 75 percent lighter than steel and 33 percent lighter than aluminum, but just as strong. Success also would mean a huge advance in space access, since "every pound you take out of the materials, that translates to about an 11-pound reduction in gross liftoff weight."

The biggest potential advance in propulsion, however, lies within a project called VAATE, for Versatile Affordable Advanced Turbine Engines. The VAATE program seeks to develop what is called a variable-cycle or adaptive-cycle engine. The power plant would be capable of changing its configuration in flight, to give optimum performance when high speed is desired, and can shift back to a different configuration when long range or fuel-miserly loiter is preferred.

In other words, Carlson said, the engine would have "the characteristics of a high-bypass fan," such as those used on airliners, "with the characteristics of a low-bypass fan," such as used in fighters.

"And so, what that means [is], in a long-range strike platform, just by changing out the engine, you could get a 50 percent increase in mission and a five-times increase in loiter time," Carlson noted. For high-speed dash, "we think you could reduce the time to target by about 80 percent."

A short takeoff and vertical landing (STOVL) version, called the Compact Efficient Direct-Lift Engine, is also being explored.

The Quadrennial Defense Review stated that the Air Force should field a new long-range strike capability by 2018, and Carlson said both the VAATE and the scramjet programs "have off-ramps" to a potential long-range strike program.

Because it isn't known yet whether that new program will be manned or unmanned, AFMC also is working to demonstrate the aerial refueling of an unmanned aircraft, as well as "sense and avoid autonomous maneuver" capabilities in an unmanned aircraft, Carlson said.

USAF photo

Here is the business end of the Airborne Laser. While electric lasers are developing apace, their power doesn't compare with chemical lasers like that on the ABL. Directed energy holds huge promise for fast engagement of targets.

UAVs Surge Ahead

The Air Force is "rounding the bend" on unmanned aerial vehicles, Carlson observed, and he believes that UAVs are about to make a big leap in capability.

The unmanned aircraft are about to "come of age," he said, because "we're getting past" all the problems that made them unattractive, such as the tendency to crash.

In fact, the technology emphasis now is how to use UAVs as "a swarm," controlled by computer and operating cooperatively. The command and control of such groups of vehicles is very complex, Carlson added. "It has to be done by computers. It can't be done by one guy. And we're beginning to make breakthroughs in that area."

Carlson, noting that the QDR anticipated that UAVs could be as much as 45 percent of the Air Force's strike fleet in the coming years, said he doesn't consider such a figure unrealistic.

"We're going to see an explosion [of missions and vehicles] in this mission area," he said.

He added that observers should be prepared to see "more exotic shapes than we've seen in the past" in UAVs, but performance will be tied more to "big jumps" in propulsion rather than airfoils.

Shaping has a lot to do with stealth, and Carlson said there's no apparent limit on how stealthy an aircraft can be. The issue is effort and expense.

From one generation of stealth to the next, explained Carlson, "the amount

New and Improved Yet Not Quite Perfect Fuels

What happens when you fly a Global Hawk surveillance UAV to 13 miles altitude? Among other challenges to the mission is the fact that some of the fuel freezes, limiting the aircraft's time on station. To combat that, AFRL is doing research to use additives and other techniques to keep the fuel liquid even at temperatures of 60 degrees below zero, according to William Harrison, chief of AFRL's fuels branch.

Harrison's shop is also looking at the opposite extreme—making fuel stable even when it's heated to very high temperatures. The "plus-100" additive has been in the field a number of years already, but Harrison said AFRL is looking at going "even higher." This is not only important to avoid unwanted combustion, it's useful because fuel is employed to cool the electronics on aircraft such as the F-22, whose avionics generate tremendous heat. The heated fuel can also make for more efficient burning in an aircraft's engines, improving range and top speed.

AFRL is also working on alternative fuels that could reduce dependence on foreign sources of oil. The Assured Fuels Program is studying efficient ways to convert coal or biomass to a usable liquid fuel. There will be a demonstration of the technology this year on a B-52 aircraft, one engine of which will be powered by natural gas made by the conversion process. Harrison said the jet fuel could potentially be produced for $45 to $60 a barrel, "compared to the $106 a barrel we're paying right now."

The Birth of a New, High-Speed Pathfinder

The Air Force doesn't have a high-Mach hypersonic wind tunnel. In order to test high-Mach scramjet engines, the service has embarked on the X-51A project. This scramjet-powered X-plane, which picks up where NASA's X-43 Hyper X program left off, will be lofted to high speed by an Army ATACMS booster, then fly on its own, using the same JP-7 fuel that once powered the SR-71. The craft will accelerate to about Mach 6.5 at 90,000 feet, where it will cruise for a few minutes, then make a controlled—but self-destructive—ocean impact at Mach 2. Tests are planned for 2008-09, and as many as five vehicles may be flown.

The X-51A isn't a prototype for an aircraft or missile, but a derivative vehicle, able to cover 690 miles in about 10 minutes, and might make a good long-range strike system, according to Robert A. Mercier, deputy for technology with AFRL's propulsion directorate aerospace propulsion division.

With such a weapon, "one airplane could hold a significant amount of territory at threat." It might also make a good weapon for use against time-critical targets, Mercier asserted.

It was "not an accident" that the X-51A is sized at about 14 feet length, because that's the size that will fit on the internal rotary launchers of America's bombers, according to Charles Brink, AFRL's scramjet engine demonstrator program manager. He said the X-51A has potential to become an advanced concept technology demonstrator, much as the early Predator and Global Hawk unmanned vehicles were. The scramjet technology, if successful, could also provide the basis of a single stage to orbit spacecraft, in conjunction with other engines and boosters.

of science required ... has gotten more and more difficult. ... It's not just a linear progression." The B-2's level of stealth was "maybe twice as hard" to accomplish as that in the F-117, and the F-22 "five times as hard," he said. In the next generation, "it might be 10 times as hard."

However, "we're working on that," said Carlson, adding that there may be a theoretical limit to how stealthy an aircraft can be, "but we don't see it right now. We think we can go another generation ... and do it in a reasonable amount of time ... if we're willing to dedicate the time and the effort to solve those problems." He said his organization could "demonstrate that technology ... soon."

He also said that AFRL has many projects under way to improve the reliability, maintainability, and performance of today's stealth materials, particularly those that will be used on the F-35. On the F-22, work is aimed at making the materials last longer, prevent icing, and shed moisture, among other efforts.

Painful, but Not Permanent

The Air Force Research Lab has built a man-portable directed energy weapon that can cause pain but not permanent damage. However, Carlson said this is only an early byproduct of ongoing directed energy weapon research.

"It feels like [when] you stick your hand on a hot stove," Carlson said. "It just makes you decide to not do whatever it is you're doing."

However, the trick will be to put such weapons on aircraft and work out the problems of aiming them properly to only create the desired effects, "so you know you're not going to fry someone's brain." Such a system might only be five years away and could be useful causing crowds to disperse or to cause an advancing ground force to retreat.

"Then, a little bit farther out, are the directed energy weapons that allow you to do things like fly over an area and shut down everything that's electrical or computer oriented ... without hurting anything else." Carlson said that it would be accurate to think of such a weapon as able to deliver a focused electromagnetic pulse, which produces the same effect.

The Air Force has high hopes for lasers powered by electricity. Such devices could soon be used for self-defense of aircraft and sensor-blinding functions.

"Quite frankly," Carlson observed, "the limit on that front is not the laser, it's the other stuff: the pointing mechanism, the fast reaction, and the sort of [concept of operations] of how you do that without shooting something else, ... how ... you aim it. It's all that stuff that's really hard."

However, he doesn't see electric lasers equaling the power of chemical lasers as a "weapon class" device anytime soon.

The Air Force thinks electric lasers are "very, very good" for low power, short-range functions, especially since they don't require large quantities of chemicals and plumbing as the YAL-1 Airborne Laser does. But Carlson said the two types aren't going to "trade places ... in the next three or four years."

Carlson admitted that one area of technological advance that hasn't paid off as expected is in the area of hyperspectral imagery. In this endeavor, sensors survey an area of interest in multiple wavelengths—infrared, millimeter wave radar, sound, infrasound, etc.—in order to see and characterize objects even through camouflage.

The concept was "harder ... than we thought," Carlson said. "It just takes a lot of power or bandwidth—or both—to do this, and then there are other technical challenges with cooling and miniaturizing things." Although "it sounded really good when we started, ... the basic science and engineering challenges associated with it were tough."

Hyperspectral imagery was expected to be available now, but Carlson said it will start to appear in "pod" form on high-flying Global Hawk UAVs or as a suite on satellites "in the next ... three to four years." The project is called Spectral Infrared Remote Imaging Transition testbed, or SPIRIT.

At that point, "we're going to see near-real-time day/night detection in camouflage, in concealed targets. We're going to be able to identify materials through spectral analysis. It's going to give us the capability to do much better enhanced combat assessment."

Carlson is particularly impressed by the potential of biomimetics, which he described as "the combination of nanotechnology and biotechnology." By studying and imitating the functions of biological systems, the Air Force hopes to develop new ways of detecting the presence of nuclear, chemical, or biological weapons.

Besides detecting weapons of mass destruction, a biomimetic device could be injected into a pilot to monitor his health fatigue. It could also be incorporated into protective coverings like a chem-bio suit to accurately assess its effectiveness.

If "the tag says it's good for 14 hours of exposure, how do you know? If the toxicity is much greater than forecast—if it wore out in 10 hours—it would be nice to know that," Carlson said.

Biomimetics may also be the means by which there could be an interface between biological or organic devices and the silicon devices that serve as the brains of today's electronic devices. It represents a means to "make ones and zeroes" out of biological data. ■