Photo by Joe Oliva

The F-117A stealth fighter first flew 20 years ago this month.

TWO DECADES OF

By John A. Tirpak, Senior Editor

STEALTH

For 20 years, the Air Force has enjoyed a monopoly on stealth combat aircraft. No other nation appears to be even close to deploying a capability like the F-117 Nighthawk, which made its first flight in June 1981. The Air Force plans to keep stealth at the center of its strategy, even as it evolves the technology and practice of low observables to overmatch the attempts of adversaries to counter it.

"Stealth"—a catchall term that encompasses technologies and tactics intended to reduce the detectability of a vehicle—has given the United States a previously unimagined dominance in modern warfare. The F-117 was the star of the 1991 Gulf War, routinely destroying the most fiercely defended targets in Baghdad and returning untouched.

In the 1999 Balkans war, the B-2 bomber, one generation of stealth beyond the F-117, stole the show in its combat debut by precisely hitting over a dozen targets per mission—against air defenses that had gone to school on the lessons of the Gulf War. It also returned without a scratch. In short, stealth contributed enormously to the lopsided victories of the last decade.

Fielding of the next generation of stealth aircraft—the F-22 and Joint Strike Fighter—awaits the results of the Pentagon's ongoing strategy review, due to be completed in the fall. Air Force officials, however, are confident the Bush Administration will see the indisputable value of stealth as the enabler of swift military victories.

USAF plans an all-stealth force in its future, according to Maj. Gen. (sel.) David A. Deptula, the service's national defense review director. In March, Deptula told the House Armed Services subcommittee on procurement that the Air Force's stealth airplanes will be able to "operate with great precision and survivability in the modern air defense environment—an environment where nonstealthy aircraft simply cannot go." America's intelligence, surveillance, and reconnaissance assets, "networked avionics," communications systems—and stealth—represent "the

Photo by Joe Oliva

Twenty years later, no other nation has yet fielded a stealth aircraft comparable to the F-117. It applies a variety of techniques—shaping, materials, technology—to hide from sensors as sophisticated as radar down to the human eye.

United States' asymmetric advantage and are key to retaining our position as the world's sole superpower," he told the House panel.

USAF's still-strong enthusiasm for low observable technology, however, is tempered somewhat by the reality that, after 20 years, the concept of stealth—once a word not even uttered for fear of compromise—is no longer a secret. The principles underlying stealth are now widely understood, and the nation's adversaries have had 13 years to study the F-117—from a distance—and attempt to calculate its weaknesses.

Stealth's Mystique

"Stealth is a huge advantage," said Gen. Michael E. Ryan, USAF Chief of Staff. However, he added, stealth aircraft are "not invisible," and the mystique of stealth as a cloak of invulnerability, allowing solo penetrations of enemy airspace under any conditions "simply isn't supported by science."

What might have been the most sobering event in the short history of stealth was the loss, in March 1999, of an F-117 to enemy fire in Kosovo. It shattered the aura of invincibility that had been enjoyed by the aircraft until that point. The Serb foe paraded the wreckage on television. The pieces undoubtedly were shipped to America's adversaries for scrutiny, and critics of the Air Force and stealth technology had a field day.

Senior service leaders say that, while it would have been preferable to keep pieces of the F-117 from enemy hands, neither stealth in general nor the F-117 in particular are in especially greater peril because of what happened in the Balkans.

"It doesn't worry me," said Gen. John P. Jumper, head of Air Combat Command.

From the pieces of the F-117 alone, Jumper said, it would be "very, very hard to duplicate" a stealth aircraft by reverse engineering it.

He went on, "There are intricacies to stealth that come with our many years of experience." Pieces alone—without the means to duplicate the way they were manufactured or their overall shape on the aircraft—could only give small hints about what makes the F-117 stealthy.

One program official speculated that US adversaries have probably already formed some ideas about how the F-117 works after watching it for 13 years. Being able to "put a micrometer on [some of the pieces] isn't going to tell them a whole lot extra that they didn't already know." He added that Air Force "Red Team" specialists—whose job it is to look for and identify vulnerabilities in stealth—still find the F-117 "a challenge, and they have all the data" on it.

"My opinion is, that having that hardware in their hands is certainly something we would rather not have had happen," said John Somerlot, a stealth expert with Lockheed Martin, now working on the F-22 program.

"However," he continued, "the real technological advantage is the integration and systems engineering. It's not just having some material in your hand that's able to absorb X number of [decibels].

"It's the ability to take that and design it in, produce it, deploy it, and support it. A lot of people can build models that are high performing, but when you have to put wheels on the ramp and then support those, that's where the real technology is."

Don't Ask, Won't Tell

The Air Force has been understandably reluctant to discuss the specifics of how the F-117 was brought down in Kosovo, preferring to keep US adversaries in the dark about what tactics might have been effective against the stealth fighter. However, senior USAF officials report privately that stealth technology itself was not to blame in the loss.

According to these officials, the true culprits were NATO constraints on how F-117s could approach Kosovo in the early days of Operation Allied Force, the intense media coverage of aircraft taking off from Aviano, Italy, and the presence in Italy of spies who sent immediate reports of air activity to Serbian gunners. These factors allowed the Serbs to make gross estimates of the whereabouts of aircraft en route to targets in Yugoslavia, the F-117 among them.

"We were more predictable than we should have been, under the circumstances," said one senior official.

About 20 miles outside of Belgrade, the F-117's luck ran out. An undetected surface-to-air missile battery was lurking in the darkness below. It had not appeared on intelligence maps of the area, and the F-117 pilot was not aware of it. When the F-117 became briefly visible on radar as it opened its bomb bay doors, Serb radar operators on the ground, aware that an F-117 would be entering their area, had a momentary opportunity to shoot. It is possible that they didn't even have a radar lock on the stealth airplane but were close enough to guide the missile optically. Badly damaged by the blast of the warhead, the F-117 could not be controlled, and the pilot ejected. He was soon rescued.

Jumper said the shootdown was mostly the result of "a lucky shot. Those limited times of exposure that we know exist"—when the F-117 opens its bomb bay doors, or presents certain angles to a radar—"lasted just a little bit too long. We were targeted by a SAM site that we didn't have precisely located."

Jumper added that the setback must be measured in relation to the great successes achieved by the F-117.

Photo by Joe Oliva

Designed as a "special operations" aircraft in the 1970s, the F-117 has taken advantage of evolving stealth technology to remain a potent capability. Initial plans called for just 20 airplanes, but wiser heads raised the figure to 60.

One and Only One

"We had flown hundreds of sorties in the most demanding and high-threat, ... most heavily defended ... places that we've encountered in the decade of the '90s," such as the heart of Belgrade and Baghdad, "and we lost one," he pointed out.

Had the Air Force concluded there was a fundamental flaw in stealth, it would not have continued to use the F-117 and B-2 in Kosovo or would have reassigned the types to less-challenging targets, service officials insisted.

SMSgt. Walter Franks, superintendent of maintenance for the F-117 at ACC, said there have been no maintenance change orders issued on the airplane as a result of the loss of the airplane in Kosovo.

While Jumper echoed Ryan's observation that the F-117 is not invisible, he noted that "in the right circumstances, it's very, very hard to see. It will continue to be that way. And its performance continues to improve, both in its maintainability and its stealth qualities. So, I don't see stealth being 'on the ropes' in any way."

A prominent criticism of both the F-117 and the B-2 in Kosovo centered on the fact that, even though both were billed as radar evaders, both types were supported by jamming aircraft. This was not supposed to be necessary.

Jumper said bluntly that the F-117s and B-2s "don't need escort jammers." However, senior USAF officials acknowledge that the stealth aircraft certainly did coordinate missions with jamming aircraft, particularly the EA-6Bs operated jointly by the Air Force, Navy, and Marine Corps, to increase the safety margin when attacking tough targets.

"When there was jamming in the area, we were glad to take advantage of that," said Maj. Gen. Leroy Barnidge Jr., who commanded the 509th Bomb Wing of B-2s during Allied Force and who is now vice commander of 9th Air Force.

"Anytime you can maximize the problem for your adversary, that's a good thing," he added.

Lt. Col. Jack D. Hayes, chief of the F-117 Weapons System Branch at ACC and an F-117 pilot engaged in intelligence work for F-117s operating in Kosovo, said the jamming controversy is overblown.

"I wouldn't mind having F-16CJ [that is, the defense suppression variant] and EA-6 support" on a stealth mission, said Hayes, "but all they do is make my job easier. They help hide me [and] they keep the [enemy's] radars off." Compared to an F-15 or F-16, "we're still leaps and bounds ahead of them in terms of where we can go and what we can do."

Jammers also would be a detriment on some missions, Hayes said, because the presence of jamming would alert an enemy that an attack was coming. One of the basics of being stealthy is to maintain radio—and radar—silence.

One of the lessons learned from Kosovo was that the Air Force may

Loss of an F-117 outside Belgrade was the sole blemish on an otherwise spotless combat record. USAF leaders say adversaries won't learn enough from the pieces to build their own stealth airplane or compromise the F-117's stealth.

have made a misstep in eliminating its F-4G defense suppression and EF-111 escort jammer force from the inventory, since both types were sorely missed in Kosovo. Ryan said that USAF is placing a higher emphasis on electronic warfare now and has cast stealth as "part of the overall electronic warfare issue."

"Most of our assets still need to be packaged in some way," Ryan said, meaning that strike aircraft usually need to be escorted by fighters and jammers in a "package" of capabilities to accomplish a mission.

USAF photo

Laser-Guided Bombs precisely on target at a precisely planned time are the F-117's trademark. New LGBs with backup satellite guidance mean bad weather and smoke no longer offer refuge to the enemy. More new weapons are coming.

The Best Trick

"Not always," he continued, "and that depends on the operational situation." However, "we use every good trick we have, and we package our good tricks together to give us the best trick. ... It's all about survivability."

The F-117 mission begins with meticulous planning, which takes into account known or suspected surface-to-air-defenses. The plotted mission is loaded into a computer cartridge, which is physically carried out to the airplane and plugged into it by the pilot. After takeoff, the airplane's autopilot—affectionately known as "George"—takes over, flying the airplane to the release coordinates. The autopilot also flies the F-117 home again.

The extensive use of autopilot is necessary for two reasons. One, the aircraft must always present the precise optimum attitude toward any radars it will encounter—something that is beyond the capacity of the steadiest human hand—and two, it provides a very steady ride for the pilot as he compares the target area with maps and reconnaissance photos to ensure finding and hitting the right target, at a very specific time.

Not having to maneuver the airplane, watch out for enemy missiles, or navigate and simply concentrating on bombing pays off handsomely in accuracy, according to Brig. Gen. (sel.) Marc E. Rogers, commander of the 49th Fighter Wing.

He noted that, in practice runs, the 49th does not award its pilots any credit for anything less than a bull's-eye.

"You get 100 percent or zero," he said. Such a standard is possible, he went on, because F-117 pilots practice finding the target, hitting it precisely, and timing the strike perfectly, day in and day out. "That's all they do," said Rogers, who observed that his pilots are "very, very good" at reading and interpreting reconnaissance photos.

The F-117 typically carries two Laser-Guided Bombs of the 2,000-pound variety. These usually also have a hardened warhead, to penetrate targets such as aircraft shelters or deeply buried bunkers.

Pilots of the F-117 pride themselves on "discipline on the target attack," Hayes said. "No collateral damage. That is our bread and butter: going 'downtown' and hitting only—and I repeat, only—what we're supposed to hit."

In Kosovo, Hayes said, F-117 pilots were admonished not to release weapons unless they were sure they would be able to guide their Laser-Guided Bombs all the way to impact. If a stealth airplane arrived over a target that was obscured by clouds or smoke, it had to return without dropping its bombs, since lasers can't penetrate to the ground in such conditions.

"In a lot of cases, they went in and were ... unable to employ weapons,"

Staff photo by Guy Aceto

The "platypus" is the colorful name coined to describe the F-117's unique exhaust. It hides the aircraft from infrared sensors by dispersing the exhaust heat over a wide area, mixing it with cool air and shielding it from ground view.

he said. On the positive side, F-117s caused none of the 20 or so cases of collateral damage in Kosovo. However, due to the discipline of withholding weapons if accuracy could not be guaranteed, "we wound up having a lower mission effectiveness rate overall, because of weather and because of ROE [Rules of Engagement], than we did in Desert Storm," Hayes explained.

Rogers said his F-117 pilots are learning to use the fighter in new ways. "We are getting integrated with Red Flag" exercises, he said, and experimenting with "whether it's better to be in the front, the middle, or the end of a package." Whether to be the "pathfinder" or the mop up "depends on the mission," he said.

"The more you use it, the more you learn," Rogers added.

Evolving Technology

Part of the reason the Air Force is not too worried about the safety of the F-117 is that the airplane's technology is continuing to evolve. While the outside shaping has remained the same, the technologies and techniques used to maintain its signature have been improving continually.

In the early days of the F-117, the aircraft's Radar Absorbent Materials had to be applied by hand, by maintenance personnel who described their work as "more an art than a science," said one program official. Gaps in the RAM, and access panels that needed to be opened on a regular basis, had to be me-

ALL ABOUT STEALTH

Stealth is the blanket term for the technologies, tactics, and techniques used to make an object such as an aircraft hard to detect, track, or shoot. Stealth must be taken into account in the design of the aircraft; it cannot be achieved as a developmental afterthought or with a "bolt on" device.

The principal means of detecting aircraft is by radar: Pulses of energy are broadcast, and when they strike an object, echoes come back to the receiver. The Radar Cross Section of an object is a description of how reflective it is to radar. Very large objects can be made with a small RCS and vice versa.

Stealth aircraft are shaped in a way that most of the radar energy is deflected in another direction, reducing the echo the radar set receives. The echo is further diminished by the use of Radar Absorbent Materials on the skin and in the structure of the stealth aircraft. These materials can either hold the radar energy or actually release it at an altered frequency; some of the echo comes back at a frequency to which the radar isn't listening.

By combining these techniques, the returning echo is so small that the stealth aircraft will either be lost in the electronic clutter of the radar or be mistaken for something much smaller, such as a bird.

Highly radar-reflective features, such as engine fan blades, are hidden deep within the fuselage of a stealth aircraft, at the end of a serpentine inlet that also absorbs or dissipates radar energy, or behind "blockers" that redirect radar energy.

On the F-117, radar energy is deflected by a series of facets around the airplane. This early means of radar deflection was driven by the computing power available in the 1970s, when the airplane was designed. The RCS of each facet could be calculated and their aggregate reflectivity measured. As computing power advanced, RCS could be calculated for whole areas of an aircraft and with complex, curved shapes. Once this was achieved, facets were largely abandoned in order to improve aerodynamic performance of later stealth aircraft.

A stealth airplane must also present itself differently to radars of different types, depending on the frequencies at which the radars operate. For some radars, a head-on approach is best; for others, an oblique angle may offer the most protection.

To avoid being visually detected, stealth aircraft are typically painted black and flown at night. They also tend to have a slim silhouette, making them harder to spot.

Because aircraft can be detectable by their exhaust heat, stealth aircraft do not have typical exhausts. On the F-117 and B-2, the exhausts are above the aircraft, to shield them from heat-seeking infrared detectors below. They absorb some exhaust heat with special ceramic tiles, similar to those used to protect the space shuttle from re-entry temperatures, and mix ambient cold air with the exhaust heat to reduce its intensity. They also disperse the exhaust over a wide, flat area, further disrupting and diminishing the heat signature.

Stealth aircraft reportedly also have devices that help control the creation of contrails at high altitude.

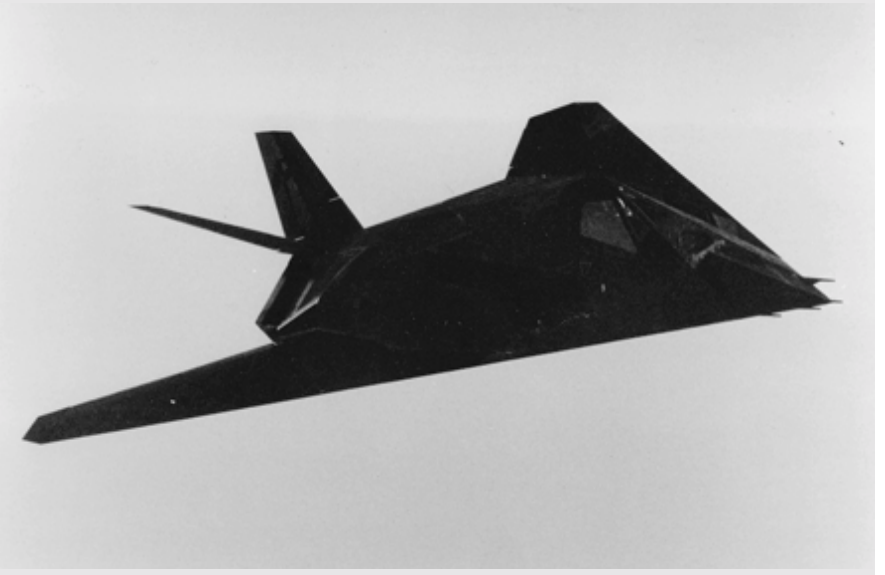
To be stealthy, an aircraft must avoid electronic emissions, such as radio signals or use of radars. Such emissions can be detected and alert defenders that an aircraft is coming. Likewise, stealth aircraft usually fly at subsonic speeds to avoid creating a sonic boom.

Stealth missions are meticulously planned to either avoid radars entirely or pass between them at the optimum angle and altitude. The 49th Fighter Wing, which operates the F-117, reportedly maintains a database of the location of every known anti-aircraft radar in the world, a database which is constantly being updated.

Photo by Paul Kennedy

Known as "Martians" (shorthand for Materials Repair Specialist), F-117 technicians for years applied Radar Absorbent Materials in a fashion more akin to art class than metal shop. Here, A1C Kenneth Sheppa trims out a replacement piece.

A SHORT HISTORY OF THE F-117



USAF photo

This grainy, retouched photo of the F-117 was the first released by the Air Force. Details were deliberately obscured and the image distorted to keep stealth watchers guessing a little while longer about the type's true shape.

Pyotr Ufimtsev, a Russian mathematician, laid the groundwork for modern stealth when he published a paper in the 1960s describing a new method for calculating Radar Cross Section across a large surface. The Soviet Union showed little interest, but when the paper was translated years later, it was noticed by Denys Overholser, a Lockheed Martin "Skunk Works" employee. Overholser came up with a computer program called "Echo 1" which could predict the RCS of a faceted aircraft.

The Air Force at the time was alarmed about the lethality of new surface-to-air missiles. Israel's largely American–built air force had lost 100 fighters in 18 days to Arab SAMs in the 1973 Yom Kippur War, so USAF was looking for an edge against the missiles.

With the approval of William J. Perry, then the Pentagon's engineering chief (later Secretary of Defense), Lockheed won a contract to build two demonstrator aircraft under the XST, or experimental stealth technology, program, later designated "Have Blue." The demonstrators had a Radar Cross Section thousands of times smaller than the stealthiest airplanes in the Air Force, about the size of a ball bearing.

The loser of the XST competition was Northrop, which later got the contract to develop the Advanced Technology Bomber, known today as the B-2. It was the promise of stealth for future bombers that caused the Carter Administration to cancel the B-1A.

Even before testing of the Have Blue aircraft was completed, the Air Force ordered 20 full-up stealth combat aircraft. They were intended to be "special operations" airplanes for surprise strikes, such as against terrorist training camps or in wartime against critical targets behind enemy lines.

To speed development time and cut costs, off-the-shelf parts, such as landing gear, engines, and flight controls from other fighter programs, were used in the new aircraft.

At the urging of the Pentagon and influential members of Congress (former Sen. Sam Nunn of Georgia, chairman of the Senate Armed Services Committee, was one) privy to the secret program, the buy of the new stealth fighter was boosted to 60 airplanes.

The first F-117 flew June 18, 1981, at Groom Lake, a secret, remote facility in Nevada. By 1983, a stealth unit was declared operational, but the entire program was strictly special access required—only those who needed to know were briefed into it.

The origin of the designation "F-117" is still debated, but the generally accepted explanation is that it happened to be the numerical name of the manual Lockheed wrote for the airplane.

Based at Tonopah Test Range—part of the Nellis AFB, Nev., gunnery range complex—the unit, first known as the 4450th Tactical Group, practiced flying at night and in radio silence. Pilots on the program were selected for maturity and skill but led a monastic existence, living at the secret base and flying in the dead of night, and coming home to their families only on the weekends.

Caspar Weinberger, Defense Secretary during the Reagan Administration, scrubbed plans to use the F-117 in the 1983 Grenada invasion and in Operation Eldorado Canyon, the 1986 air raid on Libya. Weinberger felt that it was too soon to tip off the Soviet Union as to the existence of stealth.

In 1988, the Pentagon released the first grainy photo of an F-117. The disclosure was due to the fact that F-117s would soon begin daytime flying, and it was only a matter of time before the aircraft was spotted. Security on the program had succeeded beyond the wildest expectations of anyone involved. Perry had predicted, in 1977, that the stealth cat would be out of the bag within two years.

The F-117 first went into action in 1989, when two stealth airplanes dropped bombs during Operation Just Cause in Panama. (A few months prior, the personnel and equipment of the 4450th Tactical Group were absorbed by the 37th Tactical Fighter Wing, which had moved to Tonopah from George AFB, Calif.) Two years later, the F-117s went to war against Iraq, routinely flying against the most heavily defended targets and returning unharmed. The stealth airplanes became associated with the quick victory in the Gulf and racked up an impressive record of destruction achieved per sortie.

As the F-117s became less classified, the aircraft were moved to Holloman AFB, N.M., beginning in May 1992, under the 49th Fighter Wing, which changed its mission from air-to-air to air-to-ground.

The F-117s also participated in Operation Allied Force, based out of Aviano AB, Italy. Again, they tackled the toughest targets in and around Belgrade, achieving pinpoint accuracy whenever they dropped their bombs.

ticulously smoothed over with a special putty and then left to cure for many hours before a mission.

"We called that process 'buttering,' " one former program technician said.

Now, the RAM is sprayed on robotically, with machines adapted from the automobile industry. And panel doors have been fitted with quick-access strips which eliminate the need for puttying and curing and speed the process of getting the airplane ready for battle.

The maintenance improvements over the last 20 years have further reduced the F-117's visibility on radar and have "shown anywhere from a 20 to 50 percent reduction in maintenance man-hours per flight hour," Hayes said.

The F-117 mission capable rate of 80 percent is "the envy of the Air Force," one senior program official said.

Avionics on the airplane have also been improved. Old-style "green" cathode-ray tube displays have been replaced with color multifunction displays and a moving map. The original inertial navigation system has been upgraded with a ring laser gyro, to further enhance precise navigation.

New weapons are also being added to the F-117. Since being fitted with Global Positioning System capability, the F-117s can now use what's called the EGBU-27: a dual-mode Laser-Guided Bomb that can switch to satellite guidance if the weather goes bad or if the target is obscured in the last seconds before impact. Such a weapon will allow the F-117 to press an attack when it would otherwise have to withhold bomb release. Other planned new weapons additions include the Joint Direct Attack Munition and possibly the Wind-Corrected Munitions Dispenser.

Extremely LO

Ryan said the Air Force is continuing to press ahead with efforts to develop extremely Low Observable technology, to make future generations of stealth airplanes even tougher to spot.

"We're still pushing to do significantly better ... as part of our science and technology [effort]," said Ryan. Perhaps, he joked, USAF will invent " 'the cloaking device,' eventually. ... Each time we do [stealth], we're a little bit better at it."

Stealth figures prominently in the Air Force's new Global Strike Task Force concept, which posits stealth aircraft removing anti-access threats to US forces as they enter a theater of operations.

Jumper warned, however, that "we need to ... make sure we don't try to buy stealth on the cheap." The Navy's F/A-18E/F, for example, takes advantage of some Radar Absorbent Materials, inlet shaping, and canopy coatings to diminish its frontal Radar Cross Section. However, the reduction in RCS is not substantial and in any event is undone by the external carriage of weapons, which are a large radar reflector.

"What good is reducing the RCS on a 'clean' airplane?" wondered Tom Burbage, Lockheed Martin's executive vice president and general manager for the Joint Strike Fighter program. "Once you have the weapons on the pylons, unless you have some way to recess them [into the wings] or give them their own treatment, you've undone whatever you achieved by treating the aircraft."

"Real stealth," Jumper said, means "internal carriage" of weapons.

"You can use the airplanes with externally configured stores when stealth is not an issue," he said, but stealth continues to be important.

In Kosovo, not all the SAMs could be found; witness the lost F-117. In such situations, where "there are still systems that are alive down on the ground, ... that means they have the opportunity to bring them up, [and] stealth in everyday airplanes is a good thing to have," said Jumper. "They are effective against those transportable systems that are down there somewhere."

The Air Force is planning to keep the F-117 around a good long time yet. Designed to execute hard, fighter-like maneuvers, the F-117 has not been maneuvered very aggressively, and ACC believes its airframe could conceivably last until 2030 or later.

"Lockheed designed it for a lot more Gs than we're flying it at," Hayes reported. Strictly for planning purposes, a retirement date has been set at 2018, but Ryan noted that USAF has always planned to "missionize" the just-as-stealthy and far faster F-22 to take on the F-117's role "sometime in the future."

Like all aircraft in the USAF inventory, the F-117 suffers from a number of "aging aircraft" problems. For example, the manufacturer of the multifunction displays used in the cockpit went out of business, so ACC bought up enough replacements to last until 2009. Other structural problems involve load-bearing devices inside the airplane and obtaining parts for other avionics systems suffering from "vanishing vendors" syndrome.

Without resolution of these problems, "we'll wind up grounding airplanes around 2009," Hayes reported. However, there are three more years to fix these problems financially, such that an early retirement can be headed off.

Ryan said the Air Force will likely make more use of jamming—and advances in stealth technology—to match the threat posed by new-generation double-digit SAMs. The new systems generate huge amounts of radar energy, he said.

"If you put enough power out there, you can fry the skies," he noted.

"We will ... continue to offset capabilities the other guy may come up with to counter [stealth]," he said, and in turn the Air Force will unleash a new edition of stealth which will counter the countermeasures. "It's a moving chess game." ■

Photo by Joe Oliva

Built to withstand hard maneuvering, the F-117 has instead been handled with kid gloves. The low stress on the airframe and its renewable stealth features mean the F-117 could last until 2030, though 2018 is its planned retirement.