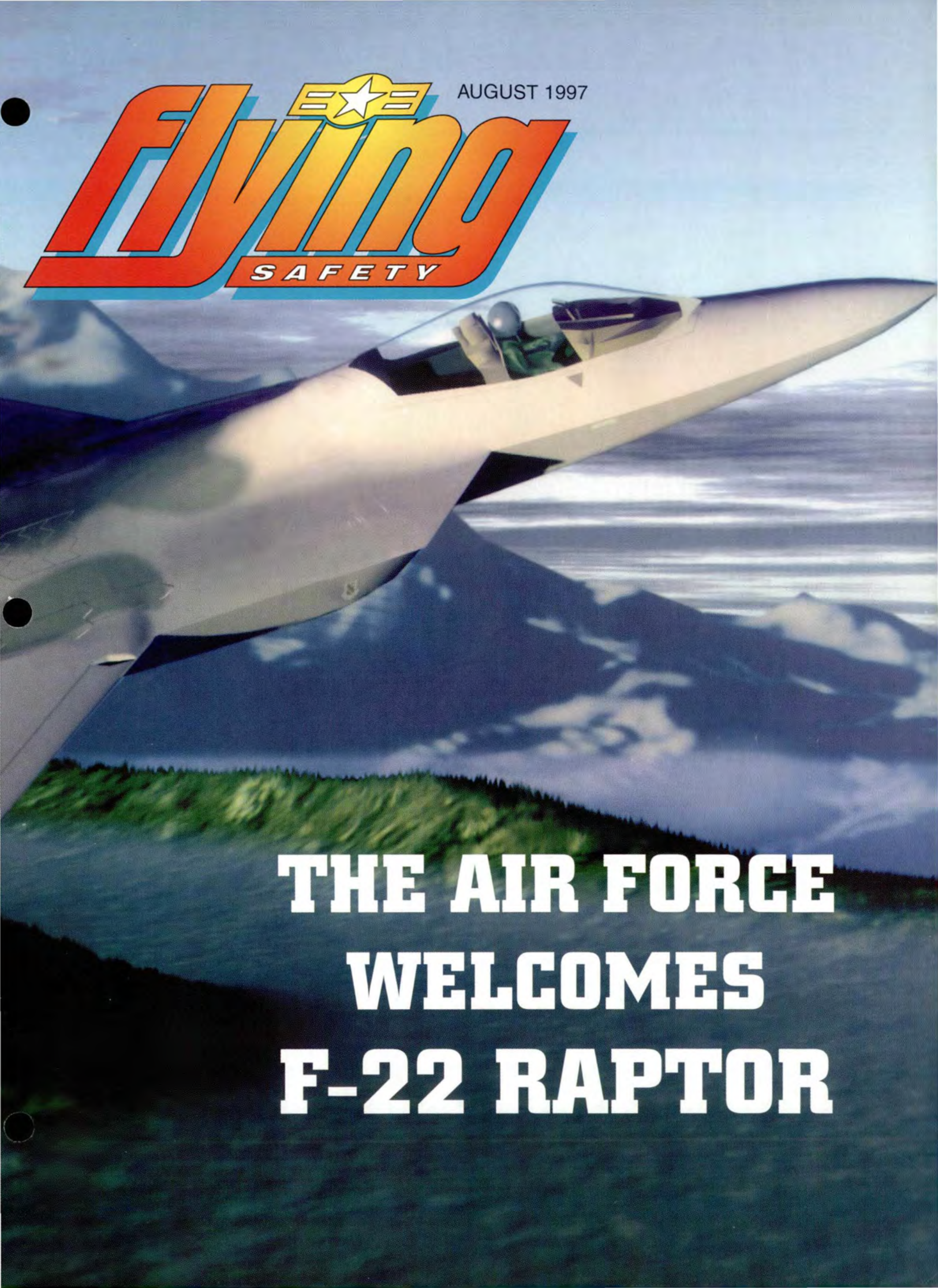
flying SAFETY
AUGUST 1997



THE AIR FORCE WELCOMES F-22 RAPTOR

Your Safety Is Our Business

MAJ GEN FRANCIS C. GIDEON, JR.
Chief of Safety, USAF

GENERAL GIDEON

As the Air Force's new Chief of Safety, I look forward to working with each of you to bring our mishap rate to an all-time low. Of course I am talking about all aspects of safety—flight, ground, weapons, nuclear, and space. The Air Force Safety Center is my window to the Air Force for assessing the health of accident prevention and safety awareness programs worldwide. Safety programs have become an increasingly important tool during recent years as a force multiplier. Air Force members have experienced additional stress from such sources as downsizing, career restructuring, deployments, and expansion of the mission, which increasingly includes peacekeeping efforts and humanitarian airlift. We must do all we can to preserve our dwindling assets. As our people live and work in increasingly diversified environments, the Air Force needs supervisory involvement at all levels to keep people working smartly and safely.

It is imperative that commanders, supervisors, and individuals ensure that safety awareness is ingrained in everything the Air Force does. Safety should serve as a gauge to measure every action, procedure, and policy. Safety considerations and risk management must be an integral part of every mission and task. Several key elements must be present to ensure safety is incorporated as realistically as possible into task and mission completion. A primary factor is the individual—his or her training and attitude. This element can often be the most challenging. We in the Air Force have clearly demonstrated how well equipped we are to incorporate into systems and equipment the safety procedures which permit people to complete work safely and efficiently. The difficulty lies in communicating the safety message to ensure each individual sees the benefit and value of mishap prevention on a personal basis. A second safety factor is the environment—weather, proper equipment and clothing, adequate training, and current and complete tech data. A third factor is supervision. Qualified supervisors who are directly involved, caring, and demonstrating a positive attitude, are essential. Only when the factors of the individual, the environment, and supervision are assessed simultaneously can we strike the right balance between risk and mission accomplishment.

Flying safety, while extremely important, is only one part of our safety equation. On-duty and off-duty ground safety, weapons safety, and overall safety awareness impact our people and resources. Aircraft mishaps attract a lot of attention and are very costly. Class A flight mishaps often mean loss of vital and valuable human resources as well. Comparatively speaking, however, loss of property and life on the ground occurs with greater frequency. The challenges to protect our resources are wider spread in the ground area where every individual, system, facility, and piece of equipment are potentially at risk. Ground safety is an around-the-clock activity that requires everyone to exercise good judgment and a sense of responsibility. Although this area has a daunting amount of statistics, it also has the greatest potential of all the safety disciplines to prevent mishaps. As commanders and supervisors, we are responsible for establishing and enforcing effective ground safety programs. As individuals, we are responsible for compliance with standards and responsible behavior. The bottom line is that safety begins with the individual. I urge all of you to heed the risks at work, in your home, and in your recreational activities. Allow yourself every opportunity to stay out of harm's way. You are the Air Force's most valuable asset, and you are the first line of defense against an unnecessary loss.

We need to all work together to instill a proactive safety attitude in ourselves and our contemporaries. Let's build on positive safety momentum and guard against complacency. Although the Air Force breeds self-confidence, don't let that confidence blind you to obvious dangers. For the past 10 months, you have heard a great deal of publicity on the Operational Risk Management (ORM) program. While many of you have utilized the basic principles of ORM for years, we have formalized the program in AFI 91-213. The daily use of ORM principles by everyone will most certainly reduce mishap rates lower than ever, both on and off duty. We must each develop and demonstrate good judgment by selecting the safest way to complete a task, consistent with mission requirements. Risk management assessments—identifying the hazard potential and controlling the risks—will provide the right systems, facilities, equipment, and procedures necessary for mission success. Working together, we can preserve the human and material resources necessary to bring our Air Force safely into the dynamic world of twenty-first century air and space force projection. I look forward to the challenge. ✈

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Steve Moore is the artist

SPECIAL FEATURES

CONTRIBUTIONS

Contributions are welcome as are comments and criticism. No payments can be made for manuscripts submitted for publication. Call the Editor at DSN 246-0936 or send correspondence to Editor, *Flying Safety* Magazine, HQ AFSC/PA, 9700 G Ave., S.E., Ste 282, Kirtland Air Force Base, New Mexico 87117-5670. The Editor reserves the right to make any editorial changes in manuscripts which he believes will improve the material without altering the intended meaning.

F-22 Iron Bird Flaps Its Wings

Photos courtesy Lockheed Martin Aeronautical

ERIC HEHS
Lockheed Martin Tactical Aircraft Systems
Fort Worth, Texas

Before the F-22 took off for the first time in June, many of its systems were tested in a nonflying version of the aircraft—the F-22 "Iron Bird." Formally known as the Vehicle System Simulator, or VSS, this unique test facility at Lockheed Martin Tactical Aircraft Systems in Fort Worth allows the F-22's hydraulic and electrical systems and all of their associated hardware and control software to be tested under simulated flight conditions.

Such ground-based testing significantly lowers program risk by allowing flight-critical systems to be tested thoroughly before the airplane actually flies. It also reduces the complexity and cost of the flight test program for the developmental aircraft. The VSS can also be used to conduct tests that would be too dangerous to attempt on a flying airplane, such as dual engine flameouts and flight control actuator failures.

The VSS itself looks like the laboratory of some crazed mechanical engineer. A web of hydraulic tubes and wiring run between a multitude of pumps and actuators fixed to a beefy blue steel framework. What the VSS may lack in aesthetic appeal, though, it makes up in usefulness. "We can put a variety of systems through a wide range of flight conditions right here on the ground," explains Gil Potter, who is in charge of the VSS Lab at Lockheed, Fort Worth. "More significantly, we can determine if the various systems are integrated properly with each other and with the flight control software."

The VSS occupies a portion of a large hangar to the north of the F-22 mid-fuselage assembly area in Fort Worth. The apparatus is isolated in an enclosed bay and encircled by a grated trench for containing potential leaks. Engineers and technicians watch the tests through safety glass from an adjacent room and from video monitors that display critical, but obscured areas. The precautions are required for dealing with the sound levels, moving parts, and pressurized hydraulic lines.

Even though the VSS shows little outward resemblance to a sleek fighter jet, it has an uncanny accuracy to the insides of the real thing. The pumps, actuators, and hydraulic lines and connectors match hardware that will be in the flying aircraft. "The locations of actuators, pumps, and electrical systems are relative to the real aircraft within inches," Potter explains. "The layout of the plumbing accurately matches all the twists and bends associated with the routing of hydraulic tubes in an actual F-22. Such fidelity is critical to valid testing."

Hydraulic power in an actual F-22 is provided by four hydraulic pumps. A pair of pumps is mounted on each of two airframe-mounted accessory drive units (AMADs), which are large high-speed gear boxes that take power from the aircraft's jet engines. A pair of actual F-22 AMADs is also nestled in the heart of the VSS. However, instead of being driven by a pair of Pratt & Whitney F119 engines, these AMADs derive their power from two large 500-hp variable-speed electric motors built by IDM Controls.

The electric motors are controlled by a dedicated computer that accurately simulates the behavior of an F119. The computer, called the stand-alone multi-engine real-time simulation, or SMRTS, was developed by Pratt & Whitney. It provides realistic feedback to a flight dynamics simulation model, which represents the motion characteristics of the F-22. This combination of computer simulators allows the electric motors to behave as the real engines would during flight. The motors react to throttle movements and flight parameters, such as altitude and airspeed.

During tests, a dynamic loading system, which is independently powered and computer controlled, applies loads to the F-22's hydraulic actuators to simulate flight loads on control surfaces. Basically, the loading system uses weights and hydraulic actuators of its own to simulate the inertia of a flight control surface and forces generated by air that would be flowing over these surfaces during real flight.

The VSS can be used to see how the hydraulic system and related flight controls deal with a wide range of operating conditions. The simulator allows engineers to analyze the operation of systems without putting a pilot or aircraft in jeopardy. For example, the system can accurately represent what will happen inside the airplane if the hydraulic system develops a major leak. The F-22's flight controls and utility systems can be monitored as the aircraft software goes through the routine of isolating the leak and closing off that branch of the hydraulic system. Once the leak is isolated, the systems are again monitored to see if they can function as designed.

Other test scenarios can be generated in the VSS with a pilot in the control loop. The VSS can then be used to simulate system failures, such as the failure of a flight control actuator, and allow the pilot to evaluate how the aircraft systems respond. This information is used to develop procedures for recovering from these failures. A test pilot in the control loop serves as an independent judge of the system performance. Randomness also plays a part in the pilot operation, since he or she may not respond as the designer expected during a specific situation.

Iron Bird testing has been around the aircraft industry for a long time. Lockheed Martin has had many such test stands, but this is the first program that has had such a thoroughly integrated stand. The F-111 had a flight controls test rig, but it was mostly mechanical in nature.

"Even after the first F-22 flies, the VSS will be available to duplicate failures and anomalies found in flight test operations," says Potter. "We will also use it to analyze the effects of new systems installed on the F-22. The VSS should prove a useful tool for development of additional capability on the F-22." ✈

Flying Safety

DR. SHEILA E. WIDNALL
Secretary of the Air Force

GEN RONALD R. FOGLEMAN
Chief of Staff, USAF

MAJ GEN FRANCIS C. GIDEON, JR.
Chief of Safety, USAF

GERALD C. STRATTON
Chief, Public and Media Affairs Division
DSN 246-0936

PEGGY E. HODGE
Managing Editor
DSN 246-0950

DOROTHY SCHUL
Editorial Assistant
DSN 246-1983

DAVE RIDER
Electronic Design Director
DSN 246-0932

MSGT PERRY J. HEIMER
Photojournalist
DSN 246-0986

Commercial Prefix (505) 846-XXXX
E-Mail — hodgep@smtps.saia.af.mil

DEPARTMENT OF THE AIR FORCE — THE CHIEF OF SAFETY, USAF

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The F-22
A Fighter Pilot's Dream

"The F-22 is truly a revolutionary step in fighter aviation and goes above and beyond anything the Air Force has done before. The design characteristics of supercruise, low-observables, thrust vectoring, high agility, integrated avionics (sensor fusion), and maintainability are what make this fighter revolutionary."

LtCol Steve Rainey
Air Force F-22 Test Pilot

Photos courtesy Lockheed Martin Aeronautical

PEGGY E. HODGE
Managing Editor

The F-22 is the first aircraft to embody all of the capabilities of stealth, low-observables, supercruise, high agility, and thrust vectoring. Let's take a look at some of this fighter's truly amazing technology and some operational insight by Lt Col Steve Rainey, who will ferry it to Edwards AFB, California, this fall for testing. This gives us a good understanding of our Air Force's newest fighter, why it is called revolutionary, and what this means to pilots.

The Technology

Integrated Avionics. "Integrated" means the F-22 can take information from many sources, compare that information, and determine a single, consistent picture of the world around the pilot. In addition to these external inputs gathered by the F-22's own sensors, several F-22s can exchange information by means of the aircraft Inter/Intra Flight Data Link (IFDL), and additional information can be gathered from off-board sensors like E-3 Airborne Warning and Control System (AWACS) aircraft and satellites.

Integrated avionics have some unusual characteristics. The F-22 has no radios, no navigation gear like the TACAN or Instrument Landing System (ILS), or even a radar in the traditional sense of a separate unit.

The Central Integrated Processor (CIP) modules have the ability to emulate any of the electronic functions through automatic reprogramming. For example, if the CIP module that is acting as the radio "dies," one of the other modules will automatically reload the radio program and take over the radio function. This approach to avionics makes the equipment extremely tolerant to combat damage as well as flexible from a design upgrade point of view.

"The integrated avionics is what truly separates the F-22 from any aircraft flying," says Lt Col Rainey. "All of the sensor information has been fused into a single picture for the pilot. In my mind, that's really the unique

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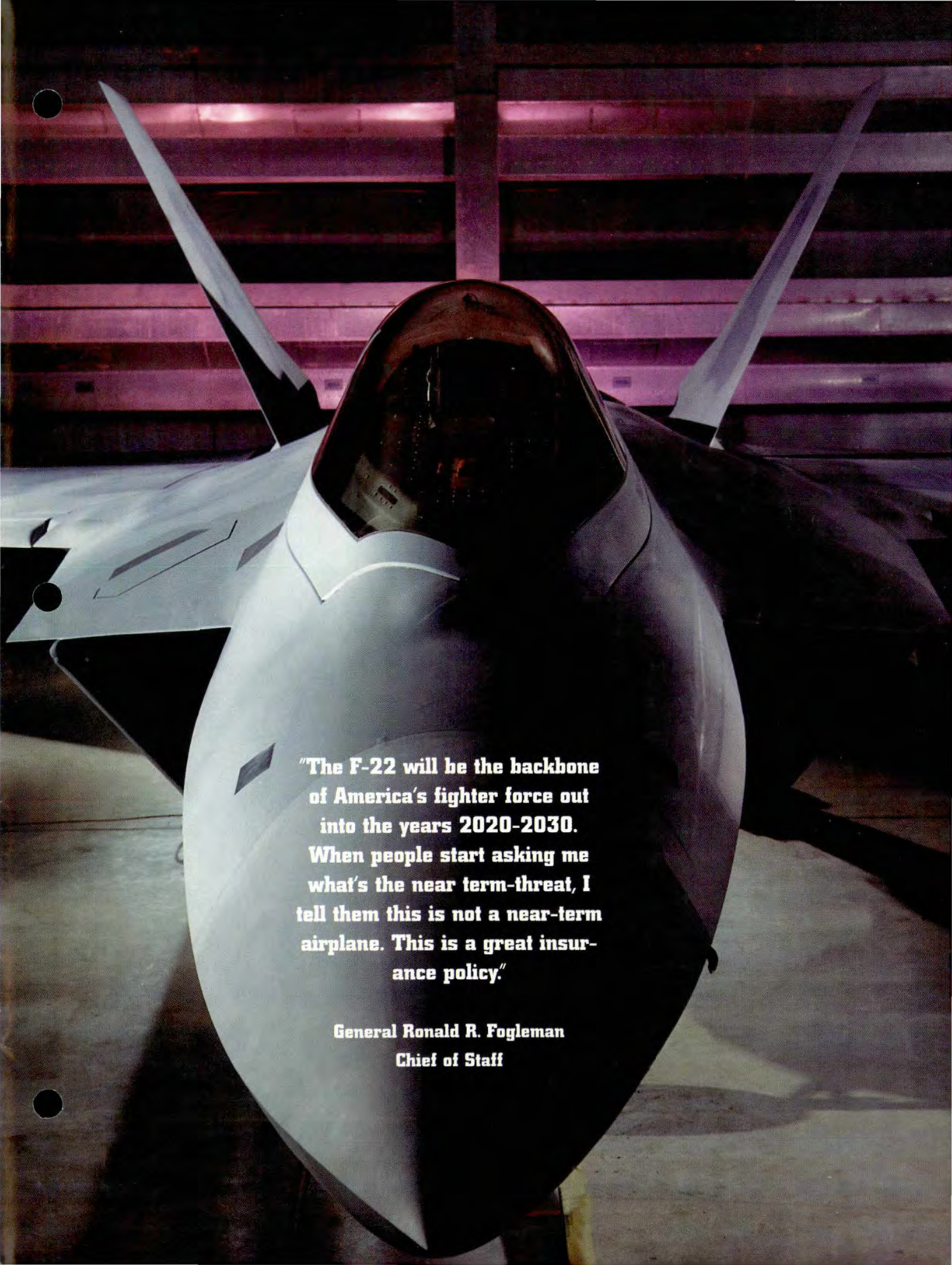

"The F-22 will be the backbone of America's fighter force out into the years 2020-2030. When people start asking me what's the near term-threat, I tell them this is not a near-term airplane. This is a great insurance policy."
General Ronald R. Fogleman
Chief of Staff

Stealth makes an object become very difficult to detect by sensors such as radar, heat seekers (infrared), sound detectors, and even the human eye. While not invisible, the F-22's radar cross section is significantly smaller when compared to other current fighters making it difficult for enemy radars to detect.

thing this aircraft does that makes it such a viable threat—especially in the information age. Information is what is going to be the key to success on the battlefield."

The Flight Controls. The Vehicle Management System (VMS) provides integrated flight and propulsion control. The VMS enables the pilot to aggressively and safely maneuver the F-22 to its maximum capabilities. The system includes hardware, such as the control stick, throttle, rudder pedals and actuators, air data probes, accelerometers, leading edge flap drive actuators, and the primary flight control actuators. The VMS also encompasses the software that controls these devices.

The F-22 is the only fighter to have thrust vectoring. "We use thrust vectoring on takeoff," says Lt Col Rainey. "It's used to aid in rotation and then it's blended out. The pilot doesn't have an additional switch that says thrust vectoring on or off—it's all part of the flight control system. When you are at slower airspeeds, i.e., when we get less than 225 knots or greater than 12 degrees angle of attack (AOA), then it's blended back in and provides increased control power, pitch axis (longitudinal) only. This feature enables the pilot to bring the nose wherever he or she wants to and provides carefree post-stall maneuvering capability.

"Departure from controlled flight in this aircraft is a different animal than in the F-16. When the F-16 departs controlled flight, it goes into a deep stall mode where the tail is blanked out, and you're really just along for the ride. You have to manually select a switch called the manual pitch override and pitch rock the aircraft out of a deep stall," explains Lt Col Rainey. The F-22 is designed to operate at extremely high angles of attack called post-stall maneuvering with no adverse departure characteristics.

"In the F-22, there is no AOA limit, so you can pretty much put the nose where you want to, and it's very controllable even when you're falling straight down," says Lt Col Rainey. "To get out of this, it's a simple matter of pushing the nose over. There's no pitch rocking involved. For whatever reason, if you were to get into a mode where you were unable to control the aircraft, there is logic in the flight control system that will stop your yaw rate and automatically pitch rock you out of the situation.

"Some aircraft, like the F-15, have an over-G warning system. This system warns pilots when they are going to over-G the aircraft. The F-16 has a G-limiter, but it is only for symmetrical Gs. In the F-22, the flight control system and the control laws within that system protect the aircraft from a symmetrical or an asymmetrical over-G in any aircraft configuration so the pilot can do whatever he or she wants to with the stick."

Stealth. The most publicized and most revolutionary technology for aircraft is stealth. Stealth makes an object become very difficult to detect by sensors such as radar, heat seekers (infrared), sound detectors, and even the human eye. While not invisible, the F-22's radar cross section is significantly smaller when compared to other current fighters making it difficult for enemy radars to detect.

The leading and trailing edges of the wing and tail have identical sweep angles (a design technique called platform alignment). The fuselage and canopy have sloping sides. The canopy seam, bay doors, and other surface interfaces are sawtoothed. The vertical tails are canted. The engine face is deeply hidden by a serpentine inlet duct and weapons are carried internally.

"While the F-22 sensors are superior and provide long-range detection capability, stealth ensures the F-22 is not targeted during engagement," says Lt Col Rainey.

Supercruise and Agility. Supercruise is the term given to the capability of sustaining supersonic speeds for long periods of time without afterburner. Conventional fighters, while capable of supersonic flight, can sustain these speeds for only relatively short periods as the result of excessively high fuel consumption using afterburner. The F-22 can cruise supersonic without afterburner and therefore can sustain these speeds for long periods. The enemy must react to any intruder, and that reaction time to detect, aim weapons, and launch is severely reduced when the intruder is moving fast. At supercruise speeds, the F-22 becomes less vulnerable to enemy missiles and aircraft simply because they cannot react fast enough.

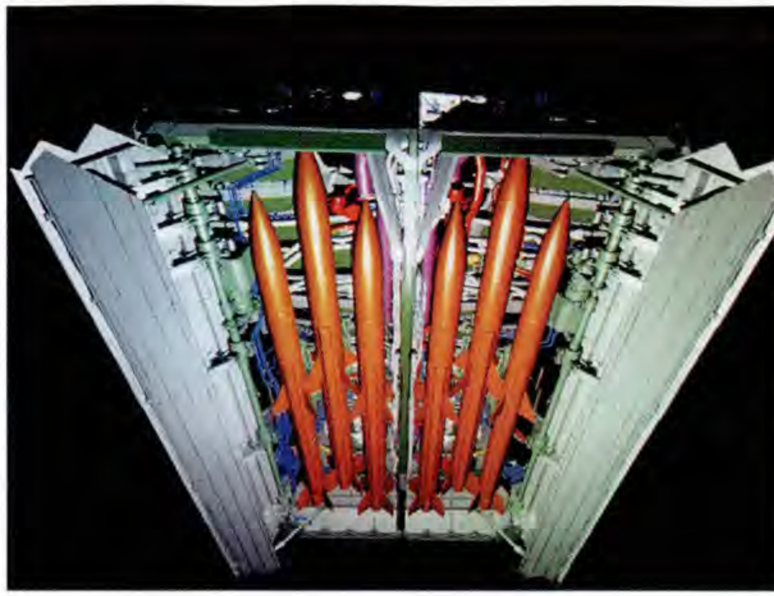
"The F-15 and F-16 can certainly go supersonic, but the ability to do that for an extended period of time without using afterburner is really revolutionary," explains Lt Col Rainey. "The -15 and -16 generally have to use the afterburner to go supersonic, especially if they fly supersonic for any extended period of time.

"As well, the F-15 and F-16 can certainly fly at very slow speeds and are very agile, but the ability to put the nose where you want to put it any point in time and go to post-stall angles of attack with impunity is again really revolutionary. AOA in the F-22 is unlimited. Once you've decided to use this capability to point the nose wherever you want to, the ability to then recover or get the airplane back to 1-G flight is relatively simple and uses very little altitude."

Housekeeping and Carefree Abandon. The elimination of "housekeeping" design criteria was driven by the desire to off-load the pilot from the many system operations that have classically taken a significant portion of the pilot's attention in the cockpit. In the F-22, computers and built-in testing (BIT) could replace much of the traditional pilot "housekeeping." The idea was to relieve the pilot of the bulk of system manipulations associated with flying and allow him (and now her) to do what a human does best—be a tactician. Using the power of the onboard computers, coupled with the extensive maintenance diagnostics built into the F-22, that workload has been significantly reduced.

"Most of the housekeeping is done automatically by the aircraft," says Lt Col Rainey. "And that's done by something we call the IVSC—Integrated Vehicle Subsystem Controller. It is basically six computer subassemblies controlling all of the critical aircraft subsystems. It controls hydraulics, the electrical and fuel management systems, the environmental control system, the auxiliary power system, and fire protection. It also controls the Integrated Caution and Warning System, life support, and diagnostic health management for the aircraft.

"So, it is fairly transparent to the pilot as to exactly what is happening to the aircraft at all



times. If the pilot should have a problem, let's say electrical, the aircraft will reconfigure its electrical load-by-load shedding. If a hydraulic leak should occur, there is a hydraulic leak and isolation detection capability so it will detect and isolate the leak so the pilot can continue the mission.

"Another example—if you should have a single-engine failure, the aircraft will automatically reconfigure the flight controls for your single-engine landing. It will reconfigure such that now the optimum AOA to land at is 11 1/2 degrees AOA instead of 12 degrees AOA and will automatically reconfigure the flaps for single-engine landing. The pilot doesn't have to think about these things. He simply flies on speed.

"So, all of this housekeeping is taken care of for us. Hopefully, in the end, it will prove to be beneficial and decrease pilot workload," explains Lt Col Rainey.

Carefree abandon translates into the ability of the fighter pilot to do whatever he wishes with the F-22, without fear of loss of control, loss of thrust, or aircraft structural overstress. Specifically, it is an unlimited AOA capability for the aircraft's basic combat configuration, i.e., all internal carriage of weapons and no external stores. There are no AOA limiters, and, most importantly, no restrictions on flightpath. The pilot can run the aircraft out of speed and maneuver in the post-stall regime with integrated flight controls and thrust vectoring. The F-22 responds smoothly to the pilot and can change flight conditions at his command.

There are no AOA limiters, and, most importantly, no restrictions on flightpath. The pilot can run the aircraft out of speed and maneuver in the post-stall regime with integrated flight controls and thrust vectoring.

"The team concept is really a major player for all of us in the F-22 program. Teamwork and integrity are the two real cornerstones of this program..."

Lt Col Steve Rainey
F-22 Test Pilot

"What this means," Lt Col Rainey explains, "is the pilot can do anything with the stick and throttles without fear of damaging the aircraft or getting into trouble. In most aircraft today, the pilot has to make sure that the aircraft is not damaged, over-G'd, or overstressed."

The Pilot's Role

"Typically, new fighter aircraft have been evolutionary," Lt Col Rainey says. "For example, the F-15 and F-16 evolved from previous fighters like the F-4. New technology provided improved or evolved capabilities. Each of these aircraft have continued to evolve. For instance, the F-15E and F-16, Block 40 and 50, while their evolved capability and pilot vehicle interface has certainly improved, the pilot or aircrew still has to integrate the information from the various systems. In the F-22, the mission software housed in the CIP will do most of the work in terms of assessing information from all aircraft sensors and then present a "sensor fused" integrated presentation of the tactical situation to the pilot. The pilot then manages this information and makes the command decision on weapons employment. Overall pilot workload is significantly decreased while increasing his overall situational awareness and ability to make sound tactical decisions.

"I think there are a couple of things we're going to have to think about when it comes to training pilots to fly the F-22," says Lt Col Rainey. "The performance on the F-22 is significantly better so pilots are going to have to adapt to that. It would be very easy for a pilot to unwillingly or unknowingly go supersonic at any altitude. You could easily punch this airplane through the Mach without thinking about it too hard. If you leave the throttle up at mil power, you're going to go supersonic. It doesn't matter what altitude you're at. This is new and different for pilots, and they are going to have to be trained to adapt to that.

"Also, when you are going faster, things go by quicker, so when you're performing full-mission scenarios, things happen a lot quicker, and pilots are going to have to be trained to respond a lot quicker. The integrated avionics are going to make that easier for us.

"This aircraft is optimized for supercruise as I mentioned above—optimum performance in terms of turning as well as max range profiles. They are different than they are for a typical F-15 or F-16. This means it has to be flown a little bit differently, and pilots will have to be trained for this. These are all training issues that can easily be learned in the simulator."

The Team Concept

Revolutionary fighter, concepts, and technology—but there are some things that are not revolutionary. It's called "The Team Concept." As Lt Col Rainey describes it, "The team concept is really a major player for all of us in the F-22 program. Teamwork and integrity are the two real cornerstones of this program. The people I work with on the F-22 program demonstrate the finest in teamwork and unquestionable integrity. I love my job—this is the best job in the world for a test pilot, and the F-22 is a fighter pilot's dream." ✈

Lt Col Steve Rainey

Photo by Eric H[illegible]aging Editor CODE ONE

Human Centered

Exploiting the pilot's capability as a tactician is central to the F-22 operational concept.

Courtesy *Flight International*

Photos courtesy Lockheed Martin Aeronautical Systems

Pilot-vehicle interface is a dry, but accurate, description of the centerpiece of the F-22's array of technologies. The F-22 cockpit is seen as a showcase of the team's achievement in integrating human potential into the aircraft.

It is here, under the single-piece canopy, strapped into the modified ACES II ejection seat, wearing the purpose-designed pilot's ensemble, hands on throttle and sidestick, facing an array of flat-panel displays, that the F-22's operational concept comes together—the concept of the pilot as mission manager, not sensor operator.

The F-22's integrated avionics operate the sensors, within limits set by the pilot, explains Ken Thomas, cockpit team manager. "The pilot commands information, and the system picks the sensors to answer the pilot's questions," he says. The pilot does not turn a sensor on, but instead sets the emission-control level, from passive through low-probability-of-intercept to fully active, within which the avionics must operate.

"The concept is based on a decision-making globe. The pilot needs information to make a decision, and the avionics need to provide it," Thomas explains. The time available to make a decision determines the quality of information required. "It's based on timeline, on whether the threat is a slow or fast mover," he says. "The outside ring is bearing-only, but the pilot can slew the cursor, and the avionics will go get more information and create a range/bearing track. If the pilot designates a target, the avionics will go get a weapon-quality track," Thomas says.

Need to Know

The pilot's need for information in time to make decisions determines zones of operational interest around the aircraft, based on the relative capabilities of the F-22 and the threat, such as signatures and sensor and weapon ranges. These zones determine the data the avionics must collect, fuse, and present to the pilot.

In the outermost zone, only situational awareness is required in the form of tracks provided by passive sensors. As targets move closer, they are prioritized by identity and/or threat potential. Based on target priority, the sensors are tasked to collect the additional information required to enable the pilot to decide whether to engage or avoid. At any time the pilot can slew the sensors' area of interest, but the system will maintain vigilance to detect threats that pop up.

The highest-priority targets are placed in the shoot list; the pilot can accept or change the priority, and the system will provide attack steering cues to launch AMRAAMs beyond visual range.

Information is presented to the pilot on three tactical displays, using icons which convey target identity and track quality. Thomas says that the concept proved to be intuitive in dem/val, when Air Force pilots with little combat experience emerged from full-mission simulations with some of the highest rankings. F-22 chief test pilot Paul Metz agrees: "An incredible assimilation of information appears in front of you very intuitively. The use of color, shape, and size passes information in a unique way."

Symbology is being tested which indicates target classification. Five different aircraft-shaped icons will identify the threat as a high-technology fighter, low-technology fighter, bomber, helicopter, or transport.

Threat classification fuses seven different types of data, "...six of which we can't talk about," says Gherry Bender, tactical subsystem manager at Boeing, which is responsible for the tactical displays.

According to Bender, the challenge of deciding what data are important and what are not has required considerable pilot input. In evolving the displays, "...the biggest effort has been to make it usable to the pilot and not overwhelm him. We want the pilot to be a tactician

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"The concept is based on a decision-making globe. The pilot needs information to make a decision, and the avionics need to provide it."

and not a sensor manager," says Stan Kasprzyk, pilot-vehicle interface team leader.

To help the pilot concentrate on the mission, housekeeping has been eliminated by automating subsystem control. Program general manager Tom Burbage says that start-up has been reduced to four steps: "Data-transfer cartridge in, battery on, APU (auxiliary power unit) switch on, throttles to idle, close the canopy—okay, five steps," he jokes. Avionics are brought on line and tested automatically.

In the air, response to system failures has been automated. "It's the pilot's job to go out there and fight, not be an engineer," says Metz. "If an engine stalls and flames out, it will restart itself. If it won't start, the pilot will be asked to descend so the aircraft can start the APU and use it to try to restart the engine. The pilot has to tell the engine to quit trying by pulling the throttle to off."

The integrated caution/advisory/warning system is being designed to provide the pilot with information on how failures affect the mission. Clicking on a warning message on the upfront display will bring up an electronic checklist on the multifunction display below. The checklist will tell the pilot how to handle the emergency—ultimately the pilot will press "execute," and the system will handle everything, says Thomas. The system is being designed to screen out the secondary effects of individual failures so that one warning message requires one action.

Carefree Abandon

The F-22 will be easy to fly, says Metz. "We've worked hard to achieve user-friendliness in the handling qualities of the aircraft," he says. The flight-control concept of "carefree abandon" means that the pilot "...will never have to worry about losing control, overstressing the aircraft, or getting anything but power," he says. There are 20 controls with 63 functions on throttles and sidestick which enable the pilot "...to do everything hands on," says Burbage.

Unusually, canopy design was part of the cockpit team's task, says Thomas. There is no canopy bow because of low-observability and pilot-vision requirements, and the transparency is a single piece of monolithic polycarbonate with no complex curves. Bird strike testing revealed a problem when the canopy deflected and shattered the head-up display, he admits, and display supplier GEC-Marconi Avionics is developing a collapsible combiner which will "...still work as a 600kt (1,100 km/h) blast shield," he says.

The canopy rotates down and translates forward to lock. To jettison, the canopy is pushed back and lifted off by a rocket thruster at its forward edge. Thomas says that the canopy does not fall but becomes a flying object and is weighted asymmetrically to ensure that it diverges from the ejecting pilot's flightpath.

Modifications to the Air Force's McDonnell Douglas ACES II zero-zero ejection seat for operation at speeds up to 1,100 km/h in the F-22 include arm restraints and a fast-acting drogue. As the seat moves up the rails, restraint nets encapsulate the pilot, and the drogue is fired to deploy as the seat leaves the rails and before it can yaw. This prevents injuries which can occur if the seat is off axis when the drogue deploys, Thomas says. The seat is "electrified," he says, with an electronic sequencing system which can be tested on the ground.

The F-22 is the first program to include development of the man-mounted life-support system. "We wanted to be able to spend lots of time at high altitude and high G without wearing the pilot out," says Michael Wright, senior specialist engineer at Boeing. "The problem was that, to protect the pilot from chemical/biological (CB) threats, we had him wrapped in plastic. So we had to give him thermal protection. In addition, he needed more thermal protection in case he ditched in the water. If you put CB gear, a cold-weather suit, G-suit, and thermal protection on him, you'd be lucky to get him into the aircraft, let alone enable him to fly or fight, so we needed something different."

The resulting F-22 life-support system is divided into aircraft- and man-mounted pieces. An onboard oxygen-generating source has been developed by Normalair Garrett to "...fit into a small space with a peculiar shape." The UK manufacturer also developed a single breathing regulator/anti-G valve, to provide positive-pressure breathing at high altitude and high G.

Man-mounted pieces include an air-cooling garment, produced by ILC of Dover, Delaware. A dedicated line feeds conditioned air to the pilot, providing a temperature range of 13-32°C. Over this goes the flight suit, designed by Boeing and British Columbia-based META Research. Doubling as an immersion suit, as well as providing protection against flames and a CB environment, the integrated suit will meet with much higher pilot acceptance, Boeing says.

Over the suit goes an upper pressure garment, also CB-hardened, which provides counter pressure to assist breathing and counteract G. The lower G garment incorporates a one-piece bladder for the legs and lower torso. "It is still mobile enough so the pilots can fight, otherwise it would have had to be like a full pressure-suit like those used on the SR-71," says Wright.

A lightweight, low-lift helmet for successful ejection at speeds up to 600 kt and high altitudes has been developed by UK-based Helmet Systems. The helmet has provisions for noise reduction to counter the cockpit roar of the super-cruising fighter and incorporates a suspension system to prevent high-G turns affecting helmet-mounted display optics.

"From a pilot's perspective, the integrated suit is better because you get used to wearing the same thing. It's already a stressful time if you have to go into combat, and it helps if the suit, mask, and helmet are already familiar, and you don't need to add extra things for overwater flights and CB," says Boeing chief test pilot Chuck Killberg. ✈

F119 Build-Up to Begin

Design teams working on high-reliability, ease-of-maintenance for Pratt & Whitney's new engine

PRATT-WHITNEY Photo

PAUL PROCTOR
Courtesy *Overhaul & Maintenance*
Mar-Apr 96

Pratt & Whitney and the U.S. Air Force are capitalizing on cross-functional teams with decades of experience to design exceptional reliability and ease-of-maintenance into the new F119-PW-100 engine that will power USAF's F-22 air superiority fighter.

The resulting innovations should have a profound effect on both military and civil aircraft use by dramatically expanding aircraft availability and engine repair and removal intervals. Manpower, parts, training and maintenance budgets will be slashed as substantially less time and support equipment and fewer tools will be required for flightline- and depot-level maintenance.

Preliminary data indicates the new F119 powerplant, a 35,000-pound thrust-class engine designed from scratch by Pratt & Whitney, will require 75 percent fewer shop visits and at least 50 percent less support equipment than the original F100 engine used in the Air Force's F-15 and F-16 fighters, according to Ray Van Overschelde, vice president customer support and services, Pratt & Whitney's Government Engine and Space Propulsion division. These figures could improve further with experience, he said.

Pratt was chosen to supply the F119 for the F-22, for which the Air Force set tough maintainability and support goals, after a hotly contested flyoff. The company is manufacturing parts for 27 flight test engines under a lead-in engineering, manufacturing and development contract, Van Overschelde said. Build-up is scheduled to start in April 1996, with first deliveries to F-22 team-leader Lockheed Martin scheduled for September. Five heavily instrumented ground test engines already have been built, with seven planned by year-end. The multi-billion dollar F-22 program calls for 339 aircraft and 777 engines, including spares.

Key to the F-119's "user-friendly" maintenance strategy has been close scrutiny of the maintainer's tasks and viewpoints, Van Overschelde said. Pratt's goal was "to make it simple" for mechanics to work on the engine at both the flightline and depot level.

Maintainability Features

Maintenance concerns voiced by experts on the more than 100 Integrated Product Development teams that worked on the F119 design influenced overall engine design, Van Overschelde said. For the line mechanic, the

continued on next page

Each F-22 will be powered by two of these 35,000-pound thrust-class engines. By comparison, the engines powering the current F-15 and F-16 fighters have thrust ratings ranging from 23,000 to 29,000 pounds.

F119 includes:

◗ A shift to digital engine electronics with comprehensive, built-in diagnostic systems. Computerized diagnostic readouts are simple to understand and feature straightforward instructions.

◗ Location of all 29 line replaceable units (LRU) below the horizontal centerline of the engine for ease of access. LRUs also are only one deep and use captive fasteners. Some, such as the full-authority digital engine control, can be temporarily hung in place to aid assembly.

◗ Each LRU requires only one wrench size for removal and replacement. Average removal time is less than 20 minutes and the maximum is 45 minutes.

◗ No lock-wire use externally. This reduces labor and the potential for foreign object damage.

◗ Cast fuel manifold and throttle valves. This eliminates potential plumbing and related mounting problems.

◗ Flexible hoses. This eases replacement of other components, dropping the need to disconnect and remove—and possibly damage—hard plumbing lines.

◗ Wiring harnesses with quick-release, self-locking connectors and wires coded in simple colors. Harnesses also have "full engagement" indicators, and chafing is inhibited through the use of Teflon-impregnated Nomex braid.

◗ Borescope ports accessible without removal of other parts. These ports also use a common plug removal tool.

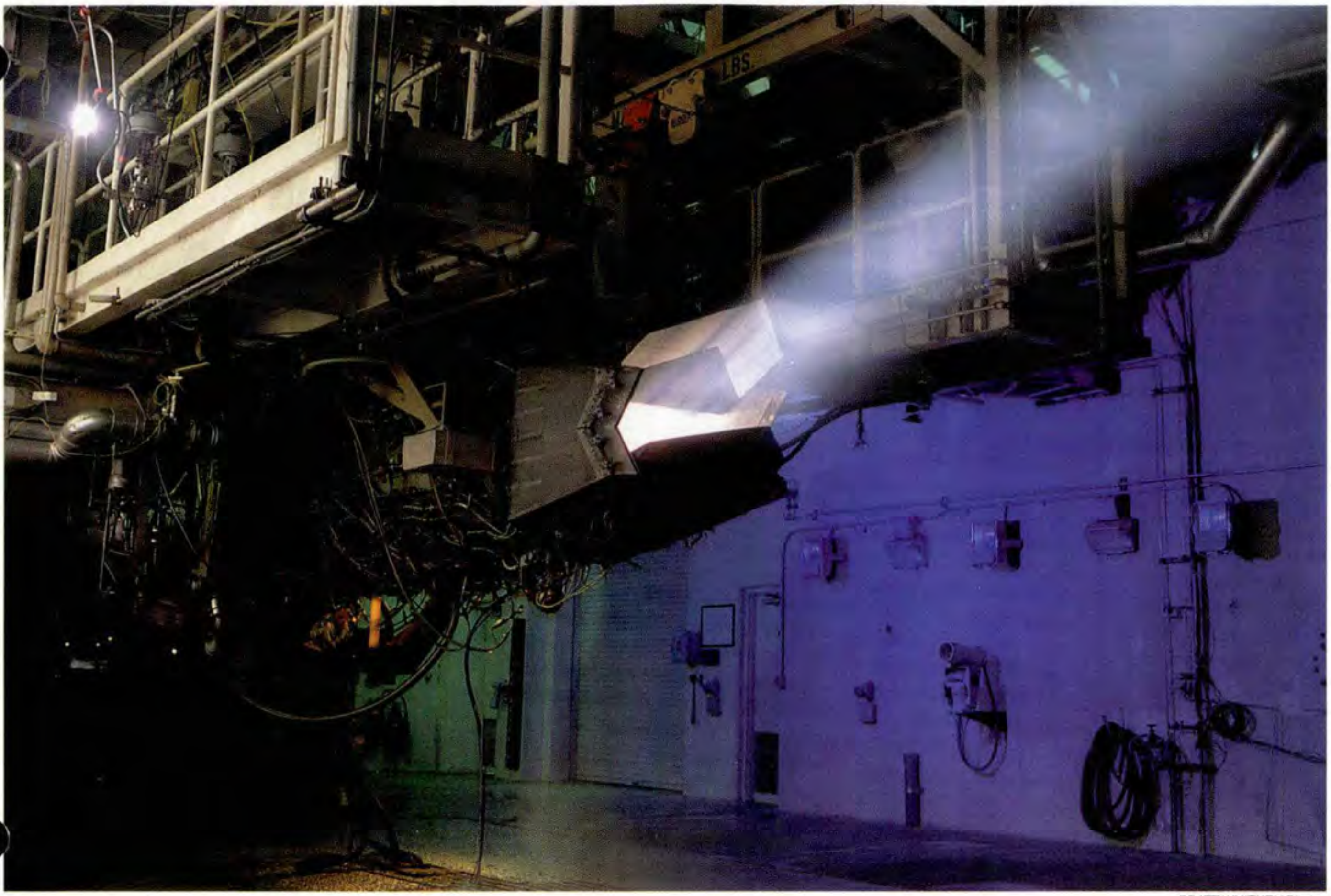
◗ Lightweight sheet metal/composite external plumbing and wire harness clamps. Clamp plates are captive to the mount, and clamp sizes have been standardized to only 19 types, compared with more than 100 on most other engines.

◗ Common cast or forged component mounts and water traps.

◗ No special repair or inspection technologies necessary. All technical manual information is available on a frequently updated electronic database.

◗ The ability for maintainers with a wide range of body sizes and strengths to easily maintain and repair the powerplant. Maintenance tasks also can be performed while wearing unwieldy nuclear/biological/chemical protection gear or in freezing weather with bulky gloves.

The engine design also features integrally bladed rotors and advanced, single crystal turbine materials. High-strength, burn-resistant Alloy C is used in the engine's compressor stators, augmentor, and nozzle. In addition to its maintainability and reliability features, the F119 boasts a two-dimensional thrust vectoring nozzle for improved aircraft performance, and the ability to cruise at supersonic speeds for long periods without afterburners. ✈



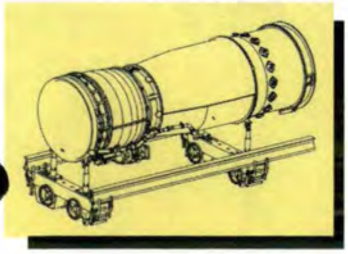
PRATT-WHITNEY Photo

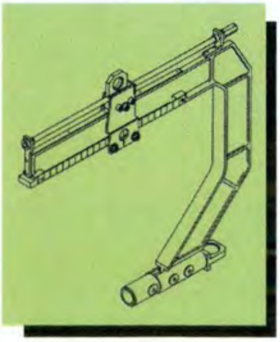
STREAMLINED TOOLING

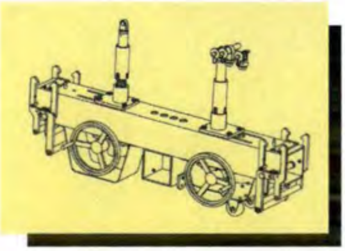
Tooling has been a major focus of F119 development. Advances include the use of 11 bolt sizes, or six individual hand wrenches, at the line maintenance level. In-shop tooling has been simplified and streamlined. Core lift arms, split case slings and engine support adapters are light-weight, multi-functional and feature pre-set center-of-gravity and other markings to speed tasks. Many are adjustable under-load.

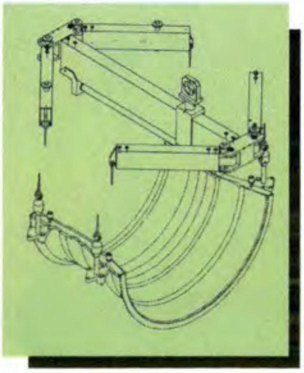
Like the engine itself, F119 shop tools capture loose details to prevent FOD. Wherever possible, the need to install attachment bolts to secure the tool to the engine was eliminated. Bright, corrosion-proof construction is intended to extend tool lifetime.

Overall, the F119 requires only 200 pieces of support equipment, compared with 400 for most of today's fighter engines, which Pratt estimated will result in a 75% reduction in the number of C-141 transport loads that will be required to support engines deployed for combat operations for 30 days.





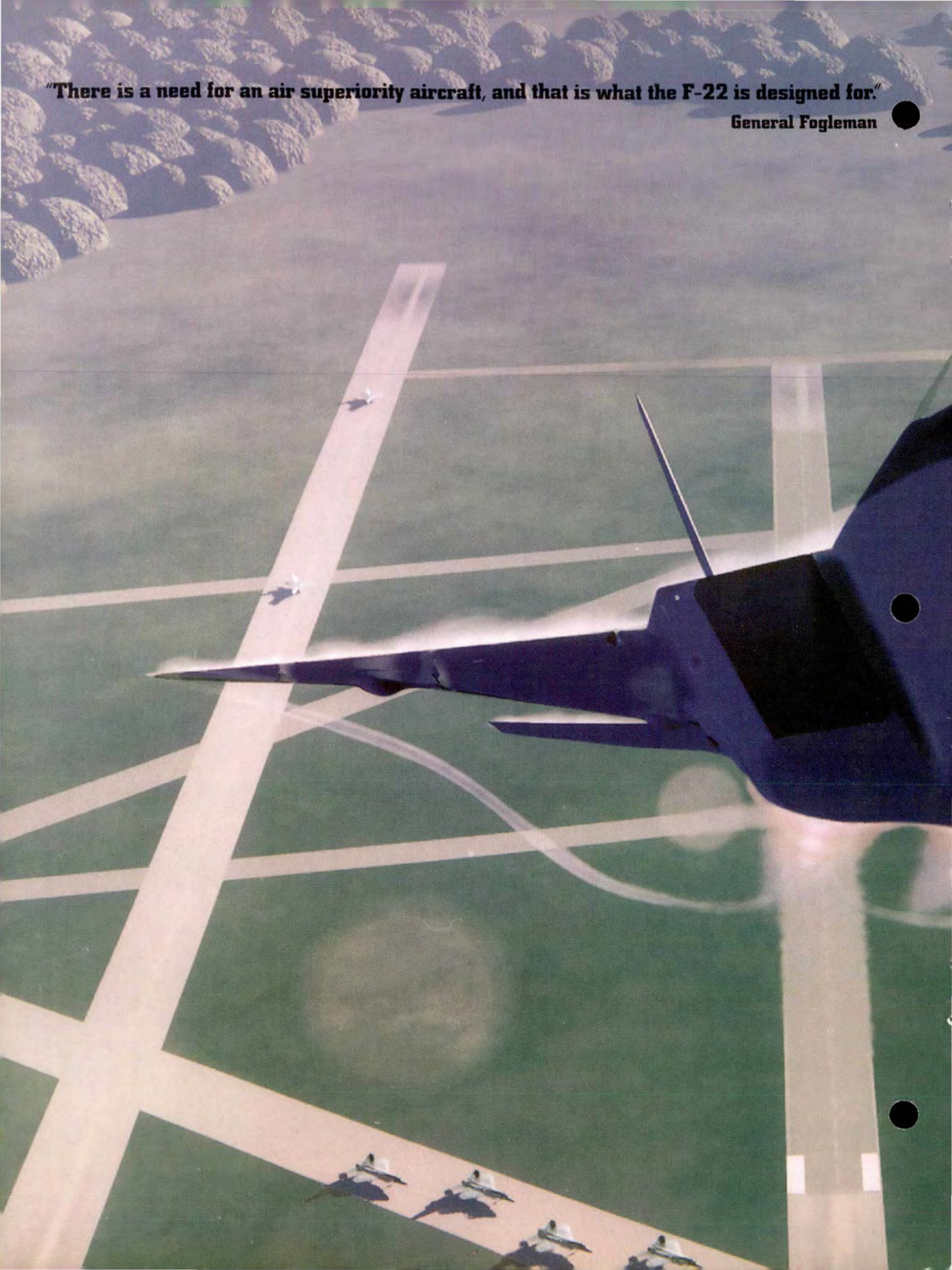




Courtesy *Overhaul & Maintenance*

"There is a need for an air superiority aircraft, and that is what the F-22 is designed for."

General Fogleman



Art courtesy Lockheed Martin Aeronautical Systems
Steven Moore; Artist

A Director's View

Composite courtesy Lockheed-Martin, Randy Spangle artist

In this issue, we take a look at some of the revolutionary capabilities and systems of the F-22. In "A Director's View," Brig Gen Michael Mushala, F-22 Program Director, Wright-Patterson AFB, Ohio, shares with us some thoughts on how safety and reliability were designed into the F-22 from the ground up.—Ed.

Brig Gen Michael Mushala

PEGGY E. HODGE
Managing Editor

Safety and Reliability

"Safety has been a key part of our design activities from day one," emphasizes Brig Gen Mushala. "The safety members of our team are a critical part of our integrated product teams and influenced the design from the beginning along with our Combined Test Force people at Edwards AFB, California. We also captured lessons learned from other programs here at the Aeronautical Systems Center, as well as the Air Force Flight Test Centers both at Edwards AFB, California, and Eglin AFB, Florida. This expertise was constantly at the forefront of the design process as our final design was established for the F-22.

"Working constantly with the operations and maintenance people was also at the forefront of our operations," explains Brig Gen Mushala. "One of the things that goes hand-in-hand with safety is high reliability. Everything about this aircraft says we want to achieve the highest reliability today's technology will allow," explains Brig Gen Mushala. "In the area of aircraft systems, because we are a low observable platform, we really put a lot of attention into reliability of the systems for ease of maintenance," he says.

"If you look at the aircraft itself," he explains, "we have gone back to the very basics. The aircraft is designed with operators and maintainers in mind. What this means in real world terms is we are able to fly more sorties with less maintenance than any other aircraft.

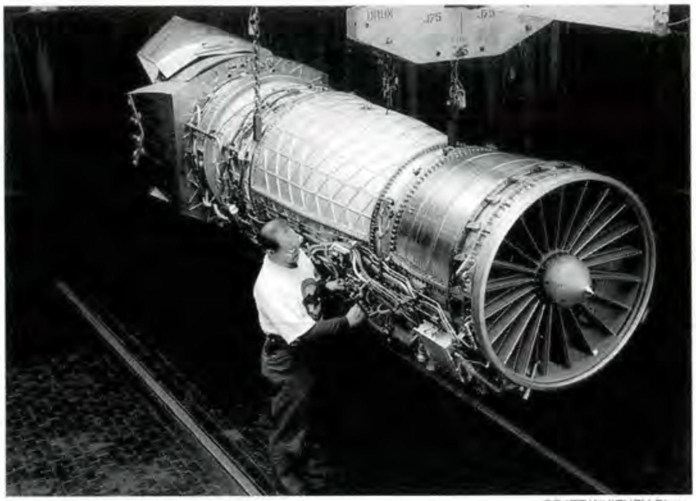
"The F-22's performance is significantly better in operations and support than any other fighter system in the past. What we have is an aircraft that is a dream for both our operators and maintainers. By looking at the F-22's cockpit and engine, you get a good idea of how our ground-up design work succeeds."

The Pilot's Cockpit

The F-22's cockpit represents a revolution over current "pilot offices," as it is designed to let the pilot manage the battle space rather than work as a sensor operator. The F-22 cockpit lets the pilot do what humans do best, and it fully uses the power of the computer to do what it does best.

"We basically have an all-glass cockpit," explains Brig Gen Mushala. "We have gone from the very basics of both understanding what it takes to develop a quality evaluation of a software that drives the individual displays. Pilots from Air Combat Command (ACC) looked at how we designed and built the cockpit displays to make sure the information presented was most easily understood. This is a major step in safety. If you can communicate effectively and get the most important information to the pilot, I think that significantly contributes to a safer environment.

"We're doing our homework now, and we've got a lot of people with tremendous amounts of flight experience and flight test experience to evaluate things like the cockpit and the cockpit display. We want to ease the workload in the cockpit and make a pilot's job of being able to effectively manage their battle space as easy as possible."


PRATT-WHITNEY Photo

The Maintainer's Engine

The F119-PW-100 is a revolutionary advance in fighter aircraft propulsion. "We again take advantage of expertise directly from maintainers," explains Brig Gen Mushala. "We asked maintainers from ACC if they had their way, what would they like to see on an engine? What they wanted most was all of the accessories on the *bottom* of the engine for easy access. And that's what we did. In the F119 engine, all of the accessories are accessible from underneath. A maintainer can remove the engine and work on it with six wrenches and six sockets. This gives us the ability to rapidly install and remove engines. Maintainability and ease of access were designed from the ground up.

"The tools the maintainers will use on the F-22 are the tools we are using today in developing this aircraft. What is used on the factory floor is what will be used on the flightline. We are making sure that it is going to be a very effective tool set for our maintainers.

"Maintenance people from ACC are on the shop floor, and they are looking at our tools, and they're looking at how we're using them. They're looking at ways to help us identify ways to do the job better.

"We've developed the portable maintenance aid which is an all-electronic and digital maintenance device which allows us to go out and interface with the aircraft. We have a completely digital maintenance environment from the integrated maintenance information system which allows access to everything."

A Whole New Vista

"With this aircraft, our crews have the capability to do some pretty amazing things," Brig Gen Mushala says. "The F-22 brings a whole new vista of capabilities that will help assure we can maintain superiority and guarantee air dominance for forces deployed anywhere in the world for the first half of the next century." ✈

Photo courtesy Lockheed Martin Aeronautical Systems

System Safety and the F-22

MAJ ROBERT M. WATSON, JR.
Chief System Safety Division
F-22 Program Office

System Safety: What is it? How does it relate to the F-22 Program? As a member of a flying squadron, you may ask "What is the connection between system safety and the flying safety program in my squadron?"

These are excellent questions and are very similar to the ones I had when I applied for my job in system safety. The purpose of this article is to answer these questions and give you, the squadron member, a better understanding of what system safety is and what we do as system safety managers.

What Is It?

Air Force Instruction 91-202, *The United States Air Force Mishap Prevention Program,* defines system safety as: ***"The application of engineering and management principles, criteria, and techniques throughout the life cycle of a system within the constraints of operational effectiveness, schedule, and cost. The degree of safety achieved in a system is directly dependent upon government and contractor management emphasis."***

A definition is a nice starting point, but how is this requirement carried out? The Department of Defense has mandated all major acquisition programs have a system safety program. The primary responsibility of the system safety program is to identify hazards (a hazard is a condition or design deficiency that could lead to a mishap), provide a means either to eliminate or control the hazard, and keep senior management informed on residual risks associated with the initial design of a system (e.g., Joint Strike Fighter and F-22 programs), as well as during any modification or upgrade to fielded designs (e.g., F-16 Block 40 upgrade or the Stall Inhibiting System/Stability Enhancement Function Modification to the B-1B).

Hazards can be identified many ways. The most common methods are by safety analysis and lessons learned from other programs and aircraft mishaps. A data base (Automated Lessons Learned Capture and Retrieval System (ALLCARS)) is maintained by the Air Force to help system safety personnel relate lessons learned to the particular program they are working. These hazards apply not only to the airframe and engines but to support equipment, training, technical order data, and software as well.

With today's highly advanced technology, computers play a key role in many systems, and the software in these computers can generate hazards and potential system loss. Software is a key part of a system, and the system safety manager needs to evaluate it for hazards.

Once the hazards have been identified, they must be controlled. This is done by using the "Safety Order of Precedence":

1. Design out the hazard—change the design to eliminate the hazard, e.g., eliminate the hazard of a high-pressure hydraulic leak in the cockpit by rerouting the hydraulic lines away from the cockpit.
2. Incorporate safety devices—features that automatically happen when a failure occurs, e.g., fly-up command for terrain-following radar.
3. Provide warning devices—a feature letting the pilot know he/she has a problem, e.g., engine fire light.
4. Use of training, procedures, and personal protective devices to mitigate the hazard—specific training for and documentation of a known hazardous condition, e.g., a maintenance task requiring use of hazardous materials and the associated warnings for the use of personal protection equipment.

System safety personnel can never design out all the hazards associated with a particular part/system, but we can control them to a certain level of risk. Once this risk is defined by analysis, it is up to the program manager, with recommendations from the user of the end product, to accept the remaining/residual risk or go back and have the particular part/system redesigned. This is an ongoing process throughout the development of a new system or modification of existing systems and does not end until disposal of the system.

Photo courtesy Lockheed-Martin

How Does System Safety Work in the F-22 Program?

First, one has to understand what is meant when we say the "F-22 Program." This program is not just the development and acquisition of the airframe, but includes the development and acquisition of the engine, operational and maintenance training systems (courseware, simulators, and training devices), and all support equipment required to field the F-22 weapon system. The F-22 System Safety Office is responsible to the program director for all safety issues in the development of the entire program—not a small task.

However, the F-22 program has implemented the Integrated Product Team (IPT) process in the F-22 weapon system development. Each IPT has representation from all the key disciplines in the acquisition business. (An analogy would be a mini-wing, capable of all required war-fighting functions).

By having experts from the varied disciplines working closely together, the team can make key decisions on the weapon system development at the appropriate level (centralized control via the program office—decentralized execution via the IPTs) resulting in reduced acquisition time and lower cost procurements. These are two major requirements in today's environment of reduced defense budgets and overwhelming need to modernize our combat forces. System safety is a member of all these IPTs ensuring appropriate safety requirements are in the design within the constraints of operational cost, schedule, and performance.

As a Member of a Flying Squadron, What Is the Connection Between System Safety and the Flying Safety Program in My Squadron?

Identifying safety requirements early in the weapon system development is vital in reducing costs in the acquisition process and developing a system that can be operated and maintained safely. System safety, working in concert with the IPTs and using MAJCOM experts (current operational pilots and maintainers), define safety requirements early in the acquisition process. These requirements can include a need for certain aircraft safety equipment or defining specialized maintenance procedures. By using the MAJCOM experts along with the IPTs, an acceptable aircraft baseline can be established blending in both safety and operational requirements.

Once the baseline aircraft is built, it is flight and ground tested to ensure all requirements are met so the system can be fielded. When the aircraft is fielded, system safety continues to aggressively monitor the aircraft for problems. If problems are encountered with aircraft design, the Air Force has a process for reporting these and handling them called the Air Force Deficiency Reporting (DR) System. Also, if a problem with technical data arises, there is a formal process to handle these changes (AF Form 847 and AF Form 22).

The DR process is the key link between the user and the acquisition process. The keeper of the DR process is usually the local wing quality assurance (QA) section. They have a specific data base for DRs, and the program office has access to this data base. It is the program office's responsibility to review each DR in a timely manner and make recommendations.

If the DR affects the safety of the weapon system or personnel, it has to be handled immediately and takes priority over other program office duties. (The problem should also be investigated/reported through the formal AFI 91-204 process.) A recommendation will be made to the using MAJCOM on how to fix the problem along with the associated costs. It will be up to the MAJCOM to determine if the fix should be incorporated into the weapon system. The key for you, the operator, is you can request QA input a DR on an aircraft part. This is very important because what the program office does not know, they cannot try to fix. So the problem/hazard remains until it is discovered by someone else or we have a mishap.

If I can leave you with one thought about system safety and its relationship to you, the operator, ***"Report problems so the program office can do its job and help you, the user, have the safest system possible in which to accomplish your mission!"***

Well, that's what system safety is in a nutshell. We are here to help you, the user/maintainer. Keep us informed so we can better support you. Keep the gray side up, stay fast, and check six. ✈

Nonalcoholic Beer and Flying

LT COL WALLACE SEAY
Chief, Aeromedical Education Branch
U.S. Army School of Aviation Medicine
Fort Rucker, Alabama

Every member of the Army aviation community is familiar with the old "12 hours bottle-to-throttle" maxim. Specifically, AR 40-8 restricts flying duties for 12 hours from the last drink and until no residual effects remain. Safety is the ultimate concern.

Over the last few years, as drinking and driving has become socially, militarily, and legally unacceptable, nonalcoholic beers have hit the market. What are they? They are, in fact, beer—brewed, fermented, malt beverages. However, "nonalcoholic" is a misnomer; the brew is ***low*** alcohol, not ***no*** alcohol.

The average nonalcoholic brew contains 0.5 percent ethyl alcohol, compared to 5 to 7 percent (and occasionally more) in traditional beer. Because it is required by law to be labeled, nonalcoholic beer is classified as an alcoholic beverage.

This brings up the question of Army aviation policy regarding nonalcoholic beer. The Aeromedical Consultants Advisory Panel of the Army Aeromedical Center at Fort Rucker reviewed information on nonalcoholic beer, including "perception" issues. Under AR 600-85, Army Drug and Alcohol Prevention and Control (ADAPC) does not differentiate nonalcoholic from alcoholic beer; rather, beer is beer. As noted earlier, nonalcoholic beer does have some alcohol content, albeit a very small amount.

And then there is the "perception" issue to consider. A person drinking nonalcoholic beer gives the appearance of drinking beer, nonalcoholic beer smells like beer on the breath and on clothing, and it is marketed in bottles and cans that are identical to other beers. Therefore, the aeromedical policy on nonalcoholic beer is that it is an alcoholic beverage. The medical recommendation in AR 40-8 of 12 hours from the last drink and until no residual effects remain will not be altered for nonalcoholic beer.

"Twelve hours bottle-to-throttle" remains the rule.

Courtesy *Flightfax*, May 97

Legendary ACES II Ejection Seat Improved for Twenty-First Century

BOBBIE MIXON
ASC/PAM
Wright-Patterson AFB, Ohio


Official USAF Photo

The Air Force's new fighter jet, the F-22 Raptor, will fly for extended periods at speeds greater than Mach 1. It has a top speed of Mach 1.8 plus. It has thrust-vectoring engine nozzles which make it the most agile aircraft in the U.S. military inventory. But its high-speed and high-tech advancements also make harder the job of keeping the pilot safe should an ejection from his craft be necessary.

To cope with the Raptor's high-speed flight environments, engineers at the Aeronautical Systems Center's F-22 System Program Office (SPO) have developed an improved USAF ACES II (Advanced Concept Ejection Seat), thus modernizing the legendary lifesaver for the twenty-first century.

"When a pilot runs out of options, the escape system is there to allow survival," said Vic Santi, the Air Force's F-22 Escape System Program Manager. "My goal is to put a pilot on the ground in good enough condition to evade capture, help with rescue, and return to the cockpit."

Testing of the improved ACES II has been ongoing at the "sled facility," Holloman AFB, New Mexico, since November of last year, with the most recent sled test conducted in February.

A full-scale forebody model has been used to conduct sled tests at 0, 275, 325, 450, and 560 knots equivalent airspeed (KEAS), a measure of how fast an aircraft is traveling. Differing airspeeds are used to study wind forces during ejections and how those forces act upon an ejection seat and the human body.

"At high speeds, wind forces become very difficult to control and tolerate," said Santi. "In an aircraft like the F-22, where we'll be operating for much longer at higher speeds, we anticipate average ejection speeds to increase 50 to 100 KEAS to a region where injuries become more likely," he said.

According to Santi, average ejection speeds are just below injury threshold levels, with major injuries and fatalities rising sharply at speeds near 600 KEAS. ACES II testing at Holloman and testing at other locations is designed to investigate modifications that improve seat maintainability and pilot safety at higher speeds.

The tests, which were the first to use the Armstrong Laboratory's Advanced Dynamic Anthropometric Manikin (ADAM) in an aircraft certification program, have successfully proven the effectiveness of a new arm-restraint system added to reduce arm-flail injuries during high-speed ejection.

The arm restraint showed good results through 450 KEAS, preventing arm flailing which is a major cause of pilot injury when aircraft escape systems are deployed. A minor seat modification is being studied to increase the restraint system's capabilities through 600 KEAS.

ADAM, a research tool used by the laboratory's Biodynamics and Biocommunications Division here, is a fully instrumented manikin designed to replicate the physical characteristics of the human body in dangerous situations and provide accurate answers about human reactions.

The modified ACES II also uses a fast-acting drogue-chute system to improve seat stability and reduce possible injuries resulting from acceleration. In a typical ejection, there are a myriad of forces acting upon the seat. In some situations, it is possible for the seat to rotate/tumble in the first few seconds of the ejection. This could injure the pilot, so stabilizing the seat is critical at high speeds.

According to Santi, the drogue chute is possibly the biggest improvement in ACES II seat performance since its initial introduction in 1978. "The fast drogue is a big step forward in stabilizing the seat right off the rails," he said. "In ejection systems, stability is like air superiority—with it you can achieve everything."

Another improvement is a 50-cubic-inch oxygen system for emergency descent from altitudes in excess of 50,000 feet. The oxygen capacity provides breathing gas for a longer duration and positive-pressure breathing to protect from the effects of high-altitude exposure.

"I have a deep interest in safety equipment and an appreciation for ejection seats," said McDonnell Douglas' ACES II ejection seat program manager Glen Larson, who as a former fighter and test pilot has had some close calls.

"Our team in Florida has done an especially fine job of constructing and delivering this ejection seat. The ACES II seat was always the finest in use. Now it's even better." ✈

Safety on the Nellis Ran

In 1996 there were 186,233 sorties flown on the Nellis Air Force Range. The ranges offer a wide variety of targets for inert and live munitions for test and training missions.

99th RANS archive photo

KEVIN R. CARR, CIV, USAF
Chief, Range Safety Branch
(HQ AWFC/SEY)
Air Warfare Center

The B-52 crew is approaching the mission objective after a 3-hour flight. The fatigue caused by the sound of the engines and the vibration of the plane is now replaced with the adrenaline rush from the preparation for a low-altitude bombing of an enemy airfield, enhanced through the use of night vision goggles. The mission is completed as MK-84 general purpose 2,000-pound bombs fall from the payload bay and ignite the sky with the explosions of bombs impacting the runway. The crew gains altitude and prepares for the long ride back to base.

This mission could have been a wartime bombing mission but was actually a night training mission on the Northern Ranges of the Nellis Air Force Range (NAFR) for a B-52 crew from Barksdale AFB. The realistic capability throughout the Nellis ranges, more commonly known as the "Nellis Range Complex," has provided a foundation for Department of Defense (DoD) testing and training since World War II. The purpose of this article is to define the nature of the ranges and to share the basic safety procedures that make the Nellis ranges some of the safest in the world.

The 99th Range Squadron manages operation and maintenance of the NAFR, which comprises some 3.1 million acres of withdrawn public land and 12,000 square miles of airspace. The 99th Range Squadron is one of two squadrons assigned to the 99th Range Group. Through the Air Warfare Center (AWFC), the 99th Air Base Wing and the 99th Range Group, Air Combat Command (ACC) provides the world's "premier integrated battlespace environment," supporting advanced composite force training, tactics development, testing, and research and development.

"In 1996 there were 186,233 sorties flown on the Nellis Air Force Range. Also, 45 percent of all live ordnance dropped in peacetime by the Air Force, including 67 percent of all live ordnance dropped by Air Combat Command, is dropped on the Nellis ranges," states Maj Jason Altchek, Commander of the 99th Range Squadron's Project Management Flight. The range group carries out its charge through the efforts of some 600 contractors and nearly 300 military and civil service personnel.

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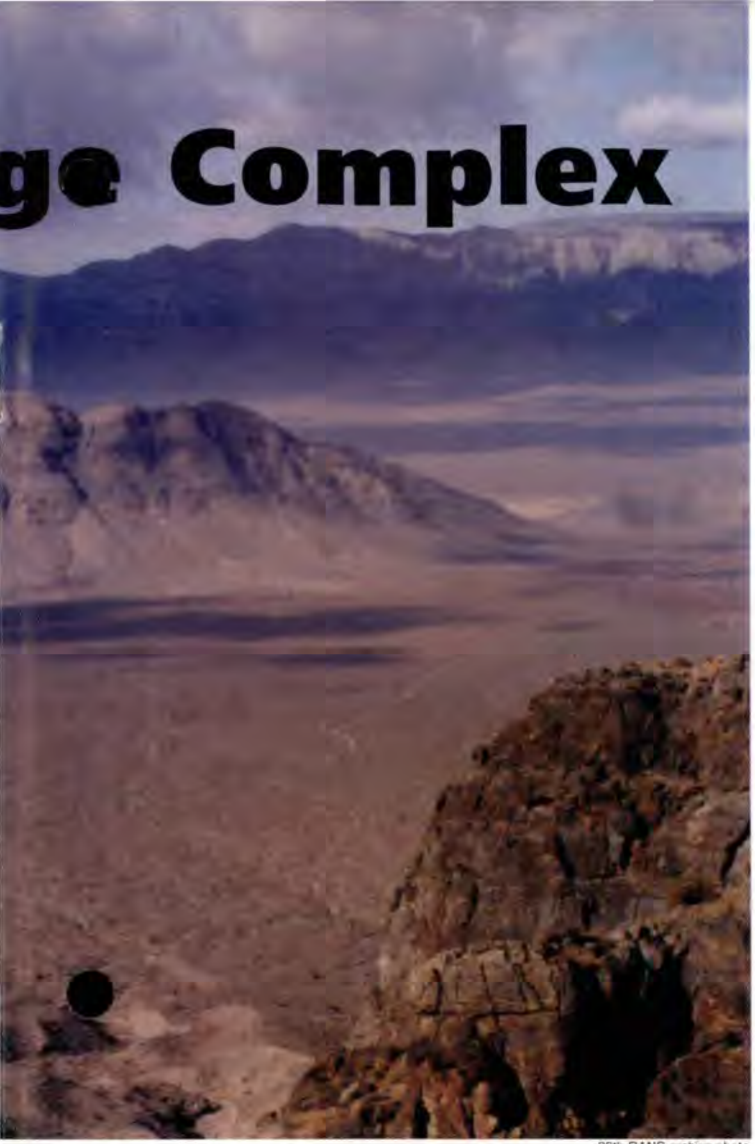

99th RANS archive photo

The 99th Range Squadron commands two detachments located on the Nellis ranges: Indian Springs Air Force Auxiliary Field, which manages Nellis' Southern Ranges; and Tonopah Test Range Airfield, which manages Nellis' Northern Ranges. In addition to these Nellis facilities, it operates, maintains, and develops four geographically separated electronic scoring sites at Colony, Wyoming; La Junta, Colorado; Dugway, Utah; and Everton, Arizona. A brief look at the missions of the Southern Ranges (Detachment 1) and Northern Ranges (Detachment 2) will help define the nature and capabilities of the NAFR.

Detachment 1 of the 99th Range Squadron is responsible for supporting all ACC activities at Indian Springs Air Force Auxiliary Field and the Southern Ranges of the NAFR. They direct support of DoD, Department of Energy (DOE) research, development, and testing programs. The detachment also supports recovery of emergency/ divert military aircraft involved in major aircrew training exercises, such as Red Flag.

The ranges offer a wide variety of targets for inert and live munitions for test and training missions. Examples of missions performed on the Southern Ranges include strafing and employment of cluster bomb unit drops, aircraft-mounted rockets, laser-guided bombs, and general-purpose bombs. Although various forms of testing are done throughout the NAFR, Det-1's Range 63 is configured to provide real-time data for operational testing and evaluation missions. This is accomplished through a variety of means, including upgraded Television Ordnance Scoring Systems (TOSS), state-of-the-art Kineto Tracking Mount optical documentation, ballistics data reduction, and Time Space Position information (TSPI) data.

In conjunction with the 99th Security Police Squadron's Ground Combat Training Flight, Det-1 hosts ACC's Desert Warfare Training Center, or Silver Flag Alpha. Recently, the 11th Reconnaissance Squadron—the Air Force's first operational unmanned aerial vehicle (UAV) squadron—began using Indian Springs to support UAV operations and training. Det-1 coordinates operational and support matters with Department of Interior, US Fish and Wildlife Service, and other federal, state, and local government agencies. Within its boundaries, the Southern Ranges include the Desert National Wildlife Range.

Detachment 2 of the 99th Range Squadron is responsible for, and directs, all ACC activities at Tonopah Test Range Airfield and the Northern Ranges. Like their southern partners, the detachment directs support of DoD, DOE research, development, and testing programs and also supports recovery of emergency/divert military aircraft involved in major testing and aircrew training exercises. The Northern Ranges offer unique test and training targets such as airfields, missile sites, trains, and bunker formations and a wide variety of threat simulators, uniquely tailored to individual mission requirements. Det-2's mission includes providing sophisticated training, testing, and weapons evaluation for various defense and other federal agencies, as well as allied nations.

To support aircrew training and testing, the Northern Ranges are further divided into the Tonopah Electronic Combat Range and the Tolicha Peak Electronic Combat Range. The detachment coordinates operational and support matters with Department of Interior, Bureau of Land Management, and other federal, state, and local government agencies. Within its boundaries, the Northern Ranges include the Nevada Wildhorse Range—the first wild horse area established in the United States. A superb host-tenant relationship exists between Det-2 and Sandia National Laboratories, which operates a specific portion of the Tonopah Test Range.

The NAFR is one of, if not the most, sophisticated, versatile, and complex training and test range in the United States. The often varied and complex nature of the NAFR represents many safety challenges that are addressed on a daily basis at Nellis AFB. Safety considerations are addressed in the early planning stages of test and training missions as well as in the daily operations of the personnel who constantly access the range, either in the air or on the ground.

During the planning stages of test and training missions, the users of the NAFR are required to coordinate

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Photo by Msgt Barry Miller, 99RANS, Nellis AFB

their mission with the 99th Range Squadron to determine the need for a Range Safety Approval (RSA) and availability of range facilities and airspace. Tests and selected training exercises involving armament, weapons delivery systems, or laser systems missions not previously approved required an RSA signed by the commander. The RSA is prepared by the Air Warfare Center's Range Safety Office (HQ AWFC/SEY). The preparation of the RSA involves a team effort between the user, the range squadron, and the Range Safety Office and results in the identification of all significant hazards associated with the mission as well as the assignment of an overall risk rating. Any RSA assigned a risk rating greater than an acceptable or low rating will identify the reason for the moderate or high risk rating as well as a recommendation to the range squadron commander for approval or disapproval. The range squadron commander is responsible for assessing the risks and accepting or rejecting those risks associated with test or training operations.

A majority of the training missions performed on the NAFR are based on pre-existing safety requirements defined in AFI 13-212, Vol 1/NAFB Supplement 1, Weapons Ranges, and AFI 13-212, Vol 2/NAFB Supplement 1, Weapons Range Management. Users can simply access the targets information web page through the internet (http://www.nellis.af.mil/range/) or (http://www.nellis.af.mil/range/99rs/99rsdo.htm) and plan their training missions using the listed approved weapons and release parameters for each bombable target. Any user that requests a modification to an existing target requires Range Safety Office and range squadron approval. These requests can result in either a short-term approval or permanent target change.

In summary, the excellent safety record of the NAFR is a result of excellent planning and preparation based on a complete safety evaluation of all hazards associated with the missions. While planning and preparation for each mission are important, the daily safety operating procedures that occur on the range implement the safety precautions identified during the planning stages.

When considering all daily safety operations, the Scheduling and Range Safety Branch of the 99th Range Squadron, or "Blackjack," coordinates the real-time scheduling and management of the ranges in a safe and effective manner. Blackjack functions as the range safety monitor by ensuring all users abide by all air and ground safety requirements and ensuring aircraft use only authorized ranges and targets. Blackjack is the central control for all sorties entering and leaving the range to ensure that the scheduled activity has been approved by range squadron and the Range Safety Office. The capabilities of Blackjack ensure flight safety and airspace requirements are met for each sortie using the new Range Airspace Management System. In addition, Blackjack maintains coordination with all ground parties and keeps an accurate record of ground and air activity.

In addition to Blackjack, all ground and air parties that enter Det-1's manned Class A ranges must gain approval and maintain two-way communications with the Southern Range Blockhouse, which Blackjack also monitors. When entering a non-manned range, ground parties must maintain two-way communication with Blackjack. Continuous communication ensures ground parties will not be exposed to munitions on active bombing ranges. Ground parties provide the number in party, person in charge, purpose of visit, route and transit time, area to be visited or worked, estimated time on range, and estimated departure time.

In addition to constant two-way communication, pilots are expected to use common sense procedures before the activation and release of ordnance. Pilots are required to become familiar with the target location before release of any ordnance. This familiarization can result from either a "dry pass" by the pilot over the target or previous use of the target on previous missions. The pilot should be aware of the location of all manned, threat, and scoring sites before the activation and release of any ordnance. In addition, pilots are not allowed to fly over any manned operations with armed weapons.

Due to the continuous communication among users, range squadron, and the Range Safety Office, the test and training missions performed on the NAFR are performed safely and efficiently. Safety has become an intricate part of all range procedures to ensure that a very busy and sophisticated complex will support today's DoD needs and posture for safe and effective use well into the twenty-first century. ✈

Everyone Stop Talking!

I'm Trying to Bring Back the CO's Plane!

LTJG JEFF LOCKE
Courtesy *Approach*, Jan-Feb 97

The skipper still wanted to talk to me, but I blocked him out. "Communicate" still comes after "aviate and navigate."

DOD Digital Image

■ It was a beautiful August day to fly. As a new CTPC with 650 hours in the C-2A, I was looking forward to the novel experience of flying FCLPs as the aircraft commander rather than as a switch pilot. We launched for NAS Oceana and bounced through sunrise and into the morning. When we finished the FCLPs with 6,000 pounds (half a bag) remaining, we completed a maintenance in-flight ramp check before going home.

The copilot flew a visual to the overhead runway 10 at Chambers. After a normal break, he lowered the gear. There was an immediate loud thump accompanied by a slight airframe shudder and swerve to the left. The copilot had no trouble controlling the aircraft as we checked our engines and other systems for secondaries. Our right main gear and nosegear came down after a normal cycle time, but the left main remained barber-poled with a light in the gear handle. The crewman could see from the cabin window that the actuator on the left main gear had separated from the strut.

I decided to call the tower and orbit overhead to complete the EPs for main-gear actuator-failure procedures before also advising base of our exact problem. I didn't want to have everyone talking to us just yet.

Before we could finish reading the appropriate section in the PCL, we had the SDO, skipper, and LSO calling on base, the tower calling to ask what assistance we might need, and approach calling to confirm we were declaring an emergency! All the help made me think how glad I was that we still had 2 hours of fuel to sort this all out.

The copilot took all the callers except the LSOs, now on paddles-tower freq, who requested some low passes so they could check the gear. The copilot flew two low passes while the LSOs read the emergency procedures to us, and we discussed options. We agreed the best course of action would be to climb to altitude, do a side-to-side seat swap, dump fuel, and fly a left-engine-secured approach to a field arrestment as noted in NATOPS. During this time, the other players still quizzed us regularly. The skipper wanted to talk to me, but I blocked him out. "Communicate" still comes after "aviate and navigate."

We reseated ourselves at altitude, did our crew brief, and told everyone calling us about our intentions. After some motivational words from the skipper, we started our approach, deselecting everyone except the tower-LSO frequency. During the descent, we completed our checks and reviewed single-engine approach, go-around, and emergency egress.

We flew an uneventful single-engine approach to a field arrestment. We had to maintain approach power on the right engine to prevent the aircraft from rolling back and collapsing the left main gear while the in-flight PC exited out the ramp and placed the ground lock on the gear.

It turned out the gear actuator had sheared at the lower attaching point, allowing the gear to fall free. The impact without snubbing action had crushed the downlock sensor and cracked the drag brace.

Lesson learned: As the aircraft commander in an emergency (even one as textbook as this), you must manage outside support while coordinating crew duties, which may mean firmly silencing unnecessary assistance. We all hate to sit by the radio, waiting to hear what's going on when an emergency is in progress. However, too much unrequested "help" can cause as much confusion in the cockpit as no help at all. ✈

When Not to Give the Skipper Extra Training

I asked myself how anyone could fly that aggressively and endure that much pain in the name of training.

USAF Photo by SSgt Andrew N. Dunaway, II

LT T. N. PHAM
Courtesy *Approach*, Jan-Feb 97

What a great deal on a beautiful Lemoore day: flying with the skipper on an out-and-in to Fallon. The first flight would be a low-level-lat hop, and after a quick run through the hot pit, the second flight would be 1 v 1 ACM. I was the squadron's senior JO serving in the ASO billet and was feeling very savvy and comfortable in the cockpit. I was sure I could always make mature and safe decisions.

The skipper was one of the most aggressive pilots I have ever flown with. He maximized training on every flight. Even more impressive was that he knew the exact limits of his abilities and knew how not to cross the line. I thought I did too, but I would have to rethink my attitude after this flight.

The first part went great—an intense road recce on a low-level route up to Fallon. I had to smile at how aggressively the CO flew. This was no sight-seeing trip through the mountains, but a high-G, sweat-inducing, high-workload flight that really reawakened my low-altitude awareness. While going through the hot pit at Fallon, I could hardly wait for the ACM portion—the favorite hop of any Hornet JO.

We took off, went straight to the area, and quickly began going after each other. After two engagements, the score was even; I won the first one, and the CO put the pipper burns into me on the second one. I was embarrassed but had to marvel at how many Gs the old man could tolerate to achieve angles. I asked myself (as I often did when fighting the CO) how anyone could fly that aggressively and endure that much pain in the name of training.

We started our third and final engagement. I made a bad reversal that allowed the CO to gain an offensive advantage. Coming downhill from a looper, the altitude warning came on as I dipped 200 feet below the 10,000-foot MSL hard deck. I thought about calling, "Knock it off," but with the CO closing in on my six, I decided to just wallow the jet above the hard deck to give the old man extra training at guns tracking. Besides, how honorable would it have been if I called knock-it-off as the CO rolled into my six with guns selected? We ended the engagement soon afterward and headed back to Lemoore.

All the way home, I was bothered by my decision not to immediately end the fight when I went below the hard deck. I justified it by telling myself that there really was no danger and that I was only providing more training for my hard-charging CO.

During the debrief, the CO asked about my decision at the end of the third engagement. When I told him about my thought process, I realized how incredibly foolish it sounded. The CO was soft-spoken and diplomatic in pointing out the hazard to his safety officer. I could only sit there and shake my head at my actions.

"A real good flight," the skipper said jovially to wrap things up.

What could the safety officer have been thinking? How did I get lulled into making such a bad decision? How can I get up at an AOM and tell everyone to fly safe and be careful, then go out and break an ACM training rule? I should have never let the fact that I was flying with my aggressive skipper skew my decision process. I let a false sense of honor and a false desire for training stand in the way of sound judgment. It should never matter who or what kind of pilot is in the other jet; training rules should never be violated. You don't apply them only 99 percent of the time. ✈

New Research Produces New Information About Aircraft and Lightning Strikes

Courtesy *Aviation Monthly*, May 96

Official USAF Photo

Recent experimental flights designed to determine probabilities and causes of aircraft lightning strikes have provided some new information related to a pilot's chances of receiving an in-flight encounter with lightning bolts. Although there have been several recent studies, the bulk of the new information comes from two research projects: a USAF/FAA study which involved the use of a Convair 580 specially instrumented transport aircraft which flew for 42 hours and experienced 21 lightning strikes; and from a NASA Storm Hazards Program, which involved the use of a specially instrumented F-106B aircraft which made 1,154 thunderstorm penetrations and received 637 lightning strikes. These studies showed:

1. The majority of strikes (greater than 90 percent) were triggered by the aircraft itself.

2. The probability of an aircraft triggering a lightning discharge in a thunderstorm increased with altitude.

3. The probability of a lightning strike to an aircraft flying in a thunderstorm increased from a minimum at the thunderstorm base to a maximum at the 36,000- to 40,000-foot level. The temperature at this level was from -40 degrees C to 45 degrees C. The strike rate encountered at these high altitudes was two strikes per minute of penetration time. At 18,000 feet, the frequency was one strike every 20 minutes. An average of only one aircraft strike every 3 hours was encountered when flying below active thunderstorms.

4. Lightning strikes at high altitudes generally resulted in greater total charge transfer than strikes at lower altitude; however, the low altitude strikes sometimes produced greater instantaneous discharge.

5. The entire surface of the aircraft may be susceptible to lightning attachment even though strikes are more probable to particular areas such as the aircraft extremities (nose, wingtips, tail) and composite surfaces.

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The statement that if you are greater than 20 miles from radar-indicated precipitation, you are not susceptible to a lightning strike is also false. Aircraft have been struck by the proverbial "bolt from the blue" on more than one occasion.

6. During penetration of thunderstorms at low levels, lightning strikes were found to occur in areas of moderate or greater turbulence at the edge of and within large downdrafts. Conversely, lightning strikes experienced in the upper areas of thunderstorms and in the vicinity of decaying thunderstorms most frequently occurred under conditions of little turbulence or precipitation.

It should be remembered that prior to this research it was thought that an aircraft had to fly into the path of naturally occurring lightning to get struck, and the altitudes near the freezing level (0 degrees C) were considered the most probable location for this to happen. The research data, however, seem to conflict with previous statistics.

This does not mean that the old rules do not apply any longer. What it does mean is that

It is true that some aircraft are less prone to lightning strikes. Size, shape, and speed are all aircraft-specific variables which determine an aircraft's susceptibility to a lightning strike. However, it is also true that all aircraft are susceptible to a lightning strike. It is also true that aircraft damage varies with aircraft type. Careful aircraft design can minimize lightning damage.

we are learning more about the behavior of lightning and its effects on aircraft. Many of the old rules are still valid, and several new rules are being developed which we will be able to apply in the future.

Thunderstorms in Perspective

Actually thunderstorms and lightning are part of a global electric circuit. According to nature's plan to maintain an electric potential between the earth's surface and the ionosphere (called the "fair weather" electric potential), thunderstorms are necessary. They, in fact, play a key role in maintaining the earth's fair weather electric potential. The total number of thunderstorms occurring at any given time around the globe is approximately 2,000. These thunderstorms average about 100 lightning strikes per second. They act as an electric generator, maintaining the electric field. From this perspective, lightning within a thunderstorm cloud helps maintain the earth's electric potential.

Statistics show that commercial pilots experience an average of one lightning strike for every 3,000 flight hours, and the commercial airlines average one hit per aircraft per year. Air Force statistics show a somewhat lesser rate than civilians, but nonetheless the USAF in the past has averaged 51 lightning mishaps per year.

Aircraft Damage Caused by Lightning

Aircraft damage from lightning can be caused as a direct or indirect effect. Direct effects result when the lightning current attaches to and flows through the aircraft skin. Locations on the aircraft where lightning strikes occur experience extreme heating which causes burning and melting damage. Current flowing through the aircraft structure can result in isolated arcing or sparking and heating. If this occurs in a fuel tank, explosion and fire can result.

Indirect effects are caused by transient electrical pulses produced by the changing electric and magnetic fields due to the lightning current. Unless avionics and other systems are properly shielded, they are easily damaged by indirect lightning effects. It is also interesting to note that 57 percent of the mishaps attributed to lightning strikes to aircraft occur during the months of March through July.

Facts and Myths

Combining new research on lightning with the lessons of the past, we can learn the following:

It is true that some aircraft are less prone to lightning strikes. Size, shape, and speed are all aircraft-specific variables which determine an aircraft's susceptibility to a lightning strike. However, it is also true that all aircraft are susceptible to a lightning strike. It is also true that aircraft damage varies with aircraft type. Careful aircraft design can minimize lightning damage. However, all surfaces are susceptible to lightning strikes, and all unprotected systems can be affected.

It is true that some pilots are better at avoiding lightning strikes than others. The wider the berth given to thunderstorms, the better the chance of avoiding a lightning strike; however, the pilot who tries to pick his or her way between thunderstorm cells is asking for trouble.

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The theory that if you avoid thunderstorms you will avoid all lightning strikes is false. Statistics show that many triggered strikes have occurred during flights that did not penetrate thunderstorms. Aircraft have triggered strikes in cirrus clouds downwind of previous thunderstorm activity, in cumulus clouds around the periphery of thunderstorms, and even in stratiform clouds and light rain showers not associated with thunderstorms.

The statement that if you are greater than 20 miles from radar-indicated precipitation, you are not susceptible to a lightning strike is also false. Aircraft have been struck by the proverbial "bolt from the blue" on more than one occasion. In fact, aircraft have been struck at distances out to 50 nautical miles from thunderstorms, particularly when cirrus clouds existed above or at their altitude, or when there were other developing showers nearby that had not yet reached maturity. Also, flying through precipitation, volcanic ash, or heavily polluted air can cause an aircraft to experience electrostatic discharge or triggered lightning. Usually these discharges cause only minor aircraft damage; however, there is always the chance for catastrophic damage if the discharge passes through the vaporized fuel-air mixture in the fuel tank.

The belief that lightning strikes to aircraft occur only near the freezing level and are always associated with turbulence and precipitation is false. Thunderstorm penetration studies show that lightning strikes can be encountered at all temperatures and altitudes. In fact, they are most likely to occur in the upper levels of mature or decaying storms near temperatures of -40 degrees C. In addition, the studies showed most strikes occurred in regions where turbulence intensities were light to negligible.

It is true that aircraft flying at altitudes above the freezing level are more likely to be involved with in-cloud or inter-cloud lightning flashes, and that aircraft flying at altitudes below the freezing level are more likely to be involved with a cloud-to-ground lightning event. It is also true that the more frequently a thunderstorm is flashing, the lower the probability of being struck by lightning if the aircraft flies into the storm. However, the greater the flash rate, the higher the potential for severe turbulence, heavy rain, and hail. Therefore, this information should in no way be interpreted as a reason to fly in or near any thunderstorm.

Some Rules to Fly By

■ The most important thing is to stay clear of thunderstorms. Do not attempt to "pick your way through"; deviate around the area on the upwind (non-anvil) side if possible.

■ The higher the aircraft altitude, the farther away from a thunderstorm you should fly. Lightning strikes have been known to occur in the clear air up to 50 miles downwind from the nearest thunderstorm.

■ At low levels, avoid flying close to high surface features (ridge tops, towers, etc.), or between such features and an overhead thunderstorm.

■ If you fly above the freezing level in or near thunderstorms, you can trigger an in-cloud or cloud-to-cloud discharge. If you fly below the freezing level, you could be involved with a cloud-to-ground lightning strike. Overall, if you must penetrate or fly close to a thunderstorm system, you can expect more strikes penetrating a thunderstorm area well above the freezing level.

The belief that lightning strikes to aircraft occur only near the freezing level and are always associated with turbulence and precipitation is false. Thunderstorm penetration studies show that lightning strikes can be encountered at all temperatures and altitudes. In fact, they are most likely to occur in the upper levels of mature or decaying storms near temperatures of -40 degrees C.

■ Lightning damage is usually worse for large total current transfers. At altitudes above the freezing level, you are more likely to experience longer-lasting lightning attachments made up of numerous small pulses and a large total current transfer. Below the freezing level, you are more likely to experience shorter lightning attachments with a few strong current pulses; however, the total current transfer is usually less than that above the freezing level.

■ Electrical activity generated by a thunderstorm may exist even after the thunderstorm cell has decayed; therefore, avoid penetrating the cirrus decks that were recently associated with thunderstorms. ✈

The F-22

"We're not in the business of being defensive when we engage. We want to take the fight to the other guy and we are going to dominate his airspace. We will operate in it, and he will not. That's the whole idea. When somebody talks about parity in the air-to-air business, they do not understand that's not good enough. You've got to be dominant."

"The F-22 won't just defend our airspace—it will allow us to dominate the other guy's airspace and take away his sanctuaries."

General Ronald R. Fogleman
Chief of Staff