April 1998 Cover Story
Edwards Home Page

"Throughout history, soldiers, sailors, Marines, and airmen have learned one extremely valuable lesson relative to engagement with an opposing force. That is, if you can analyze, act, and assess faster than your opponent, you will win." – *General Ronald R. Fogleman, Chief of Staff, U.S. Air Force*

Fifty years ago, a military propagandist stated, "He who controls the information runs the show." And as we approach the 21st century, the acquisition and management of vast amounts of information becomes more necessary to success in any field.

During wartime, information is especially critical. The loss of American lives in combat is not an option. For the Air Force, the only answer to this problem is complete superiority in the air.

The capabilities of the F-22 dwarf those of all aircraft that have gone before

"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," said Gen. Ronald R. Fogleman, Air Force Chief of Staff. "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."

Information management

Military strategists took information delivery and management very seriously when designing the next century fighter plane to replace the F-15 as America's front line air dominance fighter. In addition to the latest technological gains in low observables, avionics, materials, engine performance and aerodynamic design, the aircraft of the future needed to possess a superior information delivery system rivaled by no other.

Enter the F-22 Raptor – a combat machine that is as much supercomputer as it is aircraft.

Like some futuristic artificial intelligence that once existed only in the imagination, the F-22 collects, processes and delivers vital information at the exact moment it is needed by the pilot.

"All of the sensor information has been fused into a single picture for the pilot," said Lt. Col. Steve Rainey, who has brought the F-22 to Edwards Air Force Base for testing this month. "Information is what is going to be the key to success on the battlefield."

New role

Suddenly, the fighter pilot becomes a "mission manager," basing his decisions on the sensory information being delivered to him by the aircraft. This is dramatically different than his previous role as a skilled "sensor operator," trained to react intuitively to air combat situations.

The F-22's "integrated avionics" operate the craft's sensors, within the limits set by the pilot. "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.

"The pilot commands information, and the system picks the sensors to answer the pilot's questions," explained cockpit team manager Ken Thomas in *Flying Safety*'s August 1997 issue.

"The time available to make a decision determines the quality of information required," he added.

The design of the F-22 frees pilots from being "sensor operators" and "housekeepers," and allows them to tackle the real job at hand – combat.

As a result, F-22 pilots will need to be trained as thoroughly in managing information as they are in flying. In combat, the mastery of that information will definitively win the airspace – and the war.

It demonstrates what is possible when human potential is integrated into the aircraft.

Dramatic change

"Integrated avionics" is a revolutionary concept that has arisen from our current Information Age. It changes the playing field so dramatically that it has been likened by some to the transition from propeller-driven to jet-powered aircraft.

Just like the personal computer on your desktop, the equipment on the F-22 has been built to be "upgradeable." F-22s collect their data through on-board and off-board sensors and are "networked" to share information with one another by means of the Inter/Intra Flight Data Link.

The contrast between the old and new ways of flying is illustrated by a function we can all relate to: the radio.

An F-22 doesn’t have a "radio" in the traditional sense. It has a Common Integrated Processor module – basically a software program – that performs the function of a radio. If that module fails, one of the other modules will automatically reload the software and take over the radio function – thus making it fault tolerant. Multiply that ability to self-correct through every function on the aircraft, and the picture of the F-22’s infallibility broadens.

Knowledge gained from proven weapon systems such as the F-15, F-16 and F-117 formed the foundation for F-22 development.

Add into the equation cutting-edge technologies such as supercruise, thrust vectoring and enhanced agility – in addition to the proven concepts of stealth and low observability – and you have an aircraft that is truly revolutionary.

Strategies	Capabilities	Equipment
Mission	Integrated avionics	Computer hardware
Background	Carefree abandon	Computer software
Cost	Maneuverability	Common Integrated Processor
Modeling and simulation	Stealth	The engine
Flight testing	First flight videos	The cockpit
Safety and maintenance		The flight suit
The pilot's role		Weapons

Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

About Edwards – History

The F-22 Raptor has been designed to be the most potent fighter in the world.

From the inception of the battle, the Raptor will clear the skies of adversary aircraft, using its stealth, integrated avionics, supercruise and other revolutionary features to make it more than 100 percent more effective than any fighter currently in the Air Force arsenal.

The F-22 will be in service for more than 25 years, or more than 40 years from the time when the demonstration/validation contract for the "Advanced Tactical Fighter" was awarded in 1986.

Planning for the future

It would have been ludicrous in 1945 to argue that the P-51 was the only fighter the United States would need for the next 25 years – but in 1945, few people could imagine just how far the science of flight would progress.

Proven weapon systems such as the F-16 (pictured at bottom) formed the foundation for development of the F-22 (at top)

Yet the aircraft designer of today is being asked to make a similar leap.

Projecting that far into the future is challenging: Just compare the best U. S. air dominance fighter of 1940 – the P-51 – with the F-4, a quarter of a century later. During those 25 years, speeds had quadrupled and weapons and sensors were unlike anything available to the World War II pilot.

Three guidelines

As it was being designed, the needs of the future were kept in mind.

The F-22 team established three basic guidelines for a fighter whose service would extend more than a quarter of the way into the next century. Rather than taking a "brute force approach" as had been traditionally done ("bigger, better, faster"), the guidelines blazed a new path, focusing on the exploitation of information, the denial of information to the enemy, and overwhelming lethality.

And things will never be the same again.

One of the primary functions of the F-22 is to gather information from many sources and process that information into a simple, intuitive picture of the tactical situation for the pilot. While this revolution is not as visual as the jump from propeller to jet, it is just as profound. The explosion of computer capability now turns warfare into a war of information resources and management.

This takes the F-22 a quantum leap beyond the capabilities of current weapons. All aircraft that comes after will follow the new path or be hopelessly outclassed.

The effects of downsizing
Another reality that had to be faced during development was the reduction of defense budgets and manufacture of fewer fighters in the future. Upgrade-ability, cost and the corporate teaming became factors far more important than in the past.

The F-22's airframe and avionics architecture is specifically designed to provide its advanced capabilities without locking the design into any particular use of equipment or configuration available today.

In addition, the F-22 was developed with reduced support requirements and maintenance costs.

A lethal weapon
Because fewer numbers of fighters are to be built, they must be overwhelmingly lethal. This level of dominance was hinted at during Operation Desert Storm where fewer aircraft, using precision munitions, accomplished greater destruction of military targets in a shorter period than in previous American wars.

Thus, fewer aircraft have a far greater impact in an air battle. The goal is simply "first look/ first shot/first kill" in all environments. The F-22 possesses a sophisticated sensor suite that allows the pilot to track, identify and shoot the threat before it detects the F-22.

And with American lives at risk, there is no interest in the concept of a "fair fight." The United States must win quickly, decisively and with minimal casualties.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

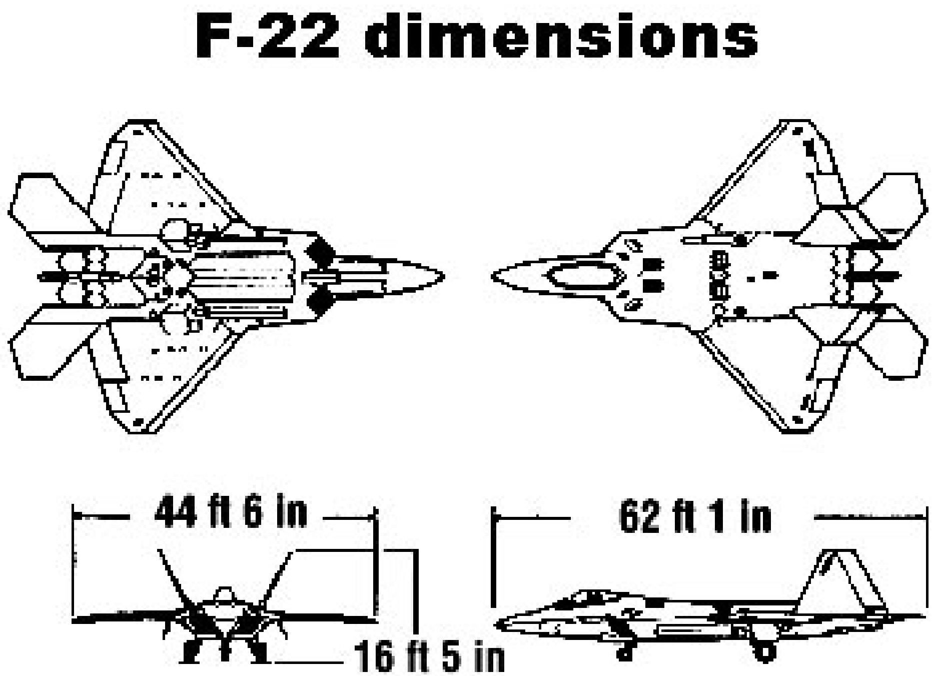
Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

About Edwards – History

Advances in low-observable technologies provide significantly improved survivability and lethality against air-to-air and surface-to-air threats. The F-22's combination of reduced observability and supercruise accentuates the advantage of surprise in a tactical environment.



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 comparable to the radar cross sections of birds and bees. Compared to other current fighters, the F-22 is much more difficult to detect.

Principles of stealth

To make a stealthy aircraft, designers had to consider five key ingredients: reducing the imprint on radar screens, muffling noise, turning down the heat of its infrared picture, stifling radio transmissions and making the plane less visible.

A quick look at the F-22 reveals an adherence to fundamental shaping principles of a stealthy design.

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

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

Anyone who works in an office knows all about the never-ending influx of information.

E-mail, voice mail, and the near compulsive desire to print copies and distribute them to the world often leaves people swamped in data from which they must derive the necessary facts and make decisions.

The F-22 design team has worked hard to eliminate this side effect of the computer age and provide the F-22 pilot with information, while tasking the computer to organize the data and present it as coherent information to the human occupant.

To design an airplane that embodies these characteristics means moving beyond traditional design approaches.

Avionics share as large a part in the success of a fighter as the ability to maneuver and fly fast

Importance of avionics
Avionics share as large a part in the success of a fighter as the ability to maneuver and fly fast, or to "turn and burn."

The design issues that had to be addressed involved solving the technical and organizational challenges of running the program. Also crucial to the design, was the reduction of pilots' "housekeeping" responsibilities, allowing them to become tacticians with time to take advantage of the F-22's carefree abandon capabilities and increased lethability.

Different definitions
During the development stage of transforming this concept into a reality, the term "integrated avionics" meant different things to different people.

Because all the information is coordinated and available from a single source, to the pilot, "integrated avionics" means there is coherent presentation and control, as well as the organization of functions and the routing of lots of data to a single display. It also includes additional functionality, such as situation assessment and weapons fire control.

To the software engineer, "integrated avionics" means access to shared data about the situation, the mission and the aircraft systems. The software view of integration means that the various functional pieces of the software must have efficient access to globally-coherent information, such as track files, navigation data, mission data and aircraft system status information.

To the hardware designer, "integrated avionics" means common modules in a single backplane with the connectivity and bandwidth to support the required processing. A hardware architecture built on common components, common modules, standard buses and a common operating system provides the infrastructure for the processing and communication between these processes.

This modular approach allows for easy expansion of capacity and capability, fault tolerance and reconfiguration.

Computational power

The exponential explosion of computer technology in the last 10 years has allowed the F-22 team to radically alter every aspect of the program from detailed design through manufacturing, communication, and into the cockpit itself.

An example of the effect of the advances in computer technology is a comparison between the computers used in the Lunar Module and those used in the F-22.

The Lunar Module's computers operated at 100,000 operations per second and had 37 kilobytes of memory. Today, the F-22's main mission computers, which are called Common Integrated Processors, operate at 10.5 billion instructions per second and have 300 megabytes of memory.

These numbers represent 100,000 times the computing speed and 8,000 times the memory of the Apollo moon lander.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

F-22 RAPTOR "Maneuverability"

The F-22 has been extensively designed, tested and refined aerodynamically in all phases of development.

Because of the F-22's sophisticated aero-design and high thrust-to-weight ratio, it can easily outmaneuver all current and projected threat aircraft, both at medium and high altitudes.

Supersonic persistence
The F-22's engines produce more thrust than any current fighter engine, especially in military (non-afterburner) power. Called "supercruise," this characteristic allows the F-22 to efficiently cruise at supersonic airspeeds without using afterburners. This capability greatly expands the F-22's operating envelope in both speed and range over current fighters that must use afterburner to operate at supersonic speeds.

The wings of the F-22 are designed to cruise at supersonic speeds for extended periods of time and withstand extremely "high-g" maneuvers

The traditional design approach stresses increases in aerodynamic performance, while the F-22 emphasizes two additional technologies: supercruise and agility.

Supercruise
"Supercruise" is the term given to the capability of sustaining supersonic speeds for long periods of time.

Conventional fighters, while capable of supersonic flight, can only sustain these speeds for relatively short periods as the result of excessively high fuel consumption using afterburner. The F-22 can cruise supersonically without afterburner and, therefore, can sustain these speeds for long periods.

The question could be asked "So what?"

The answer would be that 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 (and its pilot) becomes less vulnerable to enemy missiles and aircraft simply because they cannot react fast enough.

Agility

"Agility" is the ability of the F-22 pilot to point and shoot with his aircraft, pirouetting, and facing the enemy with his weapons at all speeds.

The F-22 pilot can maintain control of the aircraft at speeds as low as that of a Piper Cub or at very high supersonic speeds.

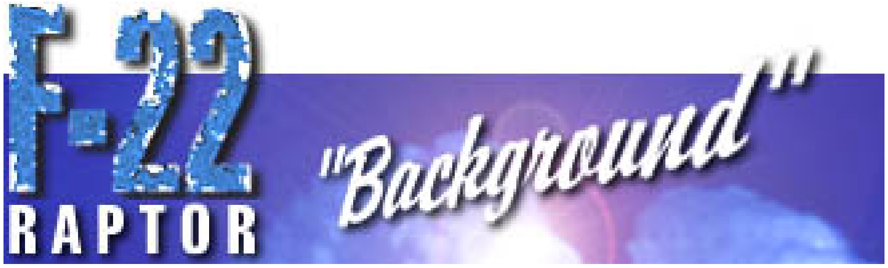
Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

ABOUT EDWARDS – HISTORY



In 1981, the Air Force developed a requirement for an Advanced Tactical Fighter as a new air superiority fighter. It would take advantage of the new technologies in fighter design on the horizon including composite materials, lightweight alloys, advanced flight control systems, higher power propulsion systems and stealth technology.

Air Force leaders believed these new technologies would make aircraft like the F-15 and F-16 obsolete by the early 21st century. In 1985, the Air Force sent out technical requests for proposals to a number of aircraft manufacturing teams.

The two competitors were Northrop-McDonnell Douglas' YF-23, and the Lockheed-Boeing-General Dynamics YF-22, which was turned over for display to the USAF Museum at Wright-Patterson Air Force Base on March 31, 1998.

Like the YF-22 team, the Northrop team built two YF-23 prototypes, one with General ElectricYF-120 engines and the other with Pratt & Whitney YF-119 engines.

After extensive flight testing the YF-22 was selected for production.

Prior to its selection as winner of the Advanced Tactical Fighter competition, the F-22 team conducted a 54-month demonstration/validation (dem/val) program. The effort involved the design, construction, and flight testing of two YF-22 prototype aircraft. The dem/val phase of the program was completed in December 1990.

The engine
Two prototype engine designs, the Pratt & Whitney YF119-PW-100 and the General Electric YF120-GE-100 were also developed and tested during the program. The Pratt & Whitney F119 was selected by the Air Force to power the F-22.

Much of the dem/val work was performed at Lockheed (now Lockheed Martin) in Burbank, Calif.; at General Dynamics (now Lockheed Martin Tactical Aircraft Systems) in Fort

Worth, Texas; and at Boeing in Seattle, Wash. The prototypes were assembled in Lockheed's Palmdale, Calif., facility and made their maiden flight from there.

Boeing crane operators load the aft fuselage for the first F-22 fighter into a shipping container at the Boeing Development Center in Seattle for delivery to Lockheed Martin in Marietta, Ga.

Since that time, Lockheed Martin's program management and aircraft assembly operations have moved to Marietta, Ga., for the Engineering and Manufacturing Development and production phases.

On Sept. 7, 1997, the first Lockheed-Boeing F-22 was flown for the first time, taking to the skies over Marietta and north Georgia. This was followed by several airworthiness flights prior to the ferry flight to the the Air Force Flight Test Center at Edwards AFB.

Ferry to California

The F-22 was transported in sections to Edwards AFB in the early months of 1998, and is now being reassembled in anticipation of the flight testing, which is scheduled to begin at the end of April. The F-22's performance will be measured at all required flight regimes.

The first aircraft will undergo roughly 50 test flights prior to delivery of the second aircraft to Edwards in mid-1998. The second aircraft is now in final assembly at Lockheed Martin Aeronautical Systems in Marietta and is scheduled for completion in late spring 1998.

Five years of tests

The test program runs for five years and consists of approximately 2,700 flights and 7,800 hours. The first three F-22 aircraft are essentially engines and airframes and do not have the full-up tactical avionics and sensors. They will be used for envelope expansion, structural loads, propulsion, and weapons and other flight test areas such as high angle-of-attack flights and arresting gear tests.

The remaining six F-22s are interchangeable avionics test aircraft. The avionics suite will mature through four stages or 'blocks' of avionics, however, each of the six avionics aircraft will all carry the same configuration of avionics at the same time. This allows any airframe to be used for any avionics test and not lose a test flight maintenance down days or modifications on a particular airframe.

The workforce

The combined test force (CTF) will start at about 290 people and build to a maximum of 650 in 2001. Initially the CTF will comprise a sixty-forty percent mix of contractor and Air Force personnel. As testing progresses, the mix will shift to a fifty-fifty mix.

The organization will be commanded by an Air Force officer, with a contractor deputy. The internal organization is built around the Integrated Product Teams (IPTs) that produce the flight test product – data.

The IPT approach was used to develop the F-22.

Under the IPT concept, each of the more than 80 permanent teams was completely responsible for its 'product' (i.e. avionics, cockpit, airframe, utilities and subsystems, etc.) – from engineering a part or system, controlling its cost and schedule and insuring that it can be manufactured and supported once in use.

The Air Force's F-22 System Program Office (SPO) has teams that mirror the organization on the contractor side, improving communications across the team.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

F-22 RAPTOR "Cost"

The F-22 teaming arrangement has allowed unprecedented industry cost sharing and has taken advantage of different companies' strengths in advanced technology, production capability and systems integration.

The industry team of Lockheed Martin and Boeing is working with the U. S. Air Force and Pratt & Whitney to develop the F-22 to replace the F-15 as America's front line air dominance fighter.

Starting in 2005, the fast, agile and stealthy F-22 will begin to take over the air dominance role with Air Combat Command – assuring continued U.S. control of the skies during times of conflict well into the next century.

The F-22's rollout on April 9, 1997

Contracts awarded

In August 1991, two contracts totaling $10.91 billion ($9.55 billion for the airframe and $1.36 billion for engines) were awarded for Engineering and Manufacturing Development (EMD) of the F-22 and F119 to the then Lockheed/Boeing/General Dynamics team and Pratt & Whitney.

Contract changes, including three Congressional budget cuts and subsequent rephases of the schedule since then have elevated the contract values to a total of $18.6 billion.

Under the terms of the EMD contract, the F-22 team will complete the design of the aircraft, produce production tooling for the program and build and test nine flight-worthy aircraft and two ground test articles.

Rollout and first flight

The first F-22 built under the EMD contract was unveiled in a ceremony on April 9, 1997, in Marietta, Ga. The Air Force officially named the plane the F-22 "Raptor," meaning a "bird of prey."

The first flight took place on Sept. 7, 1997. Flight testing begins at the end of this month at Edwards Air Force Base.

Low-rate initial production is scheduled to begin in 1999. The Air Force plans to procure 438 production F-22s, and production is scheduled to run through 2013.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

ABOUT EDWARDS – HISTORY

The best way to determine the capability of the F-22 would be to send it into a full scale war and see how it does. That would be effective, but clearly isn't practical.

Three program tools that are credible representations of the 'real world' are used, including the use of computers to simulate war.

In this scene, rendered entirely on computer, an Air Force pilot flying an F-22 has followed two adversary aircraft, destroying one of the "bandits" with an air-to-air missile

Modeling
Through "war gaming," aircraft evaluators can create a "crucible of war" on computers.

Once reserved for hobbyists, war gaming has become a sophisticated simulation that allows modeling of enemy and friendly weapons and tactics.

Once modeled, virtually unlimited numbers of aircraft, missiles, guns and radars can be added to hypothetical scenarios.

The F-22 can be flown through this computerized combat zone at relatively little cost and over a short period of time. Many scenarios can be explored and statistical results obtained. More than 10,000 of these runs can be made per day.

So far, more than a million simulated 'battles' have been fought using these models of reality.

But these tests don't include the human element.

Simulators
Enter the simulators, where real pilots participate in the evaluations.

The F-22 program uses two simulators, one in Marietta, Ga., and the other in Fort Worth, Texas, to study the effectiveness of the F-22 using real pilots. These simulators combine some of the advantages of war gaming (the large number of enemy aircraft, defenses, and targets) with the variability and unpredictable nature of the human operator.

In the air combat simulator, up to 12 F-22 pilots flying simulated F-22s and enemy aircraft can fight each other. Ground-controlled intercepts can be directed by four human operators, and the computers can model as many as 80 other aircraft and 80 surface to air missiles can join in this air battle.

While a step closer to reality, the Air Combat Simulator still uses a model of the F-22 and, except for the 16 human operators, all other airplanes and defenses are computer models of what human operators would do.

Flight test
The F-22 represents the real world. The aircraft's sensors, performance, stealth, supercruise and pilot's performance will be what will really enter the combat fight.

Because it is not possible to actually test the F-22 against a large numbers of enemy aircraft and defenses, the flight testing verifies the modeling and simulation predictions.

Synthesis of the Tools
The three tools represent a spectrum of decreasing battlefield complexity but an increasing involvement of humans and real hardware. Interestingly, no single tool can be used to ascertain F-22 effectiveness as each is in some way, 'limited.' The problem is one of establishing a credible simulation of warfare.

To do this, several simplified scenarios will be flown in each of the three tools and results compared.

The modeling and simulations will be 'tweaked' until they match the real F-22's capabilities.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

ABOUT EDWARDS – HISTORY

In contrast to the modeling and simulation testing, the flight test program at Edwards Air Force Base will be the first look at the *real* F-22.

Although the team built and flew the prototype YF-22s and gained quite a bit of knowledge about the technologies involved, there have been some significant changes in the design for the production F-22s.

Many differences
The YF-22 and the F-22 are similar in shape but there are a number of differences.

The first wing for the first F-22 is moved into position for high-precision drilling at the Boeing plant in Seattle

Externally, the wing sweep has been reduced 8 degrees (from 48 on the prototype to 42 degrees on the F-22) and the canopy has been moved 7 inches and the inlets have been moved aft 14 inches to increase the pilot's visibility. The wing trailing edge and horizontal stabilator shape have been changed for low observability reasons, as well as structural strength and aerodynamic refinements.

The prominent vertical tails of the prototype have been reduced in size by approximately 20 percent.

Internally, the F-22 has all new subsystems based on the prototype’s approach, built to an 8,000-hour service life.

F-22A is self-contained
While the YF-22s were essentially engine and airframe demonstrators, the F-22A has complete sensor and weapons capability. The aircraft is fully self-contained for starting and can use its auxiliary power unit to perform most maintenance tasks.

In addition to a screwdriver and wrench, the F-22 maintainer will also carry a laptop-sized computer.

The maintainer accesses the F-22 by a laptop-sized computer called a "portable maintenance aide" that can read and record aircraft consumables such as fuel and oil, but can also control aircraft systems during maintenance, as well as upload new operational flight programs – the computer software that runs the aircraft.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

About Edwards – History

The F-22 Raptor was built with better reliability and maintainability than any military fighter in history. This helps ensure operational flexibility into the future.


The F-22 will be in service through the first quarter of the 21st century

Maintainers were included early in the design process for the F-22 and they quickly established a strong foothold. To improve maintenance turnaround, the maintainers insisted on extensive self diagnostics and built-in testing capability for the various subsystems.

As a result, virtually every piece of hardware in the aircraft either does its own health checks or reports when it has failed. There are more than 15,000 fault reports that can be made on the basic engine and airframe and another 15,000 fault reports available for the avionics. Most of these are low-level fault reports that do not result in warnings, cautions or advisories to the pilot or degrade the operation of the F-22.

It was reasoned that if the airplane knew so much about itself, then that capability could be leveraged to help the maintainer and the pilot.

This increased reliability and maintainability pays off in dollars, because it will require less manpower to fix the aircraft and consequently less airlift is required to support a deployed squadron.

Additionally, reduced maintenance support provides the benefit of reduced life-cycle cost and the ability to operate more efficiently from prepared or dispersed operating locations.

Vehicle management system
The Vehicle Management System (VMS) provides integrated flight and propulsion control,

enabling 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 flight control software and flight control laws that underpin the VMS were tested in a specialized laboratory at Lockheed Martin Tactical Aircraft Systems facility in Fort Worth, Texas. The VMS Integration Facility (VIF) consists of an F-22 cockpit and flight-worthy F-22 hardware and software. The VIF has been operational since March 1995.

Environmental control system

The F-22 uses a totally integrated environmental control system (ECS) that provides thermal conditioning throughout the flight envelope for the pilot and the avionics.

The five basic safety critical functions the ECS must take care of include avionics cooling, adequate air to the pilot, canopy defog, cockpit pressurization and fire protection.

Air cycle system

The air cycle system takes bleed air from engines (which comes in to the system at between 1,200-to-2,000 degrees Fahrenheit) and cools it down in the primary heat exchanger to approximately 400 degrees. From the heat exchanger, the air is fed into the air cycle refrigeration package (ACRP). The air must be dry, so the system also includes water extractors.

The air, when it comes out of the ACRP, is now chilled to approximately 50 degrees Fahrenheit. The flight-critical equipment, the systems that are for keeping the aircraft -flying, are cooled by this air. This air is also fed into the Normalair-Garrett-built On-Board Oxygen Generating System (OBOGS) to provide breathable oxygen to the pilot, to operate the Breathing Regulator/Anti-G (BRAG) valve on the pilot's ensemble, to provide canopy defogging, and cockpit pressurization.

Liquid cooling system

Unlike other fighter aircraft, the F-22 uses liquid cooling, rather than air cooling for the mission avionics. The F-22 is breaking ground in liquid cooling and the environment in which it works. Resistance to high temperature and durability were the driving factors in the liquid cooling design. AlliedSignal is the primary supplier of the liquid cooling equipment.

The closed-loop liquid cooling system is divided into two loops, one forward and one aft. These systems use brushless, DC current motor pumps that are connected for redundancy. Polyalphaolefin (PAO) is the medium used in the liquid cooling system.

The forward loop is for cooling the Mission Critical Avionics and keep them at a comfortable (for them) 68 degrees Fahrenheit. The PAO passes through the vapor cycle system and a filter and is routed to the avionics and then out to the wings to cool the embedded sensors.

From there, the now-warm PAO coolant enters the aft loop, which allows it to pass by the air cycle machine, which cools that system by receiving transferred heat. The PAO then is routed to the fuel tanks, where the heat is dumped. No coolant gets mixed with the fuel however, as this is a closed-loop cooling system. The fuel in the tank is only used as a heat sink.

Thermal management system
The thermal management system is used to keep the fuel cool. The air-cooled fuel cooler takes air from the boundary layer diverter between the inlet and the aircraft's forward fuselage. Hot fuel passes through the heat exchanger and is cooled. Greatly simplified, this is essentially blowing on hot soup to cool it down enough to eat it.

Fire protection
Fire protection is provided for the aircraft's engine bays, the auxiliary power unit, and for dry bays, such as the landing gear wells, the side-of-body cavities, the linear linkless ammunition handling system, the on-board inert gas generation system, left and right air cooled fuel coolers and environmental control system bay.

The aircraft uses infrared and ultraviolet sensor for fire detection and Halon 1301 for fire suppression. The Halon 1301 is the only ozone-depleting chemical on the F-22, and efforts are underway to find a replacement suppressing chemical. Space provisions have already been included for this new agent up to a chemical that requires 2.5 times the volume of the Halon.

Auxiliary power generation system
The auxiliary power generation system (APGS) for the F-22 is being developed, built and tested by AlliedSignal Aerospace for Boeing. The APGS consists of an auxiliary power unit (APU), and a self-contained stored energy system (SES).

The APGS provides secondary aircraft power for everyday main engine ground start, aircraft ground maintenance, and in-flight emergency power for aircraft recovery. The APGS uses the G-250 APU, a 450 horsepower turbine engine that utilizes state-of-the-art materials and design resulting in the highest power density APU in the industry (horsepower-to-weight).

Landing gear
The F-22 utilizes tricycle landing gear, with the standard two main gears (each with a single tire) and a single-wheel, steerable nose landing gear assembly. The nose gear retracts forward and main gear retracts outward.

The landing gear assemblies utilize AirMet 100, which provides greater strength and corrosion protection and are made by Menasco. The main gear uses a dual-piston design and are sized not to withstand a collapsed gear or flat tire landing.

The aircraft's AlliedSignal-made carbon brakes are always in anti-skid mode, which means the pilot has one less thing to remember to activate. The pilot applies pressure on the brakes by using the rudder pedals, but only after the F-22's weight-on-wheels sensor engages upon landing.

The nosewheel is a direct drive system, that is hydraulic force is applied to the nosewheel pivot to turn it. The nose gear is mechanically driven to align itself correctly before retraction.

As a safety precaution, the nosewheel clamshell doors and the lower inboard landing gear doors are physically linked to the landing gear itself. If an emergency blowdown is required, the doors will open when the gear comes down. Also, the gear down and locked indicators in the cockpit are battery operated, so if all other systems malfunction, the pilot still has a way of knowing whether his landing gear is down.

The tires on the F-22 are Michelin Air-X steel belted radials. Goodyear Bias-ply tires will also be qualified for the aircraft.

Fuel system
There are eight fuel tanks on the F-22, including one (designated F-1) in the forward fuselage behind the pilot's ejection seat.

The others are located in the fuselage and the wings. The F-22 will run on JP-8, a naphthalene-based fuel with a relatively high flash point.

The F-22 has single-point ground fueling, and it can be refueled without the need for ground power. It also has a Xar-built air refueling receptacle on the top side of the aircraft in the mid fuselage directly behind the cockpit. It is covered by two butterfly doors that have integral low-voltage lights to aid in night refueling.

The F-22 also has an on-board inert gas generation system that inerts the fuel tanks as the fuel is depleted. Fuel is not as explosive as its fumes are. By filling the tanks with inert nitrogen as the fuel is used, the fumes are suppressed, and the chance of explosion, such would occur if the fuel tanks were hit by gunfire, is nearly eliminated.

Electrical, hydraulic and arresting systems
The F-22 uses a Smiths Industries 270 volt, direct current (DC) electrical system. It uses two 65 kilowatt generators. The hydraulic system includes four 72 gallon-per-minute pumps and two independent 4,000 psi systems.

The F-22 has an arresting hook in an enclosed fairing between the engines on the underside of the aircraft. This hook is deployed in an emergency to stop the aircraft by means of hooking on to a wire strung out across the end of a runway. These barrier engagements work very similar to the arresting gear of an aircraft carrier. While the F-22 has an arresting hook, it cannot land on an aircraft carrier, as the F-22 does not have the heavier structure necessary to withstand the stresses of a carrier landing. The shape of the arresting hook is not compatible with low observable design, and that is why the fairing and doors are required.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

In World War II, the U. S. Army Air Corps downed 15,798 aircraft in day air to air combat.

Those kills were made by only 7,306 of the approximately 35,000 fighter pilots in combat. Of that number only 1,284 were aces. In other words, only 21 percent of the fighter pilots shot down other aircraft and only 3.6 percent were aces. In the Korean War, similar results occurred for the dedicated fighter pilots. There, 4.8 percent of the pilots were aces but they got 38 percent of all kills.

F-22 Chief Test Pilot Paul Metz

The F-22 team reasoned that a smaller force could be far more lethal if the percentage of fighter pilots who achieve combat kills could be increased significantly from the historical averages of 10 percent to 20 percent.

If freed from "housekeeping" duties, pilots will be better able to develop their combat skills and fly with carefree abandon.

Reduced workload

The idea was to relieve pilots of the bulk of system manipulations associated with flying and allow them 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 by the maintainers, that workload has been significantly reduced.

Aircraft startup and taxi are excellent examples of harnessing the power of the computer to eliminate workload.

There are only three steps to take the F-22 from cold metal and composites to full-up airplane ready for takeoff: The pilot places the battery switch 'on,' places the auxiliary power unit switch momentarily to 'start' and then places both throttles in 'idle.' That's it.

The engines start sequentially right to left and the auxiliary power unit then shuts down. All subsystems and avionics are brought on line and built-in testing checks are made. Then the necessary navigation information is loaded and even the pilot's personal preferences for avionics configuration is read and the systems are tailored to those preferences.

All of this happens automatically with no pilot actions other than the three steps. The airplane can be ready to taxi in less than 30 seconds after engine start.

Integrated warning system
To reduce pilot workload in flight, the F-22 incorporates the uniquely designed integrated caution, advisory and warning system (ICAW).

This system's messages normally appear on the 3-by-4 inch up-front display just below the glare shield. A total of 12 individual ICAW messages can appear at one time on the up-front display and additional ones can appear on sub pages of the display.

Two aspects of the ICAW display differentiate it from a traditional warning light panel. First, all ICAW fault messages are filtered to eliminate extraneous messages and tell the pilot specifically and succinctly what the problem is.

For example, when an engine fails, the generator and hydraulic cautions normally associated with an engine being shutdown are suppressed, and the pilot is provided the specific problem in the form of an engine shutdown message.

More than two years of detail design by pilots and engineers has gone into the filtering logic of the ICAW system and extensive testing of the system was done.

In addition, the success of the Army's RAH 66 Comanche helicopter's ICAW system that uses a similar filtering approach gives the F-22 team confidence in the fundamental soundness of the design.

Another feature of the ICAW system is the electronic checklist. When an ICAW message occurs, the pilot depresses the checklist push button (called a bezel button) on the bottom of the up-front display and the associated checklist appears on the left hand secondary multi-function display.

If multiple ICAWs occur, their associated checklists are selected by moving a pick box over the desired ICAW and depressing the checklist button. Associated checklists are automatically linked together so that if an engine failure occurs, the pilot will not only get the checklist for the engine failure procedure in-flight but also the single engine landing checklist. The pilot can also manually page through the checklists at any time from the main menu. This is particularly handy when helping a wing man work through an emergency.

F-22 "networking"

The Inter/Intra Flight Data Link is one of the powerful tools that make all F-22s more capable.

Each F-22 can be linked together to trade information without radio calls with each F-22s in a flight or between flight. Each pilot is then free to operate more autonomously because, for example, the leader can tell at a glance what his wing man's fuel state is, his weapons remaining, and even the enemy aircraft he has targeted. Classical tactics based on visual 'tally' (visual identification) and violent formation maneuvers that reduce the wing man to 'hanging on' may have to be rethought in light of such capabilities.

Targets can be automatically prioritized and set up in a shoot list with one button push. A 'shoot' cue in the head up display alerts the pilot to the selected weapon kill parameters and he fires the weapons. Both a pilot's and wing man's missile flight can be monitored on the cockpit displays.

Considerable effort has been expended in making the F-22 'user friendly.'

The aircraft systems operations are straightforward and simple. The airplane can be flown with carefree abandon, and the tactical situation can be understood and acted upon through intuitive presentations from many sensors.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

The non-traditional design approach of the F-22 was driven by the reality of smaller military budgets, fewer aircraft and a requirement to make those few aircraft far more lethal than their predecessors.

The F-22 allows the pilot an unlimited angle of attack

An important aspect to increasing the lethability of the aircraft was the elimination of "housekeeping," a reduction of many system operations responsibilities that have classically taken a significant portion of the pilot's attention in the cockpit.

This allows pilots to fly with "carefree abandon."

Reduced complexity

The question was asked, "Why should an airplane be any more complex to operate than your car?" "Is there really a need for all those little switches, knobs and dials in the cockpit?"

As with a car, the basic approach was to make the operation of the F-22 a true "kick the tires and light the fires" machine. All switches, even the most traditional functions, had to earn their way into the cockpit.

The cockpit displays have been set up to be intuitive to the pilot. Confirmed enemy aircraft are red triangles, friendly aircraft are green circles, unknown aircraft are yellow squares and wing men are shown as blue F-22s.

Pilots now become tacticians and information managers, making decisions on data delivered clearly and in a timely manner by the F-22's integrated avionics system.

Extension of the cockpit
One of the primary design principles is really an extension of the philosophy for the cockpit itself. The design philosophy was established up front, with engineers and pilots working closely together.

"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, this has resulted in an unlimited angle of attack (AOA) capability for the aircraft's basic combat configuration (for example, 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 airplane 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 condition at his command.

'Carefree' also applies to structural limits on the airplane, and this is handled two ways.

First, all the traditional limitations seen in flight manuals have been coded into onboard computers. For example, some components (such as landing gear and air refueling doors) have speed limits. The pilot is never prevented from exceeding those limits.

If the pilot exceeds a limit, either intentionally or unintentionally, he gets a message with an aural warning to tell him that a limit is being exceeded.

In addition to overspeed warnings to the pilot, the flight control system provides load limiting for all pilot inputs as a function of aircraft gross weight.

Second, the flight control system provides automatic load limiting for all pilot inputs as a function of aircraft gross weight. The pilot gets the maximum performance the aircraft is capable of achieving at any time when full roll, pitch or yaw commands are used.

The pilot can 'yank and bank' all he wants without fear of 'hurting' the airplane.

These flying qualities are backed by more than 8,000 hours of stability and control wind tunnel testing (during the Engineering and Manufacturing Development testing phase alone), thoroughly tailored flight control laws and countless handling quality simulation evaluations – all of which will be demonstrated during the coming flight test program.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used *in this story.*

Previous | Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

---

Please read our Privacy and Security Notice

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

ABOUT EDWARDS – HISTORY

On Sept. 7, 1997, the first Lockheed-Boeing F-22 was flown for the first time, taking to the skies over Marietta and north Georgia.

F-22 Chief Test Pilot Paul Metz flew the aircraft from Dobbins Air Reserve Base, lifting off the runway at 140 knots with the aircraft's two Pratt & Whitney F119-PW-100 engines at military power. The aircraft reached an altitude of 15,000 feet in less than three minutes, then was put through a series of power changes to test aircraft handling characteristics and engine performance

The F-22 makes its first flight over Marietta, Ga.

Flying chase for first flight in two F-16 aircraft were Lt. Col. Steve Rainey, slated to be the first Air Force pilot to fly the F-22, and Lockheed Martin Tactical Aircraft Systems F-22 test pilot Jon Beesley.

Midway through the flight, Metz climbed to 20,000 feet and retracted the F-22's landing gear. He then conducted more engine transients, evaluated the jet's performance in "clean" configuration, and flew formation on Beesley's F-16 to evaluate precision handling characteristics before landing back at Dobbins ARB.

The flight lasted just under an hour.

"This first flight was very successful and the Raptor has wings," said Metz, who is also the F-22 Team's chief test pilot. "Now we have to make sure it has talons."

F-22 First Flight **

Takeoff Video

- *.mov *(1.1M)*
- *.mov *(1.3M)*
- *.mov *(1.3M)*

Maneuvering Video

- *.mov *(1.0M)*
- *.mov *(1.1M)*

Landing Video

- *.mov *(1.0M)*

* Requires Apple QuickTime player and plug-in installed.

**Flight video courtesy of Boeing.

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

In 1986, the IBM 286 computer was just coming into use with the general public. The avionics goals for the F-22 seemed huge and the team's confidence in meeting the information delivery goals was low.

At the time, for instance, a fiber-optic transmitter and receiver – a part of the display avionics – was roughly the size of half a sheet of paper. By 1990, that same computational power had been shrunk to the approximate size of today's computer disk.

Computational power has greatly changed the use of computers in all aspects of the F-22 program

As time went on and technology progressed, the design team's confidence grew.

Today, that same computing power has been packaged into a small device a little bigger than a business card. The size, weight and power requirements for these types of modules continue to drop.

Now we know that the original goals were, indeed, achievable.

Such a quantum leap in capability has not been limited to the F-22 aircraft itself.

Computational power has greatly changed the use of computers in all aspects of the F-22 program from design, through manufacturing, and even the testing of the airplane.

CATIA and COMOK

The computer revolution has changed the detail design process of the aircraft. In association with IBM, Dassault Systems designed "computer-aided, three-dimensional interactive application" (CATIA). As a result, the aircraft designer can design the parts of the F-22 as a solid object, not just lines on a flat page.

With COMOK (a "team-developed computer mockup simulation"), the designer can visualize every aspect of the design including complex routing for wires, tubes and cables.

There is no hard mockup of the F-22.

These computer programs allow the design engineer and the manufacturing engineer to look inside the structure before it is built.

More than just a visualization, the computer data that creates these images are precisely-stored design measurements that can be transferred, again by computers, between the team's locations in Marietta, Ga., Fort Worth Texas, Seattle, Wash., and West Palm Beach Fla., and East Hartford, Conn., and supplier locations all around the country.

Even though no master tool was sent to trial-fit the pieces, the various parts of the aircraft fit remarkably well when received in Marietta, where final assembly took place.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

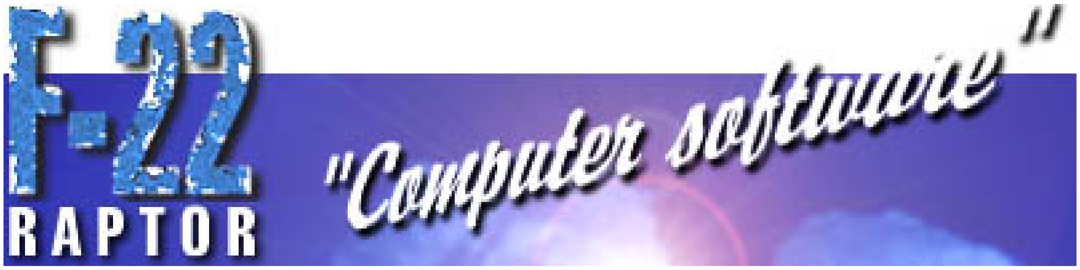
Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110



The software that provides the F-22's avionics system's full functionality is composed of approximately 1.7 million lines of code.

Ninety percent of the software is written in Ada, the Department of Defense's common computer language. Exceptions to the Ada requirement are granted only for special processing or maintenance requirements.

The software development plan, though stretched as a result of past funding constraints, remained essentially unchanged since the start of Engineering and Manufacturing Development.

The software that controls the F-22's avionics is composed of approximately 1.7 million lines of code

Three blocks

The avionics software is integrated in three blocks, each building on the capability of the previous block. Each block cycle is a sequence of subsystem deliveries, integration testing at the Avionics Integration Lab at Boeing and then delivery to Lockheed Martin in Marietta, Ga., for final integration into the aircraft and check out, as well as support to the aircraft.

Block 1 is primarily radar capability, but Block 1 does contain more than 50 percent of the avionics suite's full functionality source lines of code and provides end-to-end capability for the sensor-to-pilot data flow. The fourth F-22 to come out of Engineering and Manufacturing Development will be the first to have a full avionics suite, and it is scheduled to fly in mid-1999.

Block 2 is the start of sensor fusion. It adds radio frequency coordination, reconfiguration and some electronic warfare functions. Block 2 is scheduled to be integrated into the aircraft in late 1999.

Block 3 encompasses full sensor fusion built on enhanced electronic warfare functions. It has an embedded training capability and provides for electronic counter-counter measures.

It is scheduled to be integrated into the aircraft in the spring of 2000. Block 3.1, which adds full GBU-32 Joint Direct Attack Munition launch capability and Joint Tactical Information Distribution System receive-only capability, will be integrated in the April of 2000.

The proposed Block 4 software will be post-Engineering and Manufacturing Development. It is scheduled to be integrated on the Initial Operational Capability F-22s and will likely include helmet-mounted cueing, AIM-9X integration, and Joint Tactical Information Distribution System send capability.

Common Integrated Processor hardware was available well before the subsystem application software code and unit test phases began for the Block 1 software. The Block 1 system test tools, including simulations of the subsystems, non-avionics aircraft systems, and external environment, are on schedule for Block 1 integration.

For some of the higher risk software, such as sensor data fusion, specific algorithm testbeds have been constructed, and prototype software, which is instrumented to measure performance (correlation times, accuracy, etc.). has been operational since the start of Engineering and Manufacturing Development.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

ABOUT EDWARDS – HISTORY

The Hughes-built Common Integrated Processor (CIP) is the 'brain' of the integrated avionics system – a system which has some unusual characteristics.

For instance, the F-22 has no radios, no navigation gear like TACAN or global positioning system or instrument landing system and no radar, in the traditional sense.

Rather than radar, the CIP, which is about the size of a oversized bread box, supports all signal and data processing for all sensors and mission avionics.

Reprogramming ability
The 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 radio dies, one of the other modules will automatically reload the radio program and take over the radio function.

If the radio on an F-22 "dies," one of the other CIP modules will automatically reload the radio program

This approach to avionics makes the equipment extremely tolerant to combat damage as well as flexible from a design upgrade point of view.

The aircraft's avionics architecture remains flexible to accept future upgrades without having to design and retrofit new hardware to the fighter.

Expandability
There are two CIPs in each F-22, with 66 module slots per CIP. They have identical backplanes and all of the F-22's processing requirements can be handled by only seven different types of processors. Currently, 19 of 66 slots in CIP 1 and 22 of 66 slots in CIP are open and available for expansion.

Each module is limited by design to only 75 percent of its capability, so the F-22 has 30 percent growth capability with no change to the existing equipment. There is space, power and cooling provisions in the aircraft now for a third CIP, so the requirement for a 200 percent avionics growth capability in the F-22 can be easily met.

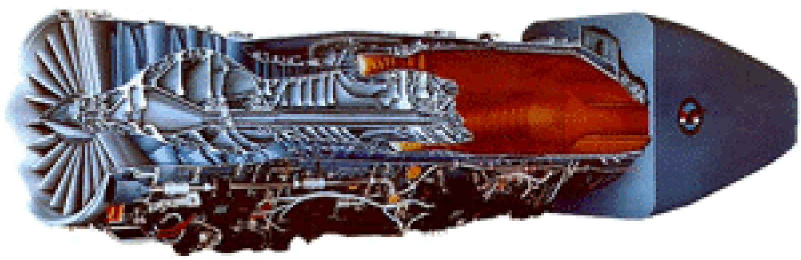
There is coordinated plan for technology growth that will help keep the CIP at state-of-the-art levels. As electronics continue to get smaller and more powerful, it is conceivable that there could be 300 percent increase in avionics capability.

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

The F-22 will incorporate Pratt & Whitney's new F119-PW-100 engine. Designed for efficient supersonic operation without afterburner use and with increased durability over today's engines, the F119 is a very high thrust-to-weight ratio engine.



Pratt & Whitney's F119-PW-100 engine

Advanced technologies in the F119 include integrated flight-propulsion controls and two-dimensional, thrust-vectoring engine nozzles.

The F119 incorporates technology advances developed and verified in joint U.S. Air Force/Pratt &Whitney research programs and for other advanced fighter engines.

It was designed using the "integrated product development" approach to ensure a balance between performance, safety and reliability, maintainability and low life-cycle cost. In addition, it has significantly fewer and more durable components than previous fighter engines.

Thrust vectoring

The F119 engine develops more than twice the thrust of current engines under supersonic conditions and more thrust without afterburner than conventional engines with afterburner.

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

Jet engines achieve additional thrust by directly injecting fuel at the engine exhaust. The process, called afterburner, gives the aircraft a rocket-like boost as the fuel ignites in the exhaust chamber.

The tradeoff is higher fuel consumption, a greater amount of heat and consequently, greater visibility to the enemy.

The F119 can push the F-22 to supersonic speeds above Mach 1.4 even without the use of afterburner, which gives the fighter a greater operating range and allows for stealthier flight operation.

The product of more than 40 years' research into high-speed propulsion systems, the F119 is proof that high-technology doesn't have to be complicated.

Special Features

- Integrally bladed rotors
- Long-chord, shroudless fan blades
- Low aspect ratio, high-stage loading compressor blades
- Alloy C high strength burn resistant titanium compressor stators
- Floatwall combustor
- Advanced single-crystal turbine materials
- Multi-pass convection and advanced film turbine cooling
- Alloy C high strength burn resistant titanium in augmentor and nozzle
- Third generation full-authority digital electronic engine control
- Integrated engine/aircraft controls
- Maximum thrust: 35,000-pound-thrust class

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

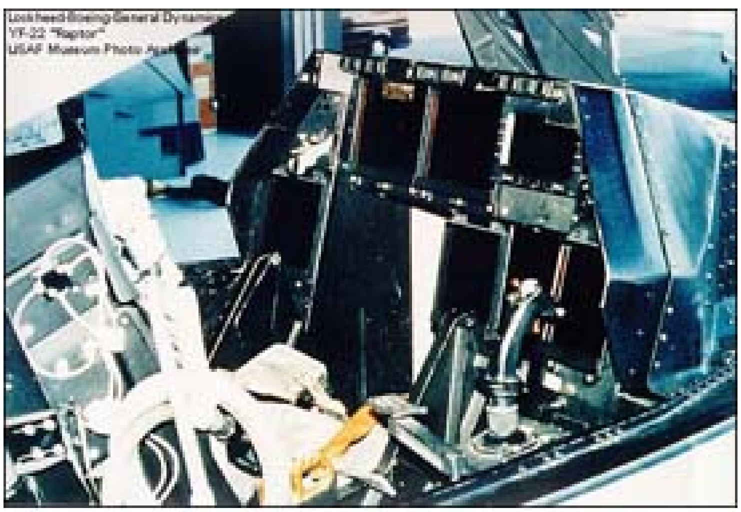
Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

The F-22's cockpit represents a revolution over current "pilot offices," as it is designed to let the pilot operate as a tactician, not a sensor operator.

Humans are good at differentiating information, but they are poor integrators. The F-22 cockpit lets the pilot do what humans do best and it fully utilizes the power of the computer to do what it does best

While that change to tactician is the biggest advance the F-22's cockpit has over current fighter cockpits, there are also several other distinctive features.



The cockpit of the YF-22 prototype

The F-22's cockpit is one of the very first "all-glass" cockpits for tactical fighters – there are no traditional round dial, standby or dedicated gauges.

It accommodates the largest range of pilots (the central 99 percent of the Air Force pilot population) of any tactical aircraft. It is the first baseline "night vision goggle" compatible cockpit, and it has designed-in growth capability for helmet-mounted systems.

The canopy is the largest piece of polycarbonate formed in the world with the largest Zone 1 (highest quality) optics for compatibility with helmet-mounted systems.

While functionality is critical, the F-22's cockpit design also ensures pilot safety with an improved version of the proven ACES II ejection seat and a new pilot personal equipment and life support ensemble.

Pilot-aircraft integration

The GEC-built "head-up display" offers a wide field of view (30 degrees horizontally by 25 degrees vertically) and serves as a primary flight instrument for the pilot.

The F-22's head-up display is approximately 4.5 inches tall and uses standardized symbolization developed by the Air Force Instrument Flight Center. It does not present information in color, but the tactical symbol set is the same that is used on the F-22's head down displays.

During F-22 canopy bird-strike tests, it was found that the head-up display combiner glass would shatter the canopy. To solve this problem, the F-22 head-up display will have a rubber buffer strip on it that will effectively shield the polycarbonate of the canopy when it flexes during a bird-strike from hitting the optical glass in the head-up display and shattering.

Design is also underway for a head-up display that will collapse during a bird-strike, but would remain upright under all other conditions. Additionally, the team is investigating the possibility of having the head-up display combiner glass laminated similar to household safety glass to preclude flying glass in the cockpit following bird-strike.

True integration
The integrated control panel is the primary means for manual pilot data entry for communications, navigation, and autopilot data. Located under the glareshield and head-up display in center top of the instrument panel, this keypad entry system also has some double-click functions, much like a computer mouse for rapid pilot access/use.

There are six liquid crystal display (LCD) panels in the cockpit. These present information in full color and are fully readable in direct sunlight. LCDs offer lower weight and less size than the cathode ray tube (CRT) displays used in most current aircraft. The lower power requirements also provide a reliability improvement over CRTs.

The two up-front displays measure 3-by-4 inches in size and are located to the left and right of the integrated control panel. The up-front displays are used to display Integrated Caution/Advisory/Warning data, communications/navigation/identification data and serve as the stand-by flight instrumentation group and fuel quantity indicator.

A total of 12 individual warning messages can appear at one time on the up-front display and additional ones can appear on sub-pages of the display.

Nontraditional
Two aspects of the integrated warning display differentiate it from a traditional warning light panels.

First, all integrated warning system fault messages are filtered to eliminate extraneous messages and tell the pilot specifically and succinctly what the problem is.

The second is the electronic checklist. When an integrated warning system message occurs, the pilot depresses the checklist push button (called a bezel button) on the bottom of the up-front display and the associated checklist appears on the left hand secondary multifunction display. This function also provides access to non-emergency checklists for display to the pilot.

In addition to the visual warning on the display, the aircraft has an audio system that alerts the pilot. A caution is indicated only by the word "caution," while a warning is announced with the specific problem - that is, "Warning. Engine Failure."

The stand-by flight group is always in operation and, although it is presented on an LCD display, it shows the basic information (such as an artificial horizon) the pilot needs to fly the aircraft. The stand-by flight group is tied to the last source of power in the aircraft, so if everything else fails, the pilot will still be able to fly the aircraft.

God's-eye view

The primary multifunction display is a 8-by-8 inch color display that is located in the middle of the instrument panel. It is the pilot's principal display for aircraft navigation (including showing waypoints and route of flight) and "situation assessment" or a "God's-eye view" of the entire environment around (above, below, both sides, front and back) the aircraft.

Three secondary multifunction displays are all 6.25-by-6.25 inches and two of them are located on either side of the primary multifunction display, on the instrument panel with the third between the pilot's knees. These are used for displaying tactical (both offensive and defensive) information as well as non-tactical information (such as checklists, subsystem status, engine thrust output, and stores management).

Cockpit display symbols

The tactical information shown on the displays is all intuitive to pilots, allowing them to understand the situation around him by glancing at the screen. Enemy aircraft are shown as red triangles, friendly aircraft are green circles, unknown aircraft are shown as yellow squares and wingmen are shown as blue F-22s. Surface-to-air missile sites are represented by pentagons (along with an indication of exactly what type missile it is) and its lethal range.

In addition to shape and color, the symbols are further refined. A filled-in triangle means that the pilot has a missile firing-quality solution against the target, while an open triangle is not a firing-quality solution.

The pilot has a cursor on each screen, and he can ask the aircraft's avionics system to retrieve more information.

The system can determine to a 98-percent probability the target's type of aircraft. If the system can't make an identification to that degree, the aircraft is shown as an unknown.

Likewise, one of the original objectives for the F-22 was to increase the percentage of fighter pilots who make "kills."

Networking
The Inter/Intra Flight Data Link is one of the powerful tools that make all F-22s more capable. Each F-22 can be linked together to trade information without radio calls with each F-22s in a flight or between flight.

Each pilot is then free to operate more autonomously because, for example, the leader can tell at a glance what his wing man's fuel state is, weapons remaining and even the enemy aircraft targeted. Classical tactics based on visual "tally" (visual identification) and violent formation maneuvers that reduce the wing man to "hanging on" may have to be rethought in light of such capabilities.

Hands-on throttle and stick
The F-22 features a side-stick controller (like an F-16) and two throttles that are the aircraft's primary flight controls.

The GEC-built stick is located on the right console and there is a swing-out, adjustable arm rest. The stick is force sensitive and has a throw of only about one-quarter of an inch. The throttles are located on the left console.

Both the stick and the throttles are high-use controls during air combat. To support pilot functional requirements, the grips include buttons and switches (that are both shape and texture coded) to control more than 60 different time-critical functions. These buttons are used for controlling the offensive (weapons targeting and release) and defensive systems (although some, like chaff and flares, can operate both automatically and manually) as well as display management.

Accommodations
Previous fighter cockpits were sized to accommodate the fifth percentile to 95th percentile pilots (a range of only 90 percent . The F-22 cockpit is sized to accommodate the 0.5 percentile to 99.5 percentile pilots (the body size of the central 99 percent of the Air Force pilot population) This represents the largest range of pilots accommodated by any tactical aircraft now in service. The rudder pedals are adjustable. The pilot has 15-degree over-the-nose visibility and excellent over-the-side and aft visibility as well.

Lighting
The cockpit interior lighting is fully night vision goggle compatible, as is the exterior lighting. The cockpit panels feature extended life, self-balancing, electroluminescent edge-lit panels with an integral life-limiting circuit that runs the lights at the correct power setting

throughout their life. It starts at one-half power and gradually increases the power output to insure consistent panel light intensity over time. As a result, the cockpit always presents a well-balanced lighting system to the pilot (there is not a mottled look in the cockpit). The panels produce low amounts of heat and power and are very reliable.

The aircraft also has integral position and anti-collision lights (including strobes) on the wings. The low voltage electroluminescent formation lights are located at critical positions for night flight operations on the aircraft (on the forward fuselage (both sides) under the chine, on the tip of the upper left and right wings, and on the outside of both vertical stabilizers.

There are similar air refueling lights on the butterfly doors that cover the air refueling receptacle.

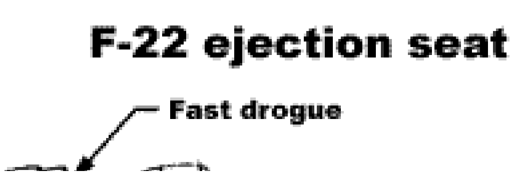
Canopy
The F-22's canopy is approximately 140 inches long, 45 inches wide, 27 inches tall and weighs approximately 360 pounds. It is a rotate/translate design, which means that it comes down, slides forward and locks in place with pins. It is a much more complex piece of equipment than it would appear to be.

The F-22 canopy's transparency (made by Sierracin) features the largest piece of monolithic polycarbonate material being formed today. It has no canopy bow and offers the pilot superior optics (Zone 1 quality) throughout (not just in the area near the HUD) and it offers the requisite stealth features.

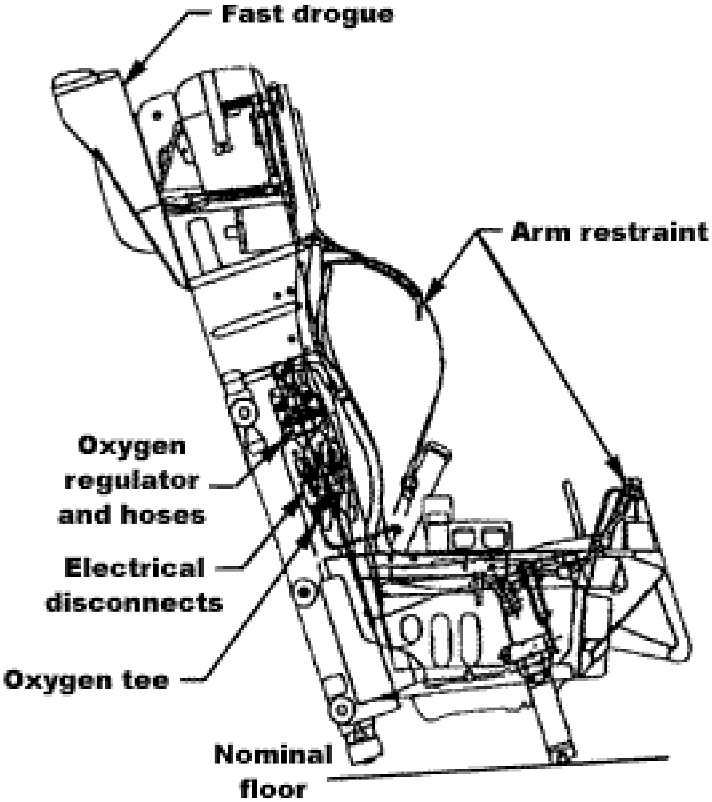
The canopy is resistant to chemical/biological and environmental agents, and has been successfully tested to withstand the impact of a four-pound bird at 350 knots. It also protects the pilot from lightning strikes.

The 3/4-inch polycarbonate transparency is actually made of two 3/8-inch thick sheets that are heated and fusion bonded (the sheets actually meld to become a single-piece article) and then drape forged. The F-16's canopy, for comparison, is made up of laminated sheets. A laminated canopy generally offers better bird-strike protection and because of the lower altitude where the F-16 operates, this is an advantage. However, lamination also adds weight as well as reduced optics.

There is no chance of a post-ejection canopy-seat-pilot collision as the canopy (with frame) weighs slightly more on one side than the other. When the canopy is jettisoned, the weight differential is enough to make it slice nearly 90 degrees to the right as it clears the aircraft.



ACES II ejection seat
The F-22 uses an improved version of the



ACES II (Advanced Concept Ejection Seat) ejection seat ACES II Ejection Seat that is used in nearly every other Air Force jet combat aircraft (F-16, F-117, F-15, A-10, B-1, B-2). The seat has a center mounted (between the pilot's legs) ejection control.

The F-22 version of the McDonnell Douglas-built ACES II includes several improvements over the previous seat models. These improvements include the following:

– The addition of an active arm restraint system to eliminate arm flail injuries during high speed ejections.

– An improved fast-acting seat stabilization drogue parachute system to provide increased seat stability and safety for the pilot during high-speed ejections. The drogue is located behind the pilot's head, rather than in the back of the seat and is mortar-deployed.

– A new electronic seat and aircraft sequencing system that improves the timing of the various events that have to happen in order for the pilot to eject (initiation, canopy jettison, and seat catapult ignition).

– A larger oxygen bottle gives the ejecting pilot more breathing air to support ejection at higher altitudes (if required).

– The F-22 ACES II ejection system utilizes the standard analog three-mode seat sequencer that automatically senses the seat speed and altitude, and then selects the proper mode for optimum seat performance and safe recovery of the pilot. Mode 1 is low speed, low altitude; Mode 2 is high speed, low altitude; and Mode 3 is high altitude.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

---

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

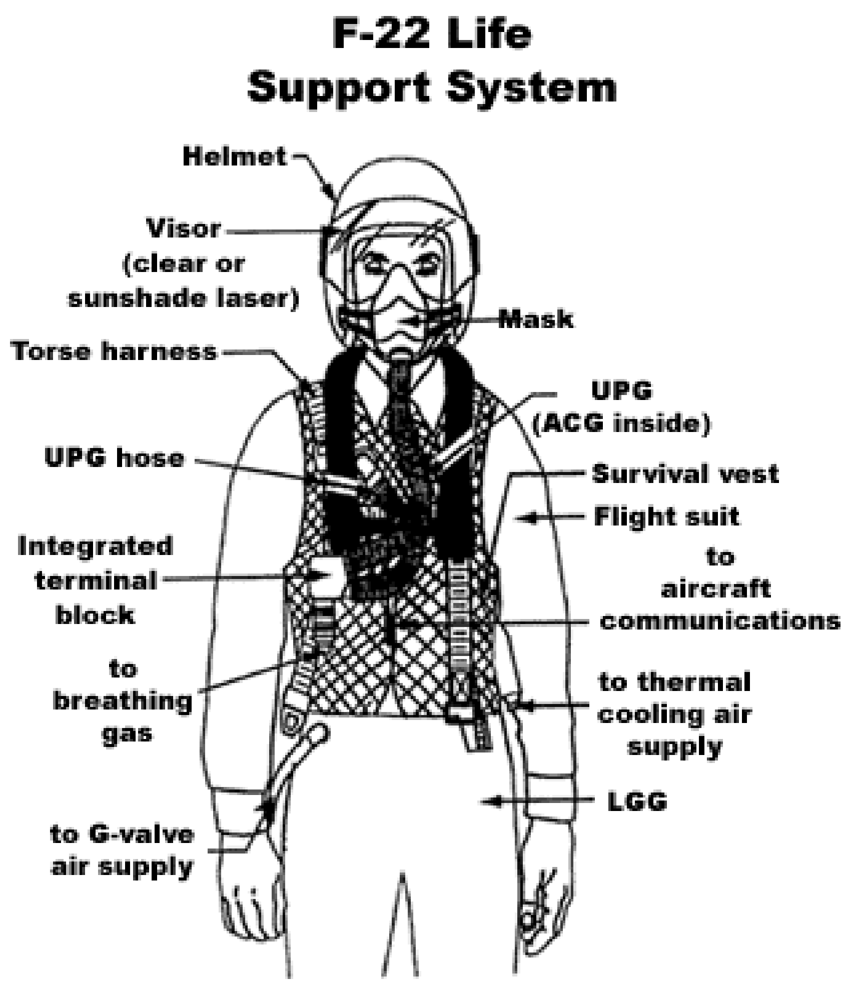
Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

The F-22 life support system F-22 life support system integrates all critical components of clothing, protective gear and aircraft equipment necessary to sustain the pilot's life while flying the aircraft.

In the past, these components had been designed and produced separately.

The life support system components include:



– An on-board oxygen generation system that supplies breathable air to the pilot.

– An integrated breathing regulator/anti-g valve that controls flow and pressure to the mask and pressure garments.

– A chemical/biological/cold-water immersion protection ensemble.

– An upper body counter-pressure garment and a lower body anti-G garment acts a partial pressure suit at high altitudes.

– An air-cooling garment, which is also going to be used by pilots on the Army's RAH-66 Comanche helicopter provides thermal relief for the pilot.

– Helmet and helmet-mounted systems including C/B goggles and C/B hood; and the MBU-22/P breathing mask and hose system.

Development

The Boeing-led life support development and its suppliers designed the life support system with the F-22's advanced performance capabilities in mind.

The separate components of the life-support system must simultaneously meet pilot protection requirements established by the Air Force in the areas of higher altitude flight, acceleration, heat distress, cold water immersion, chemical and biological environments, fire, noise and high-speed/high-altitude ejection.

Escape-system tests have demonstrated that the life-support system will protect pilots when exposed to wind speeds of up to 600 knots. Current life-support systems are designed to provide protection only up to 450 knots.

The head-mounted portions of the life-support system are approximately 30-percent lighter than existing systems, which improves mobility and endurance time for pilots.

With its advanced design, the HGU-86/P helmet used by F-22 pilots during Engineering and Manufacturing Development reduces the stresses on a pilot's neck by 20 percent during high-speed ejection compared to the current HGU-55/P helmets. The F-22 helmet fits more securely as the result of an ear cup tensioning device and is easily fitted to a pilot's head.

The helmet provides improved passive noise protection and incorporates an active noise reduction system for superior pilot protection.

The chemical/biological/cold water immersion garment is to be worn by pilots when they fly over large bodies of cold water or into chemical/biological warfare situations. These garments meet or exceed Air Force requirements.

During cold water immersion tests, the body temperature of test subjects wearing the garments fell no more than a fraction of a degree after sitting in nearly 32-degree Fahrenheit water for two hours. Current cold water immersion tests suits allow body temperatures to drop below the minimum of 96.8 degrees Fahrenheit within an hour and a half. Normal body temperature is 98.6 degrees Fahrenheit.

Other advantages of the F-22 life support system include its ability to fit a wider range of sizes and body shapes.

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous

Next

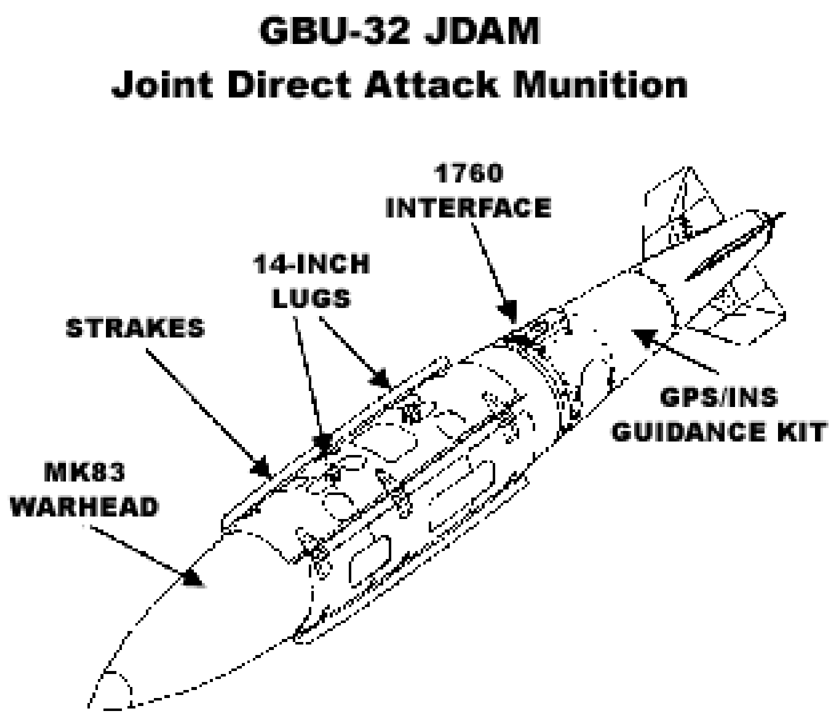
Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

Air-to-air capability
The F-22 is capable of carrying existing and planned air-to-air weapons. These include a full complement of medium-range missiles such as the AIM-120A advanced medium range air-to-air missile (AMRAAM) and short-range missiles such as the AIM-9 Sidewinder.

Joint Direct Attack Munitions
The F-22 also will have a modernized version of the proven M61 internal gun and growth provisions for other weapons. The aircraft also will be capable of carrying joint direct attack munitions (JDAMs) and other ground-attack weapons.



Air-to-surface capability
The F-22 has a secondary role to attack surface targets. The aircraft will be capable of carrying two 1,000-pound joint direct attack munitions (JDAMs) internally and will use on-board avionics for navigation and weapons delivery support.

- **AIM-120 AMRAAM**
  Advanced Medium Range Air-to-Air Missile

  Specifications
  Designation – AIM-120
  Type – Radar-guided medium-range air-to-air missile
  Contractors – Hughes Missile Systems and Raytheon Company
  Powerplant – Aerojet two-stage solid propellant rocket motor
  Guidance – Inertial midcourse, with active radar terminal homing
  Warhead – High explosive, directed fragmentation weighing 48 LB

Dimensions – Length: 12 ft. 0 in.; Body Diameter: 7 in.; Fin Span: 1 ft., 6 in. (AIM-120C)
Weight – 345 lbs.
Performance – Cruising speed approximately Mach 4; Range: Approximately 30 miles
F-22 Loadout – When the F-22 is in first-day-of-a-war combat configuration, all missiles are carried in the main weapons bay only.
Typical combat load – Six AIM-120C. Three in each side of the main weapons bay with the center missile staggered ahead of the inboard and outboard missiles. The F-22 can carry four of the older, longer-finned AIM-120A if necessary.

- **AIM-9 SIDEWINDER**

  Specifications
  Designation – AIM-9
  Nickname – Sidewinder
  Type – Heat-seeking (infrared) short range air-to-air missile
  Contractors – Raytheon Company and Loral Autoneutronics
  Powerplant – Thiokol Hercules Mk. 36 Mod 11 solid propellant rocket motor
  Guidance – Solid-state infrared (IR) homing
  Warhead – High explosive, blast fragmentation weighing 20.8 lb.
  Dimensions – Length: 9 ft. 5 in.; Body diameter: 5 in.; Fin Span: 2 ft. 1 in.
  Weight – 191 lbs.
  Performance – Maximum speed above Mach 2; Range: More than 10 miles
  F-22 Loadout – Two AIM-9M (One missile in each side weapons bay)
  NOTE: There are no plans to carry the AIM-9 in the F-22's main weapons bay.

- **GBU-32 JDAM**
  Joint Direct Attack Munition

  Specifications
  Designation – GBU-32
  Type – JDAM is a tail guidance kit that converts existing unguided free-fall bombs into near precision-guided "smart" munitions. It also includes strap-on strakes that attach to the bomb's body for stability.
  Contractor – McDonnell Douglas Aerospace
  Powerplant – None
  Guidance – Inertial Navigation System (INS)/Global Positioning System (GPS)
  Warhead – For F-22, the JDAM tail guidance kit fits on the Mk. 83 1,000-pound-class conventional bomb
  Weight – Weight of the Mk. 83 bomb and tail guidance kit is approximately 1,015 pounds
  Performance – The combination of the stealthy F-22 and the precision capability of the GBU-32 allows the F-22 pilot to drop the weapon from altitudes of approximately

40,000 feet; Range: Approximately 15 miles
F-22 Loadout – The GBU-32 is only carried in the F-22's main weapons bay.
Typical combat load – Two GBU-32. One GBU-32 is carried inboard in each side of the main weapons bay. When loaded with GBU-32, there is still sufficient room in the F-22's main weapons bay to carry two AIM-120C air-to-air missiles (one in each side of the bay, in addition to the two AIM-9 Sidewinders in the side weapons bays), which means that even on a mission to attack ground targets, the F-22 retains significant air-to-air combat capability.

- **M61A2 20-mm Cannon**

  Specifications
  Designation – M61A2
  Type – Six-barrel, hydraulically operated 20mm Gatling gun
  Contractor – General Dynamics Armament Systems
  Rate of Fire – 6,000 rounds per minute
  Rounds Available – 480
  Effective Range – Several thousand yards

Information from the web sites of Lockheed Martin, Boeing and Pratt & Whitney were used in this story.

Previous

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

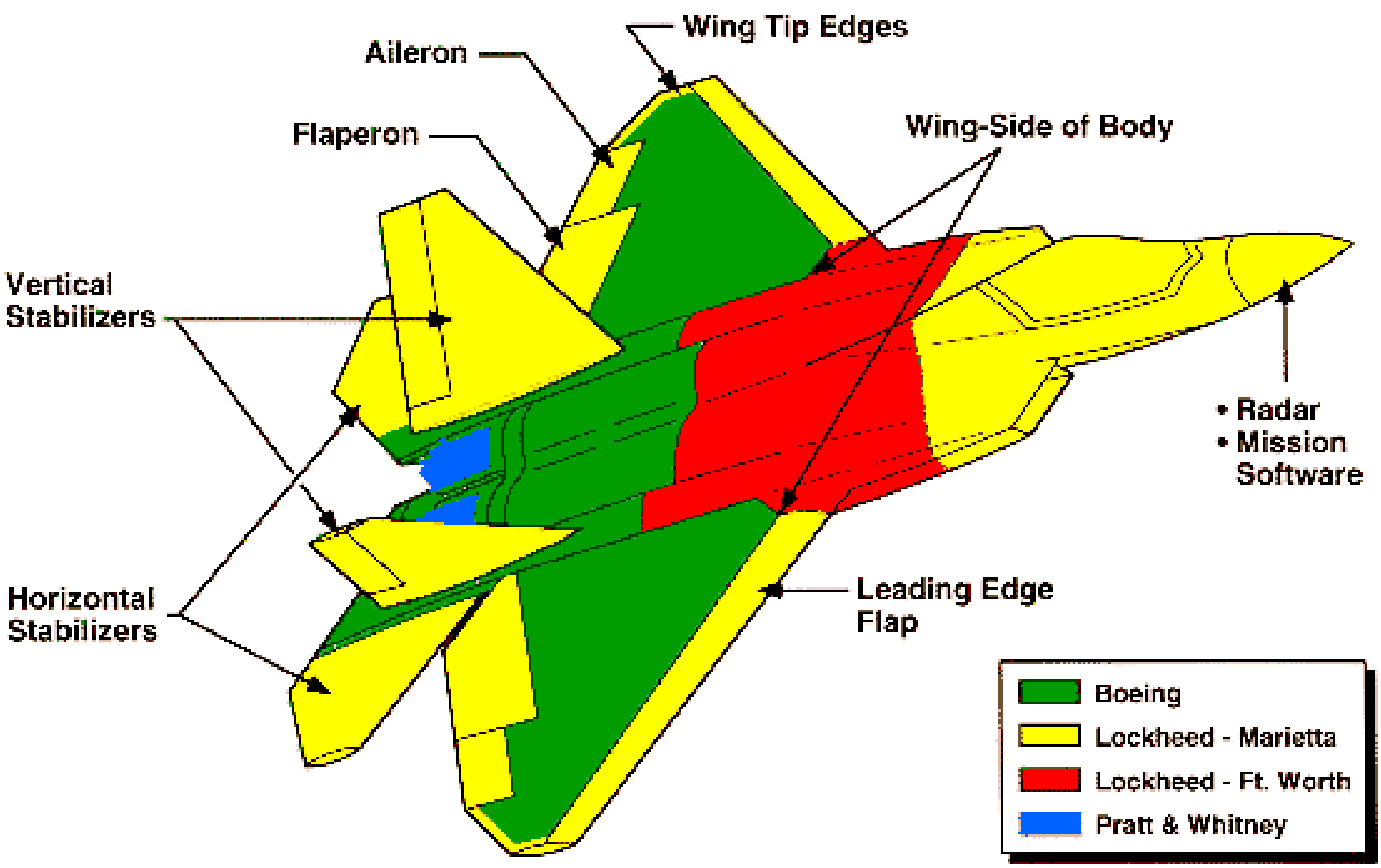
Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110

ABOUT EDWARDS – HISTORY

Division of labor



Previous | Next

Edwards Home | About Edwards | Base Guide | News | Products & Services

Environmental | Flight Safety | FOIA | Gallery | History | Job Opportunities | Maps | Museum | Organizations | Tours | Weather : Aviation | Weather : Local

Contracting | Links | Publications & Forms | R-2508 Air Space | Search | Site Map

Please read our Privacy and Security Notice

Air Force Flight Test Center
E-mail comments: Public Affairs
Last updated: July 29, 2004

Public Affairs
95 ABW/PA
1 S. Rosamond Blvd.
Edwards AFB, CA 93524

Public Affairs: (661) 277-3510
FAX: (661) 277-2732
DSN: 527-3510
Base Operator: (661) 277-1110