= Lockheed Martin F @-@ 22 Raptor =

The Lockheed Martin F @-@ 22 Raptor is a fifth @-@ generation , single @-@ seat , twin @-@ engine , all @-@ weather stealth tactical fighter aircraft developed for the United States Air Force (USAF) . The result of the USAF 's Advanced Tactical Fighter program , the aircraft was designed primarily as an air superiority fighter , but also has ground attack , electronic warfare , and signals intelligence capabilities . The prime contractor , Lockheed Martin , built most of the F @-@ 22 's airframe and weapons systems and did its final assembly , while Boeing provided the wings , aft fuselage , avionics integration , and training systems .

The aircraft was variously designated F @-@ 22 and F / A @-@ 22 before it formally entered service in December 2005 as the F @-@ 22A . After a protracted development and despite operational issues , the USAF considers the F @-@ 22 critical to its tactical air power , and says that the aircraft is unmatched by any known or projected fighter . The Raptor 's combination of stealth , aerodynamic performance , and situational awareness gives the aircraft unprecedented air combat capabilities .

The high cost of the aircraft , a lack of clear air @-@ to @-@ air missions due to delays in Russian and Chinese fighter programs , a ban on exports , and development of the more versatile F @-@ 35 led to the end of F @-@ 22 production . A final procurement tally of 187 operational production aircraft was established in 2009 and the last F @-@ 22 was delivered to the USAF in 2012 .

= = Development = =

= = = Origins = = =

In 1981 the U.S. Air Force developed a requirement for an Advanced Tactical Fighter (ATF) as a new air superiority fighter to replace the F @-@ 15 Eagle and F @-@ 16 Fighting Falcon . Code named " Senior Sky " , this program was influenced by the emerging worldwide threats , including development and proliferation of Soviet Su @-@ 27 " Flanker " - and MiG @-@ 29 " Fulcrum " -class fighter aircraft . It would take advantage of the new technologies in fighter design on the horizon , including composite materials , lightweight alloys , advanced flight control systems , more powerful propulsion systems , and stealth technology . The request for proposals (RFP) was issued in July 1986 and two contractor teams , Lockheed / Boeing / General Dynamics and Northrop / McDonnell Douglas , were selected on 31 October 1986 to undertake a 50 @-@ month demonstration phase , culminating in the flight test of two technology demonstrator prototypes , the YF @-@ 22 and the YF @-@ 23 .

Each design team produced two prototype air vehicles , one for each of the two engine options . The Lockheed @-@ led team employed thrust vectoring nozzles on YF @-@ 22 for enhanced maneuverability in dogfights . The ATF 's increasing weight and cost drove out certain requirements during development . Side @-@ looking radars were deleted , and the dedicated infra @-@ red search and track (IRST) system was downgraded from multi @-@ color to single color and then deleted as well . However , space and cooling provisions were retained to allow for future addition of these components . The ejection seat requirement was downgraded from a fresh design to the existing McDonnell Douglas ACES II .

After the flight test demonstration and validation of the prototypes , on 23 April 1991 , Secretary of the USAF Donald Rice announced the YF @-@ 22 as the winner of the ATF competition . The YF @-@ 23 design was considered stealthier and faster while the YF @-@ 22 was more maneuverable . The aviation press speculated that the YF @-@ 22 was also more adaptable to the U.S. Navy 's Navalized Advanced Tactical Fighter (NATF) , but by 1992 , the Navy had abandoned NATF .

= = = Production and procurement = = =

Prime contractor Lockheed Martin Aeronautics manufactured the majority of the airframe and

performed final assembly at Dobbins Air Reserve Base in Marietta , Georgia ; program partner Boeing Defense , Space & Security provided additional airframe components as well as avionics integration and training systems . F @-@ 22 production was split up over many subcontractors across 46 states to increase Congressional support , though this production split may have contributed to increased costs and delays . Many capabilities were deferred to post @-@ service upgrades , reducing the initial cost but increasing total program cost . Production supported over 1 @,@ 000 subcontractors and suppliers and up to 95 @,@ 000 jobs .

The F @-@ 22 had several design changes from the YF @-@ 22 . The swept @-@ back angle of the leading edge was decreased from 48 ° to 42 ° , while the vertical stabilizers were shifted rearward and decreased in area by 20 % . To improve pilot visibility , the canopy was moved forward 7 inches (18 cm) , and the engine intakes moved rearward 14 inches (36 cm) . The shapes of the wing and stabilator trailing edges were refined to improve aerodynamics , strength , and stealth characteristics . Increasing weight during development caused slight reductions in range and aerodynamic performance .

The first F @-@ 22 , an engineering and manufacturing development (EMD) aircraft named Raptor 4001 , was unveiled at Marietta , Georgia , on 9 April 1997 , and first flew on 7 September 1997 . In 2006 , the Raptor 's development team , composed of over 1 @,@ 000 contractors and the USAF , won the Collier Trophy , American aviation 's most prestigious award . The F @-@ 22 was in production for 15 years , at a rate of roughly two per month during peak production .

The USAF originally envisioned ordering 750 ATFs at a cost of $ 26 @.@ 2 billion , with production beginning in 1994 . The 1990 Major Aircraft Review led by Secretary of Defense Dick Cheney reduced this to 648 aircraft beginning in 1996 . By 1997 , funding instability had further cut the total to 339 , which was again reduced to 277 F @-@ 22s by 2003 . In 2004 , the Department of Defense (DoD) further reduced this to 183 operational aircraft , despite the USAF 's preference for 381 . In 2006 , a multi @-@ year procurement plan was implemented to save $ 15 billion but raise each aircraft 's cost . That year the program 's total cost was projected to be $ 62 billion for 183 F @-@ 22s distributed to seven combat squadrons . In 2007 , Lockheed Martin received a $ 7 @.@ 3 billion contract to increase the order to 183 production F @-@ 22s and extend manufacturing through 2011 .

In April 2006 , the Government Accountability Office (GAO) assessed the F @-@ 22 's cost to be $ 361 million per aircraft , with $ 28 billion invested in development and testing ; the Unit Procurement Cost was estimated at $ 178 million in 2006 , based on a production run of 181 aircraft . It was estimated by the end of production , $ 34 billion will have been spent on procurement , resulting in a total program cost of $ 62 billion , around $ 339 million per aircraft . The incremental cost for an additional F @-@ 22 was estimated at about $ 138 million in 2009 . The GAO stated the estimated cost was $ 412 million per aircraft in 2012 .

= = = Ban on exports = = =

The F @-@ 22 cannot be exported under American federal law to protect its stealth technology and other high @-@ tech features . Customers for U.S. fighters are acquiring earlier designs such as the F @-@ 15 Eagle and F @-@ 16 Fighting Falcon or the newer F @-@ 35 Lightning II Joint Strike Fighter , which contains technology from the F @-@ 22 but was designed to be cheaper , more flexible , and available for export . In September 2006 , Congress upheld the ban on foreign F @-@ 22 sales . Despite the ban , the 2010 defense authorization bill included provisions requiring the DoD to prepare a report on the costs and feasibility for an F @-@ 22 export variant , and another report on the effect of F @-@ 22 export sales on U.S. aerospace industry .

Some Australian politicians and defense commentators proposed that Australia should attempt to purchase F @-@ 22s instead of the planned F @-@ 35s , citing the F @-@ 22 's known capabilities and F @-@ 35 's delays and developmental uncertainties . However , the Royal Australian Air Force (RAAF) determined that the F @-@ 22 was unable to perform the F @-@ 35 's strike and close air support roles . The Japanese government also showed interest in the F @-@ 22 for its Replacement @-@ Fighter program . The Japan Air Self @-@ Defense Force (JASDF) would

reportedly require fewer fighters for its mission if it obtained the F @-@ 22 , thus reducing engineering and staffing costs . However , in 2009 it was reported that acquiring the F @-@ 22 would require increases to the defense budget beyond the historical 1 percent of GDP . With the end of F @-@ 22 production , Japan chose the F @-@ 35 in December 2011 . Israel also expressed interest , but eventually chose the F @-@ 35 because of the F @-@ 22 's price and unavailability .

= = = Production termination = = =

Throughout the 2000s , the need for F @-@ 22s was debated due to rising costs and the lack of relevant adversaries . In 2006 , Comptroller General of the United States David Walker found that " the DoD has not demonstrated the need " for more investment in the F @-@ 22 , and further opposition to the program was expressed by Secretary of Defense Donald Rumsfeld , Deputy Secretary of Defense Gordon R. England , Senator John McCain , and Chairman of U.S. Senate Committee on Armed Services Senator John Warner . The F @-@ 22 program lost influential supporters in 2008 after the forced resignations of Secretary of the Air Force Michael Wynne and the Chief of Staff of the Air Force General T. Michael Moseley . Nevertheless , in 2008 , Congress passed a defense spending bill funding the F @-@ 22 's continued production and the Pentagon released $ 50 million of the $ 140 million for four additional aircraft , raising the total orders for production aircraft to 187 and leaving the program in the hands of the next administration .

In November 2008 , Secretary of Defense Robert Gates stated that the Raptor was not relevant in post @-@ Cold War conflicts such as in Iraq and Afghanistan , and in April 2009 , under the new Obama Administration , he called for ending F @-@ 22 production in fiscal year (FY) 2011 , leaving the USAF with 187 production aircraft . In July , General James Cartwright , Vice Chairman of the Joint Chiefs of Staff , stated to the Senate Committee on Armed Services his reasons for supporting termination of F @-@ 22 production . They included shifting resources to the multirole F @-@ 35 to allow proliferation of fifth @-@ generation fighters for three service branches and preserving the F / A @-@ 18 production line to maintain the military 's electronic warfare (EW) capabilities in the Boeing EA @-@ 18G Growler . Issues with the F @-@ 22 's reliability and availability also raised concerns . After President Obama threatened to veto further production , the Senate voted in July 2009 in favor of ending production and the House subsequently agreed to abide by the 187 production aircraft cap . Gates stated that the decision was taken in light of the F @-@ 35 's capabilities , and in 2010 , he set the F @-@ 22 requirement to 187 aircraft by lowering the number of major regional conflict preparations from two to one .

In 2010 , USAF initiated a study to determine the costs of retaining F @-@ 22 tooling for a future Service Life Extension Program (SLEP) . A RAND Corporation paper from this study estimated that restarting production and building an additional 75 F @-@ 22s would cost $ 17 billion , resulting in $ 227 million per aircraft or 54 million higher than the flyaway cost . Lockheed Martin stated that restarting the production line itself would cost about $ 200 million . Production tooling will be documented in illustrated electronic manuals stored at the Sierra Army Depot . Retained tooling will produce additional components ; due to the limited production run there are no reserve aircraft , leading to considerable care during maintenance . Later attempts to retrieve this tooling found that the containers were empty .

Russian and Chinese fighter developments have fueled concern , and in 2009 , General John Corley , head of Air Combat Command , stated that a fleet of 187 F @-@ 22s would be inadequate , but Secretary Gates dismissed this concern . In 2011 , Gates explained that Chinese fifth @-@ generation fighter developments had been accounted for when the number of F @-@ 22s was set , and that the U.S. would have a considerable advantage in stealth aircraft in 2025 , even with F @-@ 35 delays . In December 2011 , the 195th and final F @-@ 22 was completed out of 8 test and 187 operational aircraft produced , the aircraft was delivered to the USAF on 2 May 2012 .

In April 2016 , the HASC Tactical Air and Land Forces Subcommittee proposed legislation that would direct the Air Force " to conduct a comprehensive assessment and study of the costs associated with resuming production of F @-@ 22 aircraft . " Defense Secretary Robert Gates had

production halted at 187 F @-@ 22s (at a cost of $ 67 billion) to direct funds for ongoing irregular warfare operations in Iraq and Afghanistan . Since then , lawmakers and the Pentagon have noted that air warfare systems of Russia and China are catching up to U.S. air superiority capabilities . The bill notes that Air Combat Command has a stated requirement for 381 F @-@ 22s from initial program objectives of 749 aircraft , and would require reviewing of anticipated future air superiority capacity and capability requirements , estimated costs to restart F @-@ 22 production , and other measures . In addition to identifying the cost of building another 194 aircraft , the report must also consider the possibility of the 1998 prohibition on the export of the F @-@ 22 being repealed . Previous estimates of restarting production placed figures at around $ 2 billion , including $ 300 ? 500 million in non @-@ recurring start @-@ up costs , with an estimated unit cost of $ 233 million for a production run of 75 aircraft over five years . Lockheed has proposed upgrading the 36 early training @-@ model Block 20 Raptors into combat @-@ coded Block 30 / 35 versions as a way to increase numbers available for deployment .

= = = Upgrades = = =

The first combat @-@ capable Block 3 @.@ 0 aircraft first flew in 2001 . Increment 2 , the first F @-@ 22 upgrade program , was implemented in 2005 and enables the aircraft to employ Joint Direct Attack Munitions (JDAM) . Increment 3 @.@ 1 provides improved ground @-@ attack capability through synthetic aperture radar mapping and radio emitter direction finding , electronic attack and the GBU @-@ 39 Small Diameter Bomb (SDB) ; testing began in 2009 and the first upgraded aircraft was delivered in 2012 . Increment 3 @.@ 2 is a two @-@ part upgrade process ; 3.2A focuses on electronic warfare , communications and identification , while 3.2B will allow the F @-@ 22 to fully exploit the AIM @-@ 9X and AIM @-@ 120D missiles . The subsequent Increment 3 @.@ 3 may include the adoption of an open avionics platform and air traffic control updates . Upgrades due in 2015 will allow the F @-@ 22 to employ the AIM @-@ 9X and have full Link 16 reception and transmission capability , and an upgrade scheduled in 2018 will integrate the AIM @-@ 120D into the weapons suite . The F @-@ 22 fleet is planned to have 36 Block 20 training and 149 Block 30 / 35 combat aircraft by 2016 . The Increment 3.2B upgrade planned for 2018 will include a new stores management system to show the correct symbols for the AIM @-@ 9X Sidewinder and AIM @-@ 120D AMRAAM and improved control of them .

To enable two @-@ way communication with other platforms , the F @-@ 22 can use the Battlefield Airborne Communications Node (BACN) as a gateway . The originally planned MADL integration was cut due to the lack of system maturity . In 2014 Lockheed Martin and Northrop Grumman were competing to connect the F @-@ 22 with other platforms while maintaining stealth . Other upgrades being developed include infra @-@ red search and track functionality for the AN / AAR @-@ 56 Missile Launch Detector (MLD) and integration of a helmet @-@ mounted cuing system (HMCS) to enable off @-@ boresight missile launches by 2020 . Until the F @-@ 22 gains a helmet mounted system it will use the AIM @-@ 9X 's helmetless high off @-@ boresight (HHOBS) capabilities . In March 2010 , the USAF accelerated software portions of 3 @.@ 2 to be completed in FY 2013 .

In January 2011 , the USAF opened the Raptor enhancement , development and integration (REDI) contract to bidders , with a $ 16 billion budget . In November 2011 , Lockheed Martin 's upgrade contract ceiling was raised to $ 7 @.@ 4 billion . Nearly $ 2 billion was allocated for structural repairs and to achieve fleet availability rate of 70 @.@ 6 % by 2015 . However , only 63 % was achieved . Some F @-@ 35 technology , such as more durable stealth coatings , have been applied to the F @-@ 22 . By 2012 , the update schedule had slipped seven years due to instability in requirements and funding . In 2014 the USAF moved to cut upgrade funding .

In 2012 the F @-@ 22 was upgraded with a backup oxygen system , software upgrades and oxygen sensors to address the frequent oxygen deprivation issues and normalize operations . In 2013 , the faulty flight vest valves were replaced and altitude restrictions lifted ; distance restrictions will be lifted once a backup oxygen system is installed . In April 2014 the USAF stated in Congressional testimony that installation of automatic backup oxygen systems on the F @-@ 22

fleet would be completed within twelve months .

The F @-@ 22 was designed for a lifespan of 30 years and 8 @,@ 000 flight hours , with a $ 100 million " structures retrofit program " . Investigations are being made for upgrades to extend their useful lives further . In the long term , the F @-@ 22 is expected to be superseded by a sixth @-@ generation jet fighter to be fielded in the 2030s .

= = Design = =

= = = Overview = = =

The F @-@ 22 Raptor is a fifth @-@ generation fighter that is considered fourth generation in stealth aircraft technology by the USAF . It is the first operational aircraft to combine supercruise , supermaneuverability , stealth , and sensor fusion in a single weapons platform . The Raptor has clipped delta wings with a reverse sweep on the rear , four empennage surfaces , and a retractable tricycle landing gear . Flight control surfaces include leading and trailing @-@ edge flaps , ailerons , rudders on the canted vertical stabilizers , and all @-@ moving horizontal tails ; these surfaces also serve as speed brakes .

The aircraft 's dual Pratt & Whitney F119 @-@ PW @-@ 100 afterburning turbofan engines are closely spaced and incorporate pitch @-@ axis thrust vectoring nozzles with a range of ± 20 degrees ; each engine has maximum thrust in the 35 @,@ 000 lbf (156 kN) class . The F @-@ 22 's thrust to weight ratio in typical combat configuration is nearly at unity in maximum military power and 1 @.@ 25 in full afterburner . Maximum speed without external stores is estimated to be Mach 1 @.@ 82 during supercruise and greater than Mach 2 with afterburners .

The F @-@ 22 is among only a few aircraft that can supercruise , or sustain supersonic flight without using fuel @-@ inefficient afterburners ; it can intercept targets which subsonic aircraft would lack the speed to pursue and an afterburner @-@ dependent aircraft would lack the fuel to reach . The Raptor 's high operating altitude is also a significant tactical advantage over prior fighters . The use of internal weapons bays permits the aircraft to maintain comparatively higher performance over most other combat @-@ configured fighters due to a lack of aerodynamic drag from external stores . The F @-@ 22 's structure contains a significant amount of high @-@ strength materials to withstand stress and heat of sustained supersonic flight . Respectively , titanium alloys and composites comprise 39 % and 24 % of the aircraft 's structural weight .

The F @-@ 22 is highly maneuverable at both supersonic and subsonic speeds . Computerized flight control system and full authority digital engine control (FADEC) make the aircraft highly departure resistant and controllable . The Raptor 's relaxed stability and powerful thrust @-@ vectoring engines enable the aircraft to turn tightly and perform very high alpha (angle of attack) maneuvers such as the Herbst maneuver (J @-@ turn) and Pugachev 's Cobra . The aircraft is also capable of maintaining over 60 ° alpha while having some roll control .

The Raptor 's aerodynamic performance , sensor fusion , and stealth work together for increased effectiveness . Altitude , speed , and advanced active and passive sensors allow the aircraft to spot targets at considerable ranges and increase weapons range ; altitude and speed also complement stealth 's ability to increase the aircraft 's survivability against ground defenses such as surface @-@ to @-@ air missiles .

= = = Avionics = = =

Key avionics include BAE Systems EI & S AN / ALR @-@ 94 radar warning receiver (RWR) , Lockheed Martin AN / AAR @-@ 56 infrared and ultraviolet Missile Launch Detector (MLD) and Northrop Grumman AN / APG @-@ 77 active electronically scanned array (AESA) radar . The MLD features six sensors to provide full spherical infrared coverage . The RWR is a passive radar detector with more than 30 antennas blended into the wings and fuselage for all @-@ round coverage . Tom Burbage , former F @-@ 22 program head at Lockheed Martin , described it as "

the most technically complex piece of equipment on the aircraft . " The range of the RWR (250 + nmi) exceeds the radar 's , and can cue radar emissions to be confined to a narrow beam (down to 2 ° by 2 ° in azimuth and elevation) to increase stealth . Depending on the detected threat , the defensive systems can prompt the pilot to release countermeasures such as flares or chaff . According to Bill Sweetman , experts had said the ALR @-@ 94 can be used as a passive detection system capable of searching targets and providing enough information for a radar lock on .

The AN / APG @-@ 77 radar features a low @-@ observable , active @-@ aperture , electronically scanned array that can track multiple targets under any weather conditions . Radar emissions can also be focused to overload enemy sensors as an electronic @-@ attack capability . The radar changes frequencies more than 1 @,@ 000 times per second to lower interception probability and has an estimated range of 125 ? 150 miles , though planned upgrades will allow a range of 250 miles (400 km) or more in narrow beams . Radar information is processed by two Raytheon Common Integrated Processor (CIP) s , each capable of processing up to 10 @.@ 5 billion instructions per second . In a process known as sensor fusion , data from the radar , other sensors , and external systems is filtered and combined by the CIP into a common view , reducing pilot workload . However , upgrading the aircraft 's avionics was reportedly very challenging due to their highly integrated nature .

The F @-@ 22 's ability to operate close to the battlefield gives the aircraft threat detection and identification capability comparative with the RC @-@ 135 Rivet Joint , and the ability to function as a " mini @-@ AWACS " , though the radar is less powerful than those of dedicated platforms . The F @-@ 22 can designate targets for allies , and determine whether two friendly aircraft are targeting the same aircraft . This radar system can sometimes identify targets " many times quicker than the AWACS " . The IEEE 1394B bus developed for the F @-@ 22 was derived from the commercial IEEE 1394 " FireWire " bus system . In 2007 , the F @-@ 22 's radar was tested as a wireless data transceiver , transmitting data at 548 megabits per second and receiving at gigabit speed , far faster than the Link 16 system .

The F @-@ 22 's software has some 1 @.@ 7 million lines of code , the majority involving processing radar data . Former Secretary of the USAF Michael Wynne blamed the use of the DoD 's Ada for cost overruns and delays on many military projects , including the F @-@ 22 . Cyberattacks on subcontractors have reportedly raised doubts about the security of the F @-@ 22 's systems and combat @-@ effectiveness . In 2009 , former Navy Secretary John Lehman considered the F @-@ 22 to be safe from cyberattack , citing the age of its IBM software .

= = = Cockpit = = =

The F @-@ 22 has a glass cockpit with all @-@ digital flight instruments . The monochrome head @-@ up display offers a wide field of view and serves as a primary flight instrument ; information is also displayed upon six color liquid @-@ crystal display (LCD) panels . The primary flight controls are a force @-@ sensitive side @-@ stick controller and a pair of throttles . The USAF initially wanted to implement direct voice input (DVI) controls , but this was judged to be too technically risky and was abandoned . The canopy 's dimensions are approximately 140 inches long , 45 inches wide , and 27 inches tall (355 cm x 115 cm x 69 cm) and weighs 360 pounds .

The F @-@ 22 has integrated radio functionality , the signal processing systems are virtualized rather than as a separate hardware module . There have been several reports on the F @-@ 22 's inability to communicate with other aircraft , and funding cuts have affected the integration of the Multifunction Advanced Data Link (MADL) . Voice communication is possible , but not data transfer .

The integrated control panel (ICP) is a keypad system for entering communications , navigation , and autopilot data . Two 3 in × 4 in (7 @.@ 6 cm × 10 @.@ 2 cm) up @-@ front displays located around the ICP are used to display integrated caution advisory / warning data , communications , navigation and identification (CNI) data and also serve as the stand @-@ by flight instrumentation group and fuel quantity indicator . The stand @-@ by flight group displays an artificial horizon , for basic instrument meteorological conditions . The 8 in × 8 in (20 cm × 20 cm) primary multi @-@

function display (PMFD) is located under the ICP , and is used for navigation and situation assessment . Three 6 @.@ 25 in × 6 @.@ 25 in (15 @.@ 9 cm × 15 @.@ 9 cm) secondary multi @-@ function displays are located around the PMFD for tactical information and stores management .

The ejection seat is a version of the ACES II (Advanced Concept Ejection Seat) commonly used in USAF aircraft , with a center @-@ mounted ejection control . The F @-@ 22 has a complex life support system , which includes the on @-@ board oxygen generation system (OBOGS) , protective pilot garments , and a breathing regulator / anti @-@ g (BRAG) valve controlling flow and pressure to the pilot 's mask and garments . The pilot garments were developed under the Advanced Technology Anti @-@ G Suit (ATAGS) project and are to protect against chemical / biological hazards and cold @-@ water immersion , counter g @-@ forces and low pressure at high altitudes , and provide thermal relief . Suspicions regarding the performance of the OBOGS and life support equipment have been raised by several mishaps , including a fatal crash .

= = = Armament = = =

The Raptor has three internal weapons bays : a large bay on the bottom of the fuselage , and two smaller bays on the sides of the fuselage , aft of the engine intakes . The main bay can accommodate six LAU @-@ 142 / A launchers for beyond @-@ visual @-@ range missiles and each side bay has an LAU @-@ 141 / A launcher for short @-@ range missiles . Four of the launchers in the main bay can be replaced with two bomb racks that can each carry one 1 @,@ 000 lb (450 kg) or four 250 lb (110 kg) bombs . Carrying armaments internally maintains the aircraft 's stealth and minimizes additional drag . Missile launches require the bay doors to be open for less than a second , during which hydraulic arms push missiles clear of the aircraft ; this is to reduce vulnerability to detection and to deploy missiles during high speed flight .

The F @-@ 22 can also carry air @-@ to @-@ surface weapons such as bombs with Joint Direct Attack Munition (JDAM) guidance and the Small @-@ Diameter Bomb , but cannot self @-@ designate for laser @-@ guided weapons . Internal air @-@ to @-@ surface ordnance is limited to 2 @,@ 000 lb . An internally mounted M61A2 Vulcan 20 mm cannon is embedded in the right wing root with the muzzle covered by a retractable door to maintain stealth . The radar projection of the cannon fire 's path is displayed on the pilot 's head @-@ up display .

The F @-@ 22 's high cruise speed and altitude increase the effective ranges of its munitions , it has 50 % greater employment range for the AIM @-@ 120 AMRAAM than prior platforms , and range will be further extended with the introduction of the AIM @-@ 120D . While specifics are classified , it is expected that JDAMs employed by F @-@ 22s will have twice or more the effective range of legacy platforms . In testing , an F @-@ 22 dropped a GBU @-@ 32 JDAM from 50 @,@ 000 feet (15 @,@ 000 m) while cruising at Mach 1 @.@ 5 , striking a moving target 24 miles (39 km) away .

While the F @-@ 22 typically carries weapons internally , the wings include four hardpoints , each rated to handle 5 @,@ 000 lb (2 @,@ 300 kg) . Each hardpoint can accommodate a pylon that can carry a detachable 600 @-@ gallon (2 @,@ 270 L) external fuel tank or a launcher holding two air @-@ to @-@ air missiles ; the two inboard hardpoints are " plumbed " for external fuel tanks . The use of external stores degrades the aircraft 's stealth and kinematic performance ; after releasing stores the external attachments can be jettisoned to restore those characteristics . A stealthy ordnance pod and pylon was being developed to carry additional weapons in the mid @-@ 2000s .

= = = Stealth = = =

The F @-@ 22 was designed to be highly difficult to detect and track by radar . Measures to reduce radar cross @-@ section include airframe shaping such as alignment of edges , fixed @-@ geometry serpentine inlets that prevent line @-@ of @-@ sight of the engine faces from any exterior view , use of radar @-@ absorbent material (RAM) , and attention to detail such as hinges and pilot helmets that could provide a radar return . The F @-@ 22 was also designed to have

decreased radio emissions , infrared signature and acoustic signature as well as reduced visibility to the naked eye . The aircraft 's flat thrust vectoring nozzle reduces infrared emissions to mitigate the threat of infrared homing (" heat seeking ") surface @-@ to @-@ air or air @-@ to @-@ air missiles . Additional measures to reduce the infrared signature include special paint and active cooling of leading edges to manage the heat buildup from supersonic flight .

Compared to previous stealth designs like the F @-@ 117 , the F @-@ 22 is less reliant on RAM , which are maintenance @-@ intensive and susceptible to adverse weather conditions . Unlike the B @-@ 2 , which requires climate @-@ controlled hangars , the F @-@ 22 can undergo repairs on the flight line or in a normal hangar . The F @-@ 22 features a Signature Assessment System which delivers warnings when the radar signature is degraded and necessitates repair . The F @-@ 22 's exact radar cross @-@ section (RCS) is classified ; however , in 2009 Lockheed Martin released information indicating it has an RCS (from certain angles) of ? 40 dBsm ? equivalent to the radar reflection of a " steel marble " . Effectively maintaining the stealth features can decrease the F @-@ 22 's mission capable rate to 62 ? 70 % .

The effectiveness of the stealth characteristics is difficult to gauge . The RCS value is a restrictive measurement of the aircraft 's frontal or side area from the perspective of a static radar . When an aircraft maneuvers it exposes a completely different set of angles and surface area , potentially increasing radar observability . Furthermore , the F @-@ 22 's stealth contouring and radar absorbent materials are chiefly effective against high @-@ frequency radars , usually found on other aircraft . The effects of Rayleigh scattering and resonance mean that low @-@ frequency radars such as weather radars and early @-@ warning radars are more likely to detect the F @-@ 22 due to its physical size . However , such radars are also conspicuous , susceptible to clutter , and have low precision . Additionally , while faint or fleeting radar contacts make defenders aware that a stealth aircraft is present , reliably vectoring interception to attack the aircraft is much more challenging . According to the USAF an F @-@ 22 surprised an Iranian F @-@ 4 Phantom II that was attempting to intercept an American UAV , despite Iran 's claim of having military VHF radar coverage over the Persian Gulf .

= = Operational history = =

= = = Designation and testing = = =

The YF @-@ 22 was originally given the unofficial name " Lightning II " , after the World War II Lockheed P @-@ 38 Lightning fighter , which persisted until the mid @-@ 1990s when the USAF officially named the aircraft " Raptor " . The name " Lightning II " was later given to the F @-@ 35 . The aircraft was also briefly dubbed " SuperStar " and " Rapier " . In September 2002 , USAF changed the Raptor 's designation to F / A @-@ 22 , mimicking the Navy 's McDonnell Douglas F / A @-@ 18 Hornet and intended to highlight a planned ground @-@ attack capability amid debate over the aircraft 's role and relevance . The F @-@ 22 designation was reinstated in December 2005 , when the aircraft entered service .

Flight testing of the F @-@ 22 began in 1997 with Raptor 4001 , the first EMD jet , and eight more F @-@ 22s would participate in the EMD and flight test program . Raptor 4001 was retired from flight testing in 2000 and subsequently sent to Wright @-@ Patterson Air Force Base (AFB) for survivability testing , including live fire testing and battle damage repair training . EMD F @-@ 22s have been used for testing upgrades , and also as maintenance trainers . The first production F @-@ 22 was delivered to Nellis AFB , Nevada , in January 2003 .

In May 2006 , a released report documented a problem with the F @-@ 22 's forward titanium boom , caused by defective heat @-@ treating . This made the boom on roughly the first 80 F @-@ 22s less ductile than specified and potentially shortened the part 's life . Modifications and inspections were implemented to the booms to restore life expectancy .

In August 2008 , an unmodified F @-@ 22 of the 411th Flight Test Squadron performed in the first ever air @-@ to @-@ air refueling of an aircraft using synthetic jet fuel as part of a wider USAF

effort to qualify aircraft to use the fuel , a 50 / 50 mix of JP @-@ 8 and a Fischer ? Tropsch process @-@ produced , natural gas @-@ based fuel . In 2011 , an F @-@ 22 flew supersonic on a 50 % mixture of biofuel derived from camelina .

= = = Introduction into service = = =

In December 2005 , the USAF announced that the F @-@ 22 had achieved Initial Operational Capability (IOC) . During Exercise Northern Edge in Alaska in June 2006 , in simulated combat exercises 12 F @-@ 22s of the 94th FS downed 108 adversaries with no losses . In the exercises , the Raptor @-@ led Blue Force amassed 241 kills against two losses in air @-@ to @-@ air combat , with neither loss being an F @-@ 22 . During Red Flag 07 @-@ 1 in February 2007 , 14 F @-@ 22s of the 94th FS supported Blue Force strikes and undertook close air support sorties . Against superior numbers of Red Force Aggressor F @-@ 15s and F @-@ 16s , 6 ? 8 F @-@ 22s maintained air dominance throughout . No sorties were missed because of maintenance or other failures ; a single F @-@ 22 was judged lost against the defeated opposing force . F @-@ 22s also provided airborne electronic surveillance .

The Raptor achieved Full Operational Capability (FOC) in December 2007 , when General John Corley of Air Combat Command (ACC) officially declared the F @-@ 22s of the integrated active duty 1st Fighter Wing and Virginia Air National Guard 192d Fighter Wing fully operational . This was followed by an Operational Readiness Inspection (ORI) of the integrated wing in April 2008 , in which it was rated " excellent " in all categories , with a simulated kill @-@ ratio of 221 ? 0 .

= = = Deployments = = =

F @-@ 22 fighter units have been frequently deployed to Kadena Air Base in Okinawa , Japan . In February 2007 , on the aircraft 's first overseas deployment to Kadena Air Base , six F @-@ 22s of 27th Fighter Squadron flying from Hickam AFB , Hawaii , experienced multiple software @-@ related system failures while crossing the International Date Line (180th meridian of longitude) . The aircraft returned to Hawaii by following tanker aircraft . Within 48 hours , the error was resolved and the journey resumed . In early 2013 , F @-@ 22s were involved in U.S.-South Korean military drills .

In November 2007 , F @-@ 22s of 90th Fighter Squadron at Elmendorf AFB , Alaska , performed their first NORAD interception of two Russian Tu @-@ 95MS " Bear @-@ H " bombers . Since then , F @-@ 22s have also escorted probing Tu @-@ 160 " Blackjack " bombers . The first pair of F @-@ 22s assigned to the 49th Fighter Wing became operational at Holloman AFB , New Mexico , in June 2008 . In 2014 , Holloman F @-@ 22s and their support personnel were reassigned to the reactivated 95th Fighter Squadron at Tyndall AFB .

Secretary of Defense Gates initially refused to deploy F @-@ 22s to the Middle East in 2007 . The type made its first deployment in the region at Al Dhafra Air Base in the UAE in 2009 . In April 2012 , F @-@ 22s have been rotating into Al Dhafra Air Base , less than 200 miles from Iran ; the Iranian defense minister referred to the deployment as a security threat . In March 2013 the USAF announced that an F @-@ 22 had intercepted an Iranian F @-@ 4 Phantom II that approached within 16 miles of an MQ @-@ 1 Predator flying off the Iranian coastline .

In June 2014 , F @-@ 22s from the 199th Fighter Squadron of the Hawaii Air National Guard were deployed to Malaysia to participate in the Cope Taufan 2014 exercise conducted by the USAF Pacific Air Forces and Royal Malaysian Air Force .

On 22 September 2014 , F @-@ 22s performed the type 's first combat sorties during the American @-@ led intervention in Syria ; a number of aircraft dropped 1 @,@ 000 @-@ pound GPS @-@ guided bombs on Islamic State targets in the vicinity of Tishrin Dam . Combat operations by F @-@ 22s are planned to continue into the foreseeable future . While some missions involve striking targets , the F @-@ 22 's main role is intelligence , surveillance and reconnaissance (ISR) gathering . By January 2015 , the F @-@ 22 accounted for three percent of Air Force sorties during Operation Inherent Resolve . General Mike Hostage of ACC said that it performed " flawlessly "

during this deployment . Between September 2014 and July 2015 , F @-@ 22s flew 204 sorties over Syria , dropping 270 bombs at some 60 locations . On 23 June 2015 , a pair of F @-@ 22s performed the aircraft 's first close air support (CAS) mission after receiving a short @-@ notice request for airstrikes in close proximity to friendly forces .

In late 2014 , the USAF was testing a rapid deployment concept involving four F @-@ 22s and one C @-@ 17 for support , first proposed in 2008 by two F @-@ 22 pilots . The goal was for the type to be able to set up and engage in combat within 24 hours . Four F @-@ 22s were deployed to Spangdahlem Air Base in Germany in August and Lask Air Base in Poland and Amari Air Base in Estonia in September 2015 to train with NATO allies .

= = = Maintenance and training = = =

F @-@ 22 aircraft were available for missions 62 % of the time on average in 2004 and 70 % in 2009 . The rate was at 63 % in 2015 . Early on , the F @-@ 22 required more than 30 hours of maintenance per flight hour and a total cost per flight hour of $ 44 @,@ 000 ; by 2008 it was reduced to 18 @.@ 1 , and 10 @.@ 5 by 2009 ; lower than the Pentagon 's requirement of 12 maintenance hours per flight hour . When introduced , the F @-@ 22 had a Mean Time Between Maintenance (MTBM) of 1 @.@ 7 hours , short of the required 3 @.@ 0 ; in 2012 this rose to 3 @.@ 2 hours . By 2013 , the cost per flight hour was $ 68 @,@ 362 , over three times as much as the F @-@ 16 . In 2014 , the F @-@ 22 fleet required 43 maintenance man @-@ hours per flight hour .

Each aircraft requires a month @-@ long packaged maintenance plan (PMP) every 300 flight hours . The stealth system , including its radar absorbing metallic skin , account for almost one third of maintenance . The canopy was redesigned after the original design lasted an average of 331 hours instead of the required 800 hours . F @-@ 22 depot maintenance is performed at Ogden Air Logistics Complex at Hill AFB , Utah .

In January 2007 , the F @-@ 22 reportedly maintained 97 % sortie rate , flying 102 out of 105 tasked sorties while amassing a 144 @-@ to @-@ zero kill ratio during " Northern Edge " air @-@ to @-@ air exercises in Alaska . According to Lieutenant Colonel Wade Tolliver , squadron commander of the 27th Fighter Squadron , the stealth coatings of the F @-@ 22 are more robust than those used in earlier stealth aircraft , being less sensitive to weather and wear and tear . However , rain caused " shorts and failures in sophisticated electrical components " when F @-@ 22s were posted to Guam .

To reduce operating costs and lengthen the F @-@ 22 's service life , some pilot training sorties are performed using flight simulators , while the T @-@ 38 Talon is used for adversary training . DoD budget cuts led to F @-@ 22 demonstration flights being halted in 2013 before resuming in 2014 . In 2012 , it was reported that the F @-@ 22 's maintenance demands have increased as the fleet aged , the stealth coatings being particularly demanding .

= = = = Operational problems = = = =

Operational problems have been experienced and some have caused fleet @-@ wide groundings . Critically , pilots have experienced a decreased mental status , including losing consciousness . There were reports of instances of pilots found to have a decreased level of alertness or memory loss after landing . F @-@ 22 pilots have experienced lingering respiratory problems and a chronic cough ; other symptoms include irritability , emotional lability and neurological changes . A number of possible causes were investigated , including possible exposure to noxious chemical agents from the respiratory tubing , pressure suit malfunction , side effects from oxygen delivery at greater @-@ than @-@ atmospheric concentrations , and oxygen supply disruptions . Other problems include minor mechanical problems and navigational software failures . The fleet was grounded for four months in 2011 before resuming flight , but reports of oxygen issues persisted .

In 2005 , the Raptor Aeromedical Working Group , a USAF expert panel , recommended several changes to deal with the oxygen supply issues . In October 2011 , Lockheed Martin was awarded a

$ 24M contract to investigate the breathing difficulties . In July 2012 , the Pentagon concluded that a pressure valve on flight vests worn during high @-@ altitude flights and a carbon air filter were likely sources of at least some hypoxia @-@ like symptoms . Long @-@ distance flights were resumed , but were limited to lower altitudes until corrections had been made . The carbon filters were changed to a different model to reduce lung exposure to carbon particulates . The breathing regulator / anti @-@ g (BRAG) valve , used to inflate the pilot 's vest during high G maneuvers , was found to be defective , inflating the vest at unintended intervals and restricting the pilot 's breathing . The on @-@ board oxygen generating system (OBOGS) also unexpectedly reduced oxygen levels during high @-@ G maneuvers . In late 2012 , Lockheed Martin was awarded contracts to install a supplemental automatic oxygen backup system , in addition to the primary and manual backup . Changes recommended by the Raptor Aeromedical Working Group in 2005 received further consideration in 2012 ; the USAF reportedly considered installing EEG brain wave monitors on the pilot 's helmets for inflight monitoring .

New backup oxygen generators and filters have been installed on the aircraft . The coughing symptoms have been attributed to acceleration atelectasis , which may be exacerbated by the F @-@ 22 's high performance ; there is no present solution to the condition . The presence of toxins and particles in some ground crew was deemed to be unrelated . On 4 April 2013 , the distance and altitude flight restrictions were lifted after the F @-@ 22 Combined Test Force and 412th Aerospace Medicine Squadron determined that breathing restrictions on the pilot were responsible as opposed to an issue with the oxygen provided .

= = Variants = =

YF @-@ 22A ? pre @-@ production technology demonstrator for ATF demonstration / validation phase ; two were built .

F @-@ 22A ? single @-@ seat production version , was designated F / A @-@ 22A in early 2000s .

F @-@ 22B ? planned two @-@ seat variant , but was canceled in 1996 to save development costs .

Naval F @-@ 22 variant ? a carrier @-@ borne variant of the F @-@ 22 with variable @-@ sweep wings for the U.S. Navy 's Navy Advanced Tactical Fighter (NATF) program to replace the F @-@ 14 Tomcat . Program was canceled in 1993 . Former SoAF Donald Rice has called the possibility of the naval variant the deciding factor for his choice of the YF @-@ 22 over the YF @-@ 23 .

= = = Derivatives = = =

The FB @-@ 22 was a proposed medium @-@ range bomber for the USAF . The FB @-@ 22 was projected to carry up to 30 Small Diameter Bombs to about twice the range of the F @-@ 22A , while maintaining the F @-@ 22 's stealth and supersonic speed . However , the FB @-@ 22 in its planned form appears to have been canceled with the 2006 Quadrennial Defense Review and subsequent developments , in lieu of a larger subsonic bomber with a much greater range .

The X @-@ 44 MANTA , or multi @-@ axis , no @-@ tail aircraft , was a planned experimental aircraft based on the F @-@ 22 with enhanced thrust vectoring controls and no aerodynamic surface backup . The aircraft was to be solely controlled by thrust vectoring , without featuring any rudders , ailerons , or elevators . Funding for this program was halted in 2000 .

= = Operators = =

United States

United States Air Force

The U.S. Air Force is the only operator of the F @-@ 22 . It ordered 8 test and 187 operational production aircraft . In November 2012 , it had 184 production aircraft in inventory .

Air Combat Command

1st Fighter Wing - Langley Air Force Base , Virginia
27th Fighter Squadron ? The first combat F @-@ 22 squadron . Began conversion in December 2005 .
94th Fighter Squadron
53d Wing - Tyndall Air Force Base , Florida
422d Test and Evaluation Squadron (Nellis Air Force Base , Nevada)
57th Wing - Nellis AFB , Nevada
433d Weapons Squadron
325th Fighter Wing - Tyndall AFB , Florida
43d Fighter Squadron ? First squadron to operate the F @-@ 22 and continues to serve as the Formal Training Unit .
95th Fighter Squadron
Air Force Materiel Command
412th Test Wing - Edwards Air Force Base , California
411th Flight Test Squadron
Pacific Air Forces
3d Wing - Elmendorf Air Force Base , Alaska
90th Fighter Squadron
525th Fighter Squadron
15th Wing - Hickam Air Force Base , Hawaii
19th Fighter Squadron ? Active Associate squadron to the 199th Fighter Squadron (Hawaii Air National Guard) .
Air National Guard
192d Fighter Wing (Associate) - Langley AFB , Virginia
149th Fighter Squadron
154th Wing - Hickam Air Force Base , Hawaii
199th Fighter Squadron
325th Fighter Wing Associate Unit (also known as Florida Air National Guard Headquarters Detachment 1) - Tyndall AFB , Florida
Associate ANG unit to 325th Fighter Wing (Air Combat Command)
Air Force Reserve Command
44th Fighter Group (Associate) - Tyndall AFB , Florida
301st Fighter Squadron
477th Fighter Group (Associate) - Elmendorf AFB , Alaska
302d Fighter Squadron

= = Accidents = =

In April 1992 , the second YF @-@ 22 crashed while landing at Edwards AFB . The test pilot , Tom Morgenfeld , escaped without injury . The cause of the crash was found to be a flight control software error that failed to prevent a pilot @-@ induced oscillation .
The first F @-@ 22 crash occurred during takeoff at Nellis AFB on 20 December 2004 , in which the pilot ejected safely before impact . The investigation revealed that a brief interruption in power during an engine shutdown prior to flight caused a flight @-@ control system malfunction ; consequently the aircraft design was corrected to avoid the problem . Following a brief grounding , F @-@ 22 operations resumed after a review .
On 25 March 2009 , an EMD F @-@ 22 crashed 35 miles (56 km) northeast of Edwards AFB during a test flight , resulting in the death of Lockheed Martin test pilot David P. Cooley . An Air Force Materiel Command investigation found that Cooley momentarily lost consciousness during a high @-@ G maneuver , then ejected when he found himself too low to recover . Cooley was killed during ejection by blunt @-@ force trauma from windblast due to the aircraft 's speed . The investigation found no design issues .
On 16 November 2010 , an F @-@ 22 from Elmendorf AFB crashed , killing the pilot , Captain

Jeffrey Haney . F @-@ 22s were restricted to flying below 25 @,@ 000 feet , then grounded during the investigation . The crash was attributed to a bleed air system malfunction after an engine overheat condition was detected , shutting down the Environmental Control System (ECS) and OBOGS . The accident review board ruled Haney was to blame , as he did not react properly and did not engage the emergency oxygen system . Haney 's widow sued Lockheed Martin , claiming equipment defects . She later reached a settlement . After the ruling , the engagement handle of the emergency oxygen system was redesigned ; the system should engage automatically if OBOGS shuts down due to engine failure . On 11 February 2013 , the DoD 's Inspector General released a report stating that the USAF had erred in blaming Haney , and that facts did not sufficiently support conclusions ; the USAF stated that it stood by the ruling .

During a training mission , an F @-@ 22 crashed to the east of Tyndall AFB , on 15 November 2012 . The pilot ejected safely and no injuries were reported on the ground . The investigation determined that a " chafed " electrical wire ignited the fluid in a hydraulic line , causing a fire that damaged the flight controls .

= = Aircraft on display = =

EMD F @-@ 22A 91 @-@ 4003 is on display at the National Museum of the United States Air Force .

= = Specifications (F @-@ 22A) = =

Data from USAF , F @-@ 22 Raptor Team web site , manufacturers ' data , Aviation Week , and Journal of Electronic Defense ,

General characteristics

Crew : 1

Length : 62 ft 1 in (18 @.@ 92 m)

Wingspan : 44 ft 6 in (13 @.@ 56 m)

Height : 16 ft 8 in (5 @.@ 08 m)

Wing area : 840 ft ² (78 @.@ 04 m ²)

Airfoil : NACA 64A ? 05 @.@ 92 root , NACA 64A ? 04 @.@ 29 tip

Empty weight : 43 @,@ 340 lb (19 @,@ 700 kg)

Loaded weight : 64 @,@ 840 lb (29 @,@ 410 kg)

Max. takeoff weight : 83 @,@ 500 lb (38 @,@ 000 kg)

Powerplant : 2 × Pratt & Whitney F119 @-@ PW @-@ 100 pitch thrust vectoring turbofans

Dry thrust : 26 @,@ 000 lb (116 kN) each

Thrust with afterburner : 35 @,@ 000 + lb (156 + kN) each

Fuel capacity : 18 @,@ 000 lb (8 @,@ 200 kg) internally , or 26 @,@ 000 lb (12 @,@ 000 kg) with two external fuel tanks

Performance

Maximum speed : At altitude : Mach 2 @.@ 25 (1 @,@ 500 mph , 2 @,@ 410 km / h) [estimated]

Supercruise : Mach 1 @.@ 82 (1 @,@ 220 mph , 1 @,@ 960 km / h)

Range : > 1 @,@ 600 nmi (1 @,@ 840 mi , 2 @,@ 960 km) with 2 external fuel tanks

Combat radius : 460 nmi (with 100 nmi in supercruise clean) (529 mi , 852 km)

Ferry range : 1 @,@ 740 nmi (2 @,@ 000 mi , 3 @,@ 220 km)

Service ceiling : > 65 @,@ 000 ft (20 @,@ 000 m)

Wing loading : 77 @.@ 2 lb / ft ² (377 kg / m ²)

Thrust / weight : 1 @.@ 08

Maximum design g @-@ load : + 9 @.@ 0 / ? 3 @.@ 0 g

Armament

Guns : 1 × 20 mm (0 @.@ 787 in) M61A2 Vulcan 6 @-@ barrel Gatling cannon in right wing root , 480 rounds

Air to air mission loadout :
6 × AIM @-@ 120 AMRAAM
2 × AIM @-@ 9 Sidewinder
Air to ground mission loadout :
2 × 1 @,@ 000 lb (450 kg) JDAM or 8 × 250 lb (110 kg) GBU @-@ 39 Small Diameter Bombs
2 × AIM @-@ 120 AMRAAM
2 × AIM @-@ 9 Sidewinder
Hardpoints : 4 × under @-@ wing pylon stations can be fitted to carry 600 U.S. gallon drop tanks or weapons , each with a capacity of 5 @,@ 000 lb (2 @,@ 270 kg) .
Avionics
AN / APG @-@ 77 radar : 125 ? 150 miles (200 ? 240 km) against 1 m2 (11 sq ft) targets (estimated range)
AN / AAR @-@ 56 Missile Launch Detector (MLD)
AN / ALR @-@ 94 radar warning receiver (RWR) : 250 nmi (463 km) or more detection range
MJU @-@ 39 / 40 flares for protection against IR missiles

= = Notable appearances in media = =