

## F-22 RAPTOR (ATF)



### Air Force ACAT ID Program

Total Number of Systems:	339
Total Program Cost (TY\$):	\$62.5B
Average Flyaway Cost (TY\$):	\$97.9M
Full-rate production:	3QFY03

### Prime Contractor

Lockheed Martin, Boeing, Pratt & Whitney

### SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2010

The F-22 is an air superiority fighter designed to dominate the air environment in the 21st Century. Key features include low radar observability (with internal weapons carriage) and supersonic cruise combined with the classic fighter characteristics of superior maneuverability, wide field-of-regard offensive and defensive sensors, multi-spectral countermeasures, and high reliability.

Basic armament of the F-22 will consist of six AIM-120C missiles, two AIM-9 missiles, and a 20mm cannon. F-22 will be a major contributor to the *Joint Vision 2010* future strategy. It is to be a predominant Air Force weapon system to provide *full-dimensional protection* to all forces, and its stealth, integrated offensive and defensive sensors, and air-to-air and air-to-ground weapons mix are to effectively support *precision engagement* and *dominant maneuver*.

## **BACKGROUND INFORMATION**

F-22 completed Milestone II DAB and entered the EMD phase in July 1991. Since then, the program has undergone several major changes due to budget reductions and cost growth. An independent Joint Estimating Team identified significant cost growth in the EMD phase and recommended restructuring EMD. This program restructure was approved by a February 5, 1997 DAB. A primary element of this restructure was elimination of the four Pre-Production Vehicles. The essential OT&E impact of this change was the assignment of four aircraft (4008-4011) and one spare aircraft (4007) during four ship operations. Aircraft 4010 and 4011 are Production Representative Test Vehicles (PRTV 1) and are the performance baseline for OT test aircraft. This program restructure also increased the length of the EMD phase by nine months, allowing more time for integrated avionics testing. Dedicated IOT&E is currently scheduled to begin in August 2002, with Milestone III scheduled for September 2003.

The F-22 was placed under OSD oversight for LFT&E in October 1989 as the Advanced Tactical Fighter. An Alternative Plan for meeting LFT&E objectives was approved, and a waiver from full-up, system level testing was granted with notification to Congress in August 1997. The alternate live fire test (LFT) plan includes hydrodynamic ram, dry bay fire, and critical component separation tests as well as demonstration of active fire suppression systems. LFT in prior years has included hydrodynamic ram vulnerability testing of wing box and aft fuel tanks, fire vulnerability testing of wing attach, aft side of fuselage, main landing gear (MLG), and airframe mounted accessory drive (AMAD) dry bays, and penetration vulnerability testing of avionics bays. In addition, high explosive threat effect tests were performed to evaluate component separation adequacy.

## **TEST & EVALUATION ACTIVITY**

The first flight of the EMD flight test program occurred on September 7, 1997 at Lockheed Martin, Marietta, GA. After being transported from Marietta, the first test aircraft resumed test flights at Edwards AFB on May 17, 1998. The second flight test aircraft's first flight was on June 29, 1998; and its ferry to Edwards AFB occurred on August 26, 1998. Both aircraft are continuing to expand the allowable flight envelope and have accumulated 392.4 hours as of the end of FY99. The third flight test aircraft's first flight is planned for March 2000, and the fourth flight test aircraft (the first capable of avionics testing) is scheduled to fly in May 2000.

DOT&E's activities this year continued to support test planning outlined in the August 1997 F-22 TEMP. Toward this end, DOT&E participated in integrated product team (IPT) meetings of the Test Planning Working Group, Air Combat Simulator (ACS) management reviews, and Working Level IPT meetings. Additional program insight was provided by an OSD Action Officers visit to Edwards AFB. Review of the TEMP update for final approval has provided insight into the test plans for the remainder of EMD.

Development of ACS, consisting of two domes and ten manned interactive cockpit stations at Marietta, GA, continued in the system development stage. A \$5.7 million budget reduction in March 1998 forced substitution of a Commercial-off-the-Shelf computer to host F-22 mission software instead of the original plan to host the mission software portion of the aircraft's operational flight program on the Central Integrated Processor flight hardware in ACS. Restructuring ACS to accommodate this change has occurred with IOC to support IOT&E scheduled for October 2001. DOT&E reviewed ACS development plans periodically during this fiscal year to ensure that test adequacy is not being compromised by strong cost reduction pressures.

LFT&E activities in 1999 have focused on analysis of test results for MLG and AMAD dry bays. Test planning and pre-test evaluation was also performed for upcoming tests of a replica of the fuselage fuel tank, scheduled for FY00, and the air vehicle 4001 wing, scheduled for FY02. The Air Force conducted hydrodynamic ram analyses of the fuselage fuel tank to identify appropriate shotlines. A shotline was selected which will provide data to evaluate fuselage fuel tank hydrodynamic ram damage and its affect on safe operation of the crew escape system. Analyses were also conducted in support of LFT&E to assist shotline selection for the upcoming wing hydrodynamic ram test. A shotline was selected for which detailed wing hydrodynamic ram damage analyses will be conducted to predict results of the test to be performed on air vehicle 4001.

A Flying Test Bed (FTB), consisting of a APG-77 radar in an F-22 forebody, spliced onto the nose of a Boeing 757 test aircraft, completed the radar phase of testing this year. APG-77 performance in FTB confirmed the adequacy of the basic radar design. The Director and staff observed this performance in a demonstration flight on April 27, 1999. FTB was modified to install a sensor wing (containing some of the F-22 sensors and wing antennas) on top of the fuselage for resumption of expanded testing emphasizing integration of radar and some Communication, Navigation, and Identification sensors. Testing of this next step in the integrated avionics evolution should resume in November 1999.

Software development testing is proceeding in the Avionics Integration Laboratory in Boeing's Seattle facility. Software Block 1.1 development has been completed and delivered to FTB. This will be the software for the first avionics test aircraft. Block 2.0 software was delivered to FTB on October 21, 1999.

The static test aircraft has completed the first increment critical loads tests to 100 percent of the design load limit without any problems and will progress to 150 percent of design limit load limit in FY00. The fatigue test article has been calibrated and testing of the first lifetime is scheduled to start in June 2000.

In addition to flight testing at Edwards AFB, logistics testing tasks including initial low observability maintainability tasks are ongoing using low observable test articles and exercising aircraft access doors. The basic F-22 design has some good improvements in terms of minimizing the number of access doors in their design. High reliability is also essential to minimizing access requirements and the attendant low observable restoration procedures. The brush and roll repair process has been developed and should reduce repair risk. The concept for low observable sustainment and how to test it is an issue yet to be addressed. Although new materials and techniques have been developed, the plan does not include demonstrating the ability to sustain operations in adverse conditions. In addition, operational field measurement capability has not been fully addressed; plans are to rely solely on maintainer adherence to technical data.

## **TEST & EVALUATION ASSESSMENT**

The F-22 flight test program is progressing about as expected, and flight and engine performance is matching simulation projections. While flight testing is progressing satisfactorily, the major risks and challenges to F-22 performance remain in the avionics area. No operational tests have been conducted, but IOT&E planning reflects the TEMP's integrated test approach of evaluating F-22's operational effectiveness and suitability through a combination of open air testing, ACS, Hardware-in-the-Loop (HITL), and constructive models. This balanced approach will support the F-22/F-15 Comparison Test against then-current and future threats and scenarios for which the F-22 was developed. Credible

simulation tools are mandatory to supplement evaluation data from 240 test sorties allocated for Dedicated IOT&E and some Combined DT/OT sorties. Critical HITL simulation facilities, in addition to ACS, include the Avionics Integration Laboratory in Seattle, WA; the Electronic Combat Integrated Test and the Integrated HITL Avionics Test facilities at Edwards AFB; and the Flying Test Bed. Sustaining funding for these facilities is essential to the overall F-22 test program. Planning for selection and verification, validation, and accreditation of constructive models to assist in test planning and providing evaluation data beyond that which can be supplied by ACS or open air tests is in process. This planning follows Simulation Test and Evaluation Process guidelines.

An IOT&E test planning concern is that about 20 avionics test months have been lost due to late deliveries of flight test aircraft 4004–4007, without any plans to delay the start of Dedicated IOT&E. Although continuing re-planning of the flight test program has shown that this revised test program may be executable, no risk margin remains to accommodate any significant development problems that may surface during the remaining test period.

AFOTEC has initiated a five-year OA with periodic reports based on a structured strategy-to-task assessment of all F-22 mission tasks. The first interim briefing supports the December 1999 DAE review with a plan to issue a report to support the December 2000 LRIP DAB and Readiness to Test Certification in August 2002. To date, good accessibility to AFOTEC regarding program information allowed extensive integration with developmental test and early involvement with aircraft design. AFOTEC identified both positive highlights and potential issues during the interim briefing of operational assessment results. The current results were based on bench, lab, and flying test bed data, which supplemented flight test data and extensive participation on the integrated product teams. Performance concerns included: risk to avionics integration progress, development of low observable maintenance concept of operations, flight envelope expansion considerations related to structural adequacy analysis, ground handling, cockpit design, security issues, possible operational training constraints, and future performance of the environmental control system. Test and evaluation concerns included: data processing timeline and data display capability for the primary test organization, degree and consistency of production representation among the operational test aircraft (4007-4011), ACS development risk due to threat model delivery by outside agencies and validation, verification and accreditation data prioritization during developmental test, and adequacy of instrumentation of PRTV II aircraft (4012-4017) for FOT&E and FDE events. Due to the success of the combined test force concept, the program is aware of the potential problems and actively working all of these issues within the constraints of the resources available to them.

Low observable maintainability is a risk area based on B-2 and F-117 experience; this risk category also includes reliability and logistics support. The contractor appears to have learned many support lessons from previous stealth systems; however, maintainability and logistics support typically lag airframe development and, in a cost cap environment, may have difficulty in retaining budget to complete their tasks.

Based on observation of LFT&E dry bay tests, DOT&E's preliminary assessment is that both MLG and AMAD bays contain significant vulnerabilities. Preliminary data also showed that fire suppression systems could be developed using either pentafluoroethane (HFC-125) or solid propellant gas generating technologies. However, a program decision was made by the Air Force to eliminate development of fire extinguishing systems for MLG bay. Fire extinguishing was not in the original AMAD bay design. DOT&E recommends the Air Force reconsider elimination of the fire suppression system for MLG bay and consider adding AMAD bay fire protection.

Early LFT&E of wing hydrodynamic ram effects resulted in redesign that will be tested using flight test air vehicle 4001. Changes to the wing design included addition of titanium wing spars, an extra wing rib, and extra wing skin fasteners. If successfully demonstrated, the wing redesign will have significantly decreased F-22 vulnerability.

## **CONCLUSIONS, RECOMMENDATIONS, LESSONS LEARNED**

LFT&E results thus far have shown that dry bay fires do occur but are not predicted well by current modeling and simulation. Additional modeling and simulation effort is required to develop an adequate methodology for predicting dry bay fires, taking into account all independent variables.

The original LFT&E strategy called for manufacturing a production representative wing for the hydrodynamic ram test. The Air Force has decided to use flight test air vehicle 4001 for this test as a more economical alternative. Using the flight test vehicle, in addition to economic savings, will provide a more realistic test article. This use of early flight test vehicles for some LFT&E issues should be an option considered in future programs.

