

**Statement by
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AirLand Forces Subcommittee**

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INTRODUCTION

Mr. Chairman, members of the Subcommittee, I appreciate the opportunity to appear before you to discuss the testing and evaluation for the F-22 program. This is my first appearance before this subcommittee but the fourth appearance for the office of the Director of Operational Test And Evaluation (DOT&E). I very much appreciate your commitment to demonstrated performance through realistic test and evaluation. This commitment has been expressed in your statements and comments at these hearings. I look forward to bringing you up to date on the status of the F-22 test program.

The F-22 Raptor continues in the Engineering and Manufacturing Development (EMD) phase and has completed 1,224 hours of flight test as of the end of June 2001. This is approximately 600 hours more than when the Director testified last year. However, previous Air Force plans for increased test efficiency have not been achieved and the number of flight test points flown per hour remains virtually the same as last year. The bulk of and more difficult testing remains to validate major F-22 design characteristics including stealth, integrated avionics, weapons integration, improved logistics, and flight sciences addressing performance and handling qualities. The live fire testing has progressed well but some critical tests still remain. The details of test status and performance will be discussed in these six areas.

The F-22 program had planned on a Low Rate Initial Production (LRIP) decision in December 1999. However, the program did not accomplish all required LRIP exit criteria prior to the anticipated December 2000 Defense Acquisition Board (DAB) due to late deliveries of test aircraft and numerous delays due to modifications to these aircraft. Subsequently, the program completed all DAB exit criteria by February 2001.

As the Director of Operational Test and Evaluation testified last year, the principal issue with the test program is the slow pace resulting in slipping schedules and little information with which to assess performance. Since the March 2000 DOT&E testimony, the number of aircraft test months lost has increased from 49 to 61. Many of the problems highlighted in last year's testimony still remain to be corrected including brakes, main landing gear struts, and issues associated with cockpit design, including lighting and canopy reflection issues. As these issues linger and others emerge, the bulk of the difficult testing remains to be completed. This makes it

difficult to flight test, fix, and retest. Since the Director's March 2000 testimony, three of the planned five aircraft have been delivered and begun flight test at Edwards AFB. The program has made some progress with the five total aircraft on station at Edwards. However, as the Director advised Congress in the beginning of this calendar year, and as he predicted in last year's testimony, the number of aircraft months available prior to the start of the planned August 2002 Initial Operational Test and Evaluation (IOT&E) were far too few for the task of an adequate developmental test. The Director's January 2001 correspondence to the defense subcommittees supported relief of the F-22 EMD cap by the suggested 1.5 percent but also stated that, in his opinion, the total time necessary to complete an adequate DT&E would be nine to 12 months beyond the planned IOT&E start date of August 2002.

Since January of this year, the Air Force has conducted an "executability review" of the planned developmental test. The intent was to tailor the developmental test plan to stay within the schedule dictated by the EMD cap with the additional 1.5 percent relief, which equated to a planned start of IOT&E in December 2002. As a result, the Air Force reduced the number of F-22 avionics flight test hours from 1,970 to 1,530, albeit a reduction in hours largely achieved through increasing concurrency in tests. Although some test planning efficiencies have been realized through this review, the bottom line remains the same--more time is needed, at least another eight months beyond December 2002 before IOT&E can begin. The Air Force recently agreed to establish April 2003 as objective and August 2003 as threshold dates for beginning IOT&E, which will require further relief in the EMD cost cap. I support this in concept but caution that cap relief alone is not enough. Flexibility in schedule must re-orient the program to an emphasis on content. An adequate test program is one that enables us to understand the weapons system and uncover significant development problems in time to correct them for operational test and production.

OPERATIONAL ASSESSMENT

In the 1991 F-22 Milestone II, the Defense Acquisition Board directed the Air Force Operational Test and Evaluation Center (AFOTEC) to provide an Operational Assessment (OA) to support the LRIP decision. The OA began in January 1998 and finished in December 2000. In last year's testimony, the Director summarized the OA conducted at the direction of the Defense Acquisition Executive. AFOTEC will perform another OA to support the certification

for readiness to enter the IOT&E. The most recent OA reported many of the same issues from the previous year's report and acknowledged that testing is still immature, making it not yet possible to conclude definitive operational impacts. Recurring issues with operational implications are main landing gear strut settling, environmental control system problems, intra-flight data link shortfalls, and missile launch detect performance. However, this most recent OA highlighted the aircraft brake and hook design difficulties as creating the potential for the F-22 to be forced to operate from longer airfields. Additionally, the amount of support equipment that will be necessary to maintain stealth characteristics may affect the mobility support requirements for the weapons system. Another key suitability issue highlighted in the assessment is the need to develop interfaces from the F-22 integrated maintenance information system to a logistics data support system that will be available for the F-22 IOT&E and initial beddown. Late development of the planned interfaces may not support operational test and fielding of the F-22.

FLIGHT SCIENCES

Evaluation of the F-22's performance and flying qualities has been a predominant part of the flight test program to date. Performance has generally been meeting expectations with supercruise Mach number exceeding the operational requirement. Flying qualities of the F-22 are generally assessed as excellent throughout the flight envelope explored thus far. However, a moderate uncommanded roll-off has been encountered at one transonic Mach number/angle of attack combination and the aircraft has demonstrated a tendency to "dig-in" during maneuvering in the transonic region creating overshoots in both angle of attack and g-loading. Flying qualities in the takeoff and landing configuration are judged to be outstanding with aircraft handling qualities during in-flight refueling rated as excellent. Flying qualities at both high positive as well as negative angles of attack (including with weapon's bay doors open) are superior to operational aircraft, primarily due to the advanced digital flight control system and vectored engine thrust capability of the F-22.

Recent Air Force re-planning initiatives have reduced the number of flight test points by about 25 percent. While it is not yet finalized, the plan defers content, leverages concurrency, and with the user's concurrence, deletes test points. Until we see the final plans and schedule for flight test point accomplishment, we cannot fully assess its impact on readiness for IOT&E.

To date, more test points have been flown to evaluate F-22 flying qualities than all other test disciplines combined. This has provided a sound basis for the flight test pilots' assessment that not only is the F-22 easy to fly but also that it will be very difficult for a pilot to enter uncontrolled flight, or an unintentional spin mode. Flying qualities testing that remains to be completed is primarily associated with expanding the flight envelope into areas that have not yet been cleared for flight testing, such as high g/high roll rate maneuvering, the high-speed/low-altitude flight regime, and testing with external stores and weapons.

Expansion of the flight test operating envelope, however, is totally dependent on the availability of a fully instrumented and structurally modified test aircraft. The availability of only one aircraft with the Block II configuration (Aircraft 4003) to complete essentially all of the flight sciences testing, including structural, performance, propulsion, and flying qualities, is a significant test schedule risk. This seriously impacts the possibility of significantly accelerating F-22 testing in the performance and flying qualities area and more rapidly expanding the allowable flight envelope prior to the scheduled April 2003 start of IOT&E. This is an extremely high-risk situation both in terms of the large number of test points yet to be completed and the severe impact of unexpected problems that might ground the aircraft for an extended period. Although it is difficult to predict problem areas, vertical fin buffet that might require a redesign, speed brake use causing control surface failures, and the nose roll-off at a moderate angle of attack are known potential problem areas. Even if problems are not encountered in expanding the allowable flight envelope into more challenging parts of the envelope, the test point production efficiency must significantly improve relative to past performance in order to clear the required flight envelope prior to the start of IOT&E.

Without augmentation of Aircraft 4003 with another flight test asset, our assessment is that the completion of the required testing to provide an adequate flight envelope to start IOT&E at the threshold start date of August 2003 is high risk. This date can only be achieved if Aircraft 4003 significantly improves its test point production efficiency and consistently avoids even moderate airframe and engine problems for the next two years.

F119 Engine Testing

F119 engine testing remains on schedule to support the flight test program through the end of EMD. The LRIP DAB Exit Criterion "Complete first portion of engine Initial Service Release (ISR) qualification test" was completed in November 2000 and the complete ISR

qualification test was done by early May 2001. This represented the equivalent of about six years of operational service engine life and successfully demonstrated the full hot section service life requirement in the engine specification. Modifications to correct some minor mechanical problems that were encountered during ISR testing are being incorporated into the production version of the F119 engine. To date, there has not been an engine-related shutdown in the test program although occasional anomalies have been encountered with the Airframe-Mounted Accessory Drive. The very good engine performance demonstrated in ground and flight test, as well as the history of nearly on-schedule engine deliveries to date, indicate that F119 engine availability for the aircraft that are dedicated for use in the IOT&E program is relatively low risk.

Structural Testing

The current structural test plan represents a two-year slip from the plan recommended by the Joint Estimating Team in 1999. Full-scale static testing began in April 1999. Testing was successfully completed to 150 percent of F-22 design limit load in June 2001. The remaining local structure static test cases are due to be completed by September of this year.

Fatigue testing started in late December 2000. The LRIP DAB Exit Criterion, established in December 1999, was the initiation of fatigue testing with a goal of 40 percent of first life complete by the end of calendar year 2000. This goal was not met and as of June 2001, only about 16 percent of the first fatigue life test had been completed.

AVIONICS

The F-22 flight test fleet will eventually include six aircraft equipped with a fully integrated avionics suite to support the planned avionics flight test effort. F-22 avionics subsystems, including the active element electronically-scanned Northrop Grumman APG-77 radar; Communications, Navigation and Identification (CNI); Electronic Warfare (EW); and weapons delivery functions are integrated through two Common Integrated Processors (CIPs) to provide the pilot with a sensor fusion combat capability. Development of the complex mission software to provide this integrated situation awareness capability is a major challenge. Avionics systems flight test has not progressed as far as was expected or planned due to delays in hardware and software and late delivery of avionics test aircraft to the Combined Test Force (CTF) at Edwards AFB. This limited Block 3.0 software testing on Aircraft 4005 this year.

The Air Force's executability review resulted in selecting an avionics test plan with approximately half of the number of runs as previously envisioned. The Air Force has stated that it intends to maintain the same content as the original 1,970-hour plan in the new program which will total 1,530 hours if all efficiency and anomaly resolution planning factors are realized. Although there is moderate risk in completing this revised avionics test plan, the revised plan should support readiness for IOT&E.

The Flying Testbed (FTB) consists of the Boeing 757 airliner prototype as modified to support the F-22 program. The aircraft has been altered to add the F-22 integrated forebody and Northrop Grumman APG-77 radar in the nose, as well as winglets above the cockpit containing CNI and EW antennas. Missile Launch Detector system sensors are installed in the FTB enabling their performance to be evaluated against various infrared sources. A simulated cockpit (from which the sensors are operated) and separate diagnostic display terminals are installed for use by developmental test engineers. Two common integrated processors, actual F-22 aircraft sensors, and controls and displays hardware are installed in as realistic an F-22 simulated configuration as is possible. Developmental software releases are installed and evaluated to assist in development of the mission avionics software prior to installation and flight test in actual F-22 aircraft. This provides a credible flying laboratory to evaluate avionics performance and assist in software development. The FTB has proven to be very useful in troubleshooting radar, CIP, display, and sensor problems. By early June 2001, the FTB had flown over 650 hours in support of the F-22 avionics development effort.

Section 8124 of the *DoD Appropriations Act, 2001* requires the first flight of an F-22 aircraft incorporating Block 3.0 software be conducted before a full funding contract for F-22 LRIP may be awarded. In its planning, the Air Force accelerated the need date for this interim block of mission avionics software from April 2001 to December 2000 in order to meet this exit criterion. Through the Working Integrated Product Team (WIPT) process, with both the Air Force and the Office of the Secretary of Defense involved, several lower priority avionics functions were deferred from Block 3.0 to subsequent incremental software block releases in order to meet the new need date. Avionics functions deferred from Block 3.0 avionics until later in the test program included some aspects of sensor management/sensor track fusion, electronic warfare, and CNI, along with some built-in-test and housekeeping functions. However, the Block 3.0 software, as flown on January 5, 2001, in Aircraft 4005, allows fused integrated

operations of most radar, CNI, and EW functions sufficient to detect, track, identify, and shoot AIM-120 and AIM-9M missiles. This software block has been extensively tested in the FTB.

Three additional software blocks are planned to be developed and integrated into the flight test aircraft and evaluated prior to the start of IOT&E. These are Blocks 3.1.0, 3.1.1, and 3.1.2. Block 3.1.0 software is in developmental testing and will soon be installed in the FTB. This software block will be installed in flight test aircraft during 2002 and will include most of the functions previously deferred from Block 3.0. Block 3.1.1 software will add additional functions with Block 3.1.2 being the final baseline that will be used during IOT&E to demonstrate fused integrated operations of all radar, CNI, and EW functions. Block 3.1.1 will begin flight testing in the spring of 2002 with Block 3.1.2 becoming available towards the end of that year.

Some performance issues with Electronic Countermeasures (ECM) and with some of the tactical modes are being addressed but APG-77 radar performance data gathered during flight test on F-22 aircraft show the system meeting or exceeding specifications for radar detection and tracking functions. CNI development has been behind schedule and the subsystems are maturing at a slower pace than expected. EW development is also behind schedule and has been slow to mature. Integrated testing of the EW subsystem is proceeding on the FTB.

Avionics system testing has not progressed as far as was originally expected or planned. Significant delays, primarily due to late delivery of avionics test aircraft, have limited Block 3.0 software testing in the F-22. Lack of avionics system stability, resulting in system failures requiring a 20-minute restart procedure, has required several modifications to Block 3.0 software. Avionics systems testing on the FTB has progressed satisfactorily and as of June 2001, three of the eventual six F-22 avionics test aircraft were flying in support of the avionics development effort at Edwards AFB.

WEAPONS INTEGRATION TESTING

In order to ensure a very low Radar Cross Section (RCS), the F-22 was designed to carry its air-to-air missile armament internally for operations in a high threat environment. Two AIM-9 infrared guided missiles (initially AIM-9M with AIM-9X planned for later implementation) are contained inside side fuselage weapons bays located under the wings and six AIM-120C radar guided AMRAAM missiles can be carried in two weapons bays located on the bottom

midsection of the fuselage. The missiles are launched by rail extension (AIM-9) or rapid pneumatic/hydraulic launchers (AIM-120) located behind quick-acting doors. The missile launch sequence, from doors open through missile launch to doors fully closed occurs very rapidly to preserve the F-22's stealth characteristics in combat.

Several successful AIM-9 and AIM-120 missile separation tests have demonstrated the feasibility of internal weapons carriage. Such tests, to be conducted across the operational missile employment envelope of the F-22, are key elements of the build-up to guided weapons employment testing.

Data analysis conducted following the first AIM-120 safe separation test determined that the standard AMRAAM q-bias command (necessary to safely maneuver the missile away from the launch aircraft flow field immediately after launch) would require modification for F-22 employment. The q-bias programmed into the current AIM-120 was developed based on F-15 ejector launch parameters. A new software modification to the AIM-120 missile is required to enable the missile to be fired from the F-22 under other than non-maneuvering flight conditions. This software modification is currently being developed in conjunction with the Joint Air-to-Air Missile Program Office. It will need to be validated on the F-22 and then be integrated into operational AIM-120 missiles.

The launch of precision weapons is the most critical step in the flight test program for validation of the integration of avionics and weapons systems and missile launch and control algorithms. The algorithms are also necessary for the mission-level simulation in the Air Combat Simulator (ACS) during pilot training and mission-level IOT&E sorties. Flight test validation of the Block 3.1.2 software, which contains full-up closed-loop tracking and missile launch and control algorithms, is critical to the start of IOT&E pilot upgrade training. Weapon system delivery testing involving guided missile launches is required to complete these tasks and provide data from which performance predictions can be made.

In late CY 2000, the F-22 System Program Office provided a tentative guided weapons test planning schedule to DOT&E. The schedule assumed about one month was required to accomplish each test scenario contained in the F-22 Test and Evaluation Master Plan (TEMP), including workups and rehearsals. Since that guided weapons test schedule was provided, initiation of live guided missile testing has been delayed by about five months with the first AIM-120 guided weapon launch now scheduled to occur in August of this year. Additional

guided missile combined developmental/operational testing (including integration of the AIM-9X into the F-22 weapon system and demonstration of AIM-120 launches from external weapons stations) will not be completed until after the F-22 EMD program ends in September 2003. Results of guided weapons testing using Block 3.0/3.1 software are necessary to provide adequate data for use in validation of the ACS. A fully validated ACS is essential to much of the IOT&E effort, especially in the evaluation of those aspects of F-22 combat employment that cannot be conducted in open air testing due to resource, range and safety restrictions.

DOT&E recently provided direction on adequacy of the Air Force's latest plan to execute the air-to-air missile test program contained in the January 2001 approved TEMP. The Air Force desires to use the Instrumented Test Vehicle (ITV), a captive-carry version of the AMRAAM missile that captures pre-launch and post missile launch data transmitted from the F-22 to the missile, to evaluate weapons integration and end-to-end performance in lieu of live firings on a number of the missile test scenarios specified in the TEMP. DOT&E is requiring that the Air Force validate the efficacy of this approach prior to a final decision.

Based on the very limited number of unguided missile separation tests performed to date, we cannot adequately assess the overall F-22 weapons system performance. Forty-three of the 48 planned missile safe separation tests have yet to be completed. AIM-120 guided weapons testing in conjunction with the integrated avionics system, has yet to commence, as do AIM-9M guided missile shots. Some important fully integrated guided missile test launches will not be completed by the start of IOT&E and will either be done concurrently with IOT&E or after the EMD program ends. DOT&E believes the largest development risk to overall F-22 mission effectiveness lies in the integration of the advanced avionics suite with air-to-air weapons employment.

LOGISTICS TEST AND EVALUATION

Very little progress was made in accomplishing logistics test and evaluation objectives during CY 2000. Although some progress has been made this year, nearly 3,400 logistics tasks remain to be completed prior to the start of IOT&E, and the program is over 2,700 test points behind relative to the logistics test plan schedule established at the beginning of CY 2000. Completion of remaining logistical tasks prior to the start of IOT&E is a challenge if the IOT&E effort is to succeed as planned, especially as it involves maintenance of F-22 stealth capabilities

during high sortie rate conditions and availability of a full-up Integrated Information Management System (IMIS) capability upon which a successful IOT&E depends. The test plan, however, has gained coherency and benefited from the intended dedication of avionics aircraft. The ability to produce and sustain the required high sortie rate, develop interfaces to service common support equipment, validate specific low-observable repair techniques through effectiveness tests, and conduct low-observable restoration maintenance concurrent with other tasks are examples of logistics test and evaluation issues that are pending resolution.

STEALTH CHARACTERISTICS

Stealth is one of the major technological features in the F-22 design and is essential to its intended operational effectiveness. Testing of F-22 stealth characteristics has included extensive ground and limited flight tests. Both RCS and Infrared (IR) signatures of the F-22 have been measured in flight while stability overtime testing has yet to be completed. On January 31, 2001, Aircraft 4004 completed the LRIP exit criterion that required initiation of RCS flight test on an open-air range. Preliminary data show a direct correlation with baseline measurements from ground RCS test facilities and inflight RCS imaging techniques, and provide high confidence in F-22 RCS predictions. However, due to late aircraft deliveries, a significant amount of RCS flight test remains to be completed prior to the start of IOT&E. The first fully production representative F-22 RCS test aircraft, Aircraft 4008, will not be delivered to the CTF at Edwards AFB before December of this year.

LIVE FIRE TEST AND EVALUATION (LFT&E)

The LFT&E program continues to progress in accordance with the strategy and alternative plan that DOT&E approved in 1997, although some of the testing schedule has slipped. Fifteen of the 21 scheduled ballistic tests have been completed. Two of the six live fire test series that have not been completed are intended to assess the potential for sustained fires. One of these series will investigate fire in the wing leading edge using a full-up wing and the other will evaluate the effectiveness of the engine nacelle fire suppression system given combat damage. Two remaining test series will investigate hydrodynamic ram damage to fuel tanks located in the wings and fuselage. The other two test series were originally intended to assess the capability of the onboard fire protection system in the main landing gear bays and the aft

wing attach bays. Since the Air Force no longer intends to employ fire extinguishers in these bays, these tests will not be conducted.

Live fire testing has led to an F-22 wing redesign that replaced selected composite spars with titanium spars. This design change alone is claimed by the Air Force to have reduced the vulnerable area of the aircraft by as much as 50 percent. The hydrodynamic ram test scheduled for early this calendar year is now scheduled for mid August 2001. This test will be an attempt to confirm the survivability of the new wing design to this widely experienced damage phenomenon. It is important that the upcoming live fire test with high-explosive incendiary threats against the F-22 wing be done with flight representative airflows and structural loads with the wing properly fixed to the aircraft. Prior tests with the wing mounted in a test fixture have shown the potential to introduce unrealistic results. A test procedure is in place that will permit realistic aerodynamic and structural loadings on the wings of the test article. This test procedure is intended to evaluate the survivability of the new wing design that was changed as a result of poor performance during previous live fire tests started in 1992.

Live fire testing showed that there is a substantial chance of fire from hits on avionics cooling lines in the wing tip avionics bay. The fluid used in these pressurized lines is flammable. An automatic shutoff valve was added to the F-22 avionics cooling system in an attempt to reduce this risk of fire.

Fire and explosion are the leading causes of aircraft loss, and based on existing data for other dry bays, the assessed probability of kill given a hit is very high on unprotected bays. Hence, effective fire suppression is mandatory to achieve a survivable aircraft design. The decision by the Air Force to remove fire suppression systems from the main landing gear and the aft wing attachment dry bays, as well as other factors, have increased the aircraft's probability of being killed given a hit and estimates are now that the vulnerable area is some 30 percent higher than the original F-22 specification. The F-22's vulnerable area estimates could increase further as a result of the remaining tests. The Air Force has revised upward the vulnerable area threshold for the F-22. At this time, the aircraft currently meets this revised higher vulnerable area requirement.

The F-22 fuel tanks represent the largest presented area of any F-22 aircraft subsystem. The original fuel onboard tank inert gas-generating system (OBIGGS) design could not withstand the F-22's vibration environment. Functional testing of the new OBIGGS design using

the Fuel Systems Simulator needs to be conducted. These tests are expected to demonstrate that the new design achieves the inherent concentration needed to protect the fuel tanks against explosion. The F-22 must demonstrate its fire and explosion survivability prior to the decision to enter full-rate production. The vulnerable area estimates used by the Air Force assume that the OBIGGS provides the desired protection.

CONCLUSIONS AND RECOMMENDATION

As DOT&E has repeatedly stated over the last three years in testimony before this subcommittee, Air Force efforts to reduce costs and stay within the EMD cost cap have consistently resulted in plans that accomplish less testing with correspondingly increased development risk. These development risks have become greater with elapsed time as the cost reduction options become more difficult to implement.

The Air Force has implemented several test program reductions and proposed other reductions. In fall 2000, Air Force schedule estimates showed that the previously planned test program could not be completed as originally scheduled and that IOT&E could not be started in August 2002, as earlier scheduled, without clearly unacceptable risks. In December 2000, the Air Force briefed DOT&E on a plan that would, after cap relief of 1.5 percent, defer the start of IOT&E by four months (i.e. December 2002), allowing additional time for developmental testing. Although DOT&E believed that as much as a nine-month to one-year delay in the start of F-22 IOT&E was needed to complete necessary developmental testing, DOT&E supported cap relief and delaying the start of IOT&E. In May 2001, an Air Force-sponsored independent Red Team was commissioned to assess the executability of the remaining F-22 developmental test effort to reduce risk and allow completion of necessary tasks in advance of the start of IOT&E. Currently, the Air Force is developing a redefined developmental test plan based on an objective IOT&E start date of April 2003, with a threshold start date of August 2003. As mentioned earlier, the Air Force proposed a change to the live guided missile launch program upon which DOT&E has provided direction to validate proposed live missile launch alternatives. This proposed TEMP change is under evaluation by DOT&E.

These reductions in developmental test programs have increased the risk to successfully completing an adequate IOT&E. Although these reductions in test content do contribute to relieving schedule pressures, they may not be enough to allow EMD completion within the

current schedule. Considerable uncertainty remains with the flight test aircraft sortie rate, and there is some uncertainty regarding the actual delivery dates of the last three flight test aircraft to the CTF at Edwards AFB that will permit them to start productive contributions to the test program. Therefore, I support removing the cost cap because it will help to focus the program on completing adequate developmental testing and correcting any deficiencies in preparation for a successful and adequate IOT&E.