F-35 Joint Strike Fighter (JSF)

Executive Summary

- All three F-35 variants had entered flight test by June 2010. For the first time, all three integrated test forces at Fort Worth, Texas; Patuxent River Naval Air Station (NAS), Maryland; and Edwards AFB, California, conducted flight test operations with seven Systems Design and Development (SDD) test aircraft. The cumulative data for test sorties and points indicate progress slightly ahead of that planned. The test teams exceeded the goal of 394 total sorties for calendar year 2010 by early December 2010. However, progress in testing the Short Take-Off and Vertical Landing (STOVL) aircraft was less than planned.
- Immaturity of STOVL design and unexpected component deficiencies limited successful accomplishment of test points in areas critical to short take-off and vertical landing capability. Development of mission systems software continued to experience delays that affected flight test progress.
- Program leadership began re-planning SDD flight testing at the end of FY10, in conjunction with a restructuring of mission systems software development plans. These efforts followed the recommendations of the Program Executive Office's (PEO) Technical Baseline Review (TBR) of the program, which was a technical, "bottoms-up," independent review of the air vehicle platform, sustainment, mission systems software, and test. Finalization of the test schedule and integration into a master program schedule continued into early FY11.

- Service plans for initial training and operational capability, and acquisition plans for full-rate production need to be adjusted to a realistic timeline consistent with certification through testing of the incremental capability aircraft will actually provide, as well as later completion of SDD. Although the integrated test forces and development teams made significant progress, the results of flight testing and the TBR indicate more time and resources will be needed to complete SDD than incorporated in the June 2010 program baseline.

Actual versus Planned Test Flights and Points

		ALL VARIANTS ALL TESTING		STOVL ONLY FLIGHT SCIENCES		CTOL ONLY FLIGHT SCIENCES		CV ONLY FLIGHT SCIENCES		MISSION SYSTEMS	
		Flights	Points	Flights	Points	Flights	Points	Flights	Points	Flights	Points
FY10	ACTUAL	282	2,948	130	1,467	111	963	14	344	28	174
	PLANNED	256	2,496	173	1,678	43	485	9	77	32	256
Cumulative (as of 1 Dec 10)	ACTUAL	427	4,614	216	2,649	155	1,294	24	466	32	**205**
	PLANNED	390	4,404	254	3,010	69	825	21	201	46	368

System

- The F-35 Joint Strike Fighter (JSF) program is a joint, multi-national, single-seat, single-engine family of strike aircraft consisting of three variants:
  - F-35A Conventional Take-Off and Landing (CTOL)
  - F-35B Short Take-Off and Vertical Landing (STOVL)
  - F-35C Aircraft Carrier Variant (CV)
- It is designed to survive in an advanced threat (year 2012 and beyond) environment using numerous advanced capabilities. It is also designed to have improved lethality compared to legacy multi-role aircraft.
- Using an Active Electronically Scanned Array (AESA) radar and other sensors, the F-35 is intended to employ precision-guided bombs such as the Joint Direct Attack Munition and Joint Standoff Weapon, AIM-120C radar-guided air-to-air missiles, and AIM-9 infrared-guided air-to-air missiles.

- The program incrementally provides mission capability: Block 1 (initial), Block 2 (advanced), Block 3 (full).
- The F-35 is under development by a partnership of countries: the United States, Great Britain, Italy, the Netherlands, Turkey, Canada, Australia, Denmark, and Norway.

Mission
- A force equipped with F-35 units should permit the Combatant Commander to attack targets day or night, in all weather, in highly defended areas of joint operations.
- Targets include fixed and mobile land targets, enemy surface units at sea, and air threats, including advanced cruise missiles.

Major Contractor
Lockheed Martin, Aeronautics Division, Advanced Development Programs – Fort Worth, Texas

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Activity

Activity Affecting Test Strategy, Planning, and Resourcing

Joint Estimate Team II
- The second independent Joint Estimate Team (JET) review concluded last year that the SDD flight test plan lacked sufficient resources and incorporated unrealistic assumptions for flight test productivity relative to historical experience. At the time of the JET II review, the program had accomplished approximately 25 flight test hours on only two STOVL SDD test aircraft; no aircraft had ferried to the flight test centers.
- In early FY10, the program began the process of incorporating the review's key recommendations: adding test aircraft to the SDD test fleets from production lots, adding down-time for aircraft maintenance and modifications, reducing the assumed productivity of certain flight test aircraft, increasing and extending engineering and test operations staffs to support concurrent development and test, and adding an additional software integration and test lab. The program was also directed to implement recommendations of the first Independent Manufacturing Review Team, to include reducing production in the Future Years Defense Plan by 122 aircraft, thereby reducing concurrency of development and production.
- These reviews and actions, along with a review of cost and risk in development of the propulsion system, led to the acknowledgement of a breach of the Nunn-McCurdy "critical" cost thresholds for the JSF program.

Nunn-McCurdy Certification
- An Integrated Test Review occurred in April to support the Nunn-McCurdy certification. Representatives from the Edwards and Patuxent River flight test centers, JSF Operational Test Team, and the Services conducted the review and identified numerous issues affecting the executability of the flight test schedule.
- The Nunn-McCurdy program certification occurred in June. At the time of the certification of the new program budget baseline, the flight test program had accomplished approximately 190 flight test hours and ferried five total aircraft to the test centers, including two CTOL flight sciences aircraft, with an overall average number of 3.2 months on-site at the flight test centers. Low fly rates on STOVL flight sciences aircraft and unanticipated deficiencies in the design had begun to emerge in flight test. Analysis during the review indicated STOVL flight sciences was becoming the critical path to complete SDD flight test. The program acknowledged later ferry dates for remaining SDD test aircraft. The estimate of SDD flight test completion was extended to July 2015.

Technical Baseline Review (TBR)
- The new PEO commissioned a TBR of the program in June to determine the technical adequacy of program plans and resources. The TBR benefitted from more flight test results than previous reviews because the three Integrated Test Force sites had accumulated over 440 flight test hours and the overall average in months on-site for SDD aircraft at the flight test centers was 7.2 months. However, during the months since the last program review, more problems with STOVL design and mission systems software arose.
- The TBR recommended further changes to the parameters used to plan and model flight test schedules, as well as numerous changes in staffing and other resources needed to complete SDD and enter IOT&E. Specific changes to the schedule recommended by the TBR include lower flight rates for test aircraft that are tailored to each variant (lower than prior independent reviews), additional re-fly and regression sorties that are tailored to the type of testing, and more flight test sorties. The TBR also determined more time was needed for completion of all remaining software increments. The result is a completion of developmental flight test in late 2016, with STOVL flight sciences completing later than the other two variants.

F-35 Flight Test

STOVL Flight Sciences, Flight Test with BF-1, BF-2, and BF-3 Test Aircraft
- BF-3 ferried to Patuxent River NAS, Maryland, in February 2010; it is the last of three B-model flight sciences aircraft.
- Maintenance, test operations, and engineering staffs increased significantly (approximately 25 percent) in FY10 at Patuxent River, NAS. The program intends to reach full strength in 2011, pending hiring of qualified contractor personnel.

- The government-contractor test team attempted test points in up-and-away flight envelope expansion, STOVL-mode flight, handling qualities, propulsion testing, and readiness for the first ship integration test period (planned for late 2011).
- In FY10, STOVL Flight Sciences aircraft flew 130 of 173 planned sorties; the test team completed 1,467 of 1,678 planned test points. However, the test team accomplished only 10 of 42 planned vertical landings between March and November 2010; these are key to the shore-based build-up to testing on L-class amphibious ships at sea. In the first two months of FY11, STOVL flight sciences aircraft flew 54 sorties, 5 more than planned; the test team accomplished 356 of 506 planned test points. From mid-August until early November, the test team flew CTOL-mode configurations due to limitations of the vertical-lift capability of the STOVL system. STOVL-mode flight test operations began again in BF-1 in November 2010.
- In July, the program made changes to supply chain management to provide timely spares and implemented surge scheduling and 7-day/week maintenance operations. These actions contributed to an increase in flights per month of approximately 25 percent.
- Discoveries during STOVL Flight Sciences testing this fiscal year include transonic wing roll-off, greater than expected sideslip during medium angle-of-attack testing, higher and unanticipated structural loads on STOVL doors, and poor reliability and maintainability of key components.

CTOL Flight Sciences, Flight Test with AF-1 and AF-2 Test Aircraft

- AF-1 and AF-2 ferried to Edwards AFB, California, in May, as planned.
- Maintenance, test operations, and engineering staffs increased significantly (approximately 50 percent) in FY10. The program intends to reach full strength in 2011, pending hiring of qualified contractor personnel.
- In FY10, the test team made progress in envelope expansion, handling qualities, and propulsion test points. CTOL Flight Sciences aircraft flew 111 sorties, 68 more than planned. The test team completed 963 test points, exceeding the 485 planned flight test points for the fiscal year. In the first two months of FY11, CTOL flight sciences aircraft flew 44 sorties, 18 more than planned; the test team accomplished 331 of 340 planned test points.
- The program anticipates the remaining CTOL Flight Sciences aircraft, AF-4, will ferry to Edwards, AFB, California, by January 2011, approximately two months later than planned.
- Discoveries during CTOL flight sciences flight test in this fiscal year include transonic wing roll-off, greater than expected sideslip during medium angle-of-attack testing, and problems with reliability and maintainability of key components.

CV Flight Sciences, Flight Test with CF-1 Test Aircraft

- CF-1 flew for the first time in June 2010. The aircraft ferried to Patuxent River NAS, Maryland, in early November 2010, one month later than planned.
- While at Fort Worth, Texas, CF-1 flew airworthiness and initial-service-release propulsion system test flights, accomplishing 14 flight test sorties, five more than planned. As a result, CF-1 flew 344 test points, significantly more than the 77 planned for the fiscal year. In the first two months of FY11, aircraft CF-1 flew 10 of 12 planned sorties; the test team accomplished 4 of 14 planned test points.
- The Integrated Test Force at Patuxent River NAS, Maryland, built up maintenance and engineering support personnel in anticipation of the arrival of CF-1, which the program delivered to the test center in November 2010.
- The program anticipates the remaining CV flight sciences test aircraft, CF-2 and CF-5, will ferry to Patuxent River NAS, Maryland, in February 2011 and late 2013, respectively. Aircraft CF-2 would then arrive approximately two months later than planned.

Mission Systems, BF-4 and AF-3 Flight Tests and Software Development Progress

- Block 0.5 Infrastructure
  - The program released Block 0.5 software for flight test in March 2010, five months later than planned. The software had completed mission systems lab integration activity and integration flights on the Cooperative Avionics Test Bed (CATB). Block 0.5 is the infrastructure increment, which contains communications, navigation, and limited radar functionality.
  - Aircraft BF-4, loaded with Block 0.5, accomplished first flight in April 2010, five months later than planned, and then ferried to Patuxent River NAS, Maryland, in June, two months later than planned, and began Block 0.5 flight test.
  - Test teams attempted approximately 70 percent of the planned Block 0.5 flight test points on BF-4. Software problems occurring before and during flight test were not resolved in the Block 0.5 configuration. Program leadership deemed Block 0.5 unsuitable for initial training and adjusted the software development plan to implement fixes for the Block 0.5 problems in the initial release of Block 1. The integrated test force is re-flying selected Block 0.5 flight test points in the Block 1 configuration.
- Block 1, Initial Training Capability
  - The program delivered aircraft AF-3 in a Block 1 configuration to Edwards AFB, California, in December 2010, approximately five months later than planned.
  - The program intends the Block 1 design (which includes multi-sensor fusion capability) to support the initial

training syllabus for the initial cadres at the training center. The development team conducted integration activity with an initial version of Block 1, including fixes to Block 0.5 problems, in the mission systems labs and on the CATB.
  - The program planned to release the first Block 1 increment to flight test aircraft in August 2010, but F-35 flight testing did not begin until November 2010. By the end of November, the test team flew 4 of 14 planned sorties and accomplished 31 of 112 test points.
- Block 2 and Block 3 Software Development Progress
  - The Block 2 detailed flight test planning process began in September 2010.
  - In August, the program began re-planning the software development schedule for completing and certifying Block 1, Block 2, and Block 3 increments of SDD capability.
- Ferry of Remaining SDD Mission Systems Flight Test Aircraft
  - The program anticipates ferry of BF-5 in late March 2011 and CF-3 in May 2011; these deliveries to the test centers are approximately four and five months later than planned, respectively.

Modeling and Simulation

Verification Simulation (VSIM)

- The program commenced planning of validation efforts for F-35 modeling, development of the virtual battlespace environment, and integration of the two into one simulation intended for developmental test and evaluation.
- The program identified funding shortfalls for the Verification Simulation (VSIM) to meet OT&E needs, primarily in the battlespace environment, and provided data for an independent cost assessment leading to inclusion of VSIM costs in the program baseline. The Services have been directed to fully fund VSIM for OT&E.
- The PEO completed a VSIM Sufficiency Review to determine the means to provide the required OT&E VSIM capability.

Other Models and Corporate Labs

- The program continues to plan to accredit a total of 32 models and virtual laboratories for use as test venues (including VSIM) in developmental testing. The program planned to accredit 11 models by the end of FY10; however, the program office accredited only three venues by September 2010.
- Due to software development delays and shifts in capability to later software blocks, the program decided several models are not needed to support testing of Block 1 mission systems.

Static Structural and Durability Testing

- The test teams completed STOVL and CTOL static structural testing ahead of schedule, which is an important input to envelope expansion through flight test. The CV static test article completed initial drop tests for carrier suitability.
- CTOL and STOVL durability testing began in FY10. Results for a loading equivalent to one aircraft lifetime (8,000 hours) were expected in mid-FY11 for the STOVL aircraft and early FY12 for the CTOL aircraft. However, a major fatigue crack was found in the STOVL test article at approximately 1,500 flight hours. Failure of the bulkhead in flight would have safety of flight consequences. The program stopped fatigue testing on both the STOVL and CTOL test articles and began root cause analysis in November 2010. The STOVL bulkhead is constructed of aluminum alloy. The CTOL and CV bulkheads have a similar but not identical design and are made of titanium. The difference in bulkhead material is due to actions taken several years ago to reduce the weight of the STOVL aircraft.

Propulsion System Testing

- F135. The program delivered the first initial-service-release F135 engines to SDD CV and STOVL test aircraft. By the end of November 2010, CF-1 had flown 36 flight hours with this engine; however, BF-5 had not yet flown. The program began implementing plans to modify test aircraft to rectify the afterburner "screech" problem, a problem that prevents the engine from sustaining full thrust. These modifications are necessary for the test aircraft to complete envelope expansion at the planned tempo.
- F136. Engine testing accomplished approximately 430 of 739 planned ground test hours by the end of the fiscal year. The program is examining ways to accelerate testing in order to meet the planned start of flight test with the F136 in late 2011 for CTOL, and late 2012 for STOVL.

Operational Test and Evaluation

- In June, the JSF Operational Test Team (JOTT) began OT-2E, the fifth operational assessment of progress towards developing an operationally effective and suitable Block 3 mission capability in all three variants. The JOTT plans to complete this assessment in late 2011.
- At the request of the JSF Program Executive Officer (PEO), the JOTT is also developing plans to assess the initial training capability intended for use with the first fleet pilots and maintenance crews in 2011.
- The JOTT reviewed and re-validated the November 2008 requirements documentation for the VSIM for OT&E. DOT&E approved the re-validated requirements.
- The JOTT began the Readiness-to-Test evaluation process in FY10, which uses an assessment template to determine actions necessary for the weapons system to be ready to successfully enter and complete the planned OT&E periods. This process identifies potential gaps between verification of contract specification compliance and delivery of the mission capability necessary to meet the operational requirements.
- The JOTT significantly increased its work force and the Services identified pilots and maintenance crews for execution of early operational testing and assessments.

Air System-Ship Integration and Ship Suitability Testing

- Coordination continued between the JSF program office, Naval Sea Systems Command, and Naval Air Systems Command offices responsible for planning and implementing actions to integrate the JSF aircraft and support systems on naval ships. The teams focused efforts on readiness for initial ship trial periods that the program now plans in late 2011 (one year later than previously planned), as well as on planning the other actions needed to achieve initial operating capabilities of the B-model on L-class amphibious ships and the C-model on large-deck carriers.
- The coordination teams are working significant issues in these areas: identification of personnel hazard zones around B-model aircraft, interoperability of the Autonomic Logistics Information System with Service and joint systems, carrier jet blast deflector modifications needed for CV aircraft operations, aircraft-ship connectivity for alignment of inertial navigation systems, secure facilities for handling special access material, and spectrum limitations.
- The first ship trial period for the B-model STOVL aircraft has slipped from March 2011 to no earlier than late 2011 due to the slow flight test progress in accomplishing the shore-based build-up test points. The first C-model trial period on a large deck carrier is planned for early 2013.

Live Fire Test and Evaluation

- LFT&E conducted On-Board Inert Gas Generations System (OBIGGS) tests during FY09-FY10.
- The Weapons Survivability Lab at China Lake took delivery of the Full-Up System-Level (FUSL) F-35 aircraft. The aircraft is being prepared for ballistic testing. The test team will begin this testing in 1QFY11.

Assessment

Test Schedule Re-Planning and Implementation of Changes

- The year-long process of analyses during FY10 (JET II implementation, Nunn-McCurdy certification, and TBR) served to develop a more realistic estimate of SDD completion for Block 3 in all variants and identify steps to reduce risk in execution of the verification test and evaluation strategy. Although the sample size of experience with the CV is still small, the STOVL design emerged as the highest risk of all variants and the most difficult to progress through flight test. This is due in part to the difficulty in making progress in vertical lift operations compared to that planned. The analyses also revealed that the F-35 mission systems software development and test is tending towards familiar historical patterns of extended development, discovery in flight test, and deferrals to later increments. The modifications recommended by the TBR (lower fly rates, more regression and re-fly margin, more flights, and other resource additions) that result in completion of SDD flight test for Block 3 in all three variants later than previously estimated are realistic and credible. Completion of STOVL flight sciences in this timeframe is dependent on whether or not the necessary changes to STOVL design can be implemented and tested. It will also depend on whether these changes result in fewer aircraft operating limitations and greater aircraft availability for test. The program will potentially need as much as a year longer than the other two variants to complete this variant's flight sciences and ship integration testing. The expectations approaching 10 to 12 flight sciences sorties/month/aircraft in previous schedules are not achievable in the flight test program until changes are made to all variants that improve reliability and maintainability in flight test operations. Additionally, the process must begin to reduce the aircraft operating limitations, which inhibit flight test progress particularly in vertical lift STOVL testing.
- Mission Systems flight test still contains significant uncertainty, which will affect any estimate of a Block 3 completion date. This is primarily due to the delays incurred in development thus far and the fact that only the Block 0.5 flight test plan has actually been completed and approved. A test plan for Block 1 is currently in review by test center authorities, and the Block 2 test plan is in an initial draft state. Additionally, technical issues in the helmet mounted display and sensor fusion, along with uncertainties pertaining to new capabilities with which the program has limited experience on the F-35 aircraft (multi-function advanced data link, distributed aperture system, infrared/electro-optical fused sensor tracks) are risks that affect the ability to accurately predict the conclusion of mission systems flight test. Completion by early 2016 is possible provided further delays in delivery of Block 2 and Block 3 software are not incurred, and the program can overcome the helmet mounted display problem before Block 2 flight test must begin. Mission systems labs and CATB are important to software integration and test; use of these assets has enabled the resolution of many problems before flight test. However, F-35 flight test must include integration sorties to demonstrate software performance before performing flight test points for verification of capability. F-35 flight test for the purposes of software and sensor integration has not been, but needs to be, an explicit part of the flight test plan such that integration precedes verification events.
- The TBR also revealed a number of changes needed to directly support the Edwards and Patuxent River Integrated Test Force flight test centers to assure the highest possible rate of execution. Recommendations for additional maintenance and test operations work forces, improving spare parts supply chain management, increasing engineering support for test data analysis, standardizing network connectivity at all sites, and improving priority of the program on test ranges are credible, important efforts that need follow-up and require sustained emphasis for the duration of SDD flight test.

Verification Simulation for Operational Test and Evaluation

- Open-air testing is constrained by range limitations that are incapable of providing realistic testing of many key capabilities provided by Block 3 aircraft. Consequently, a

robust, operationally realistic VSIM is critical to performing IOT&E of JSF, as required by the Test and Evaluation Master Plan (TEMP).
- The program office and contractor team have begun work on the simulation for Block 2 capability needed for the OT-2F operational utility evaluation, and are beginning to focus on the process and data requirements to validate installed F-35 performance in the simulation. This critical work needs to be carefully resourced and coordinated, and should be subject to independent review.
- The JSF VSIM developed for IOT&E will have significant utility for development and testing of upgrades to aircraft capabilities beyond Block 3 occurring well after IOT&E is complete. The JSF Program Office Sufficiency Review determined a path for completing the simulation for Block 3 IOT&E within the baseline budget adjustment made in the Nunn-McCurdy certified program. Challenges remain in identifying and collecting the needed validation data for F-35 installed performance and completing the battlespace environment.

Training
- The Integrated Training Center made significant progress in preparation for receiving aircraft, support systems, and personnel. The development of the syllabi and training devices proceeded essentially on the pace planned in FY10. However, the adequacy of the training system for the Integrated Training Center requires reassessment. Users have expressed concerns about the adequacy of course content and its allocation between training venues, such as the self-paced computer-based lessons, electronically mediated instructor lectures, desktop Pilot Training Aid, training events conducted in the cockpit simulators, and on/in-aircraft training.
- The slower than planned pace of mission systems software development and significant aircraft operating limitations affect readiness to begin formal training, which is not likely to occur in mid-2011 as planned. The JOTT operational assessment of the intended training system and its planned products requested by the PEO will provide an independent identification of issues, and progress towards resolution. The effects of immature aircraft and support systems, along with user concerns about adequacy of training venues for intended uses, will be key aspects of this assessment.

Live Fire Test and Evaluation
- The OBIGGS system fails to inert the fuel tank ullage spaces throughout the combat flight envelopes evaluated.

Recommendations
- Status of Previous Recommendations. The program and Services are satisfactorily addressing four of eight previous recommendations. The remaining four recommendations concerning adequate flight test resourcing, coordinating expected level of low-rate initial production capability with users including the JOTT, accreditation of models used as test venues, and restoring the means to minimize fueldraulics leaks and coolant shutoff valves are outstanding.
- FY10 Recommendations. The program should:
  1. Assure the re-planned detailed mission systems development schedule and detailed flight test schedule are realistic.
  2. Annually evaluate flight test progress against planned performance, assess resources, and recommend adjustment of Service early fielding goals. Remain prepared to deal with continued discovery in flight test as more complex testing begins.
  3. Determine the impact of resolution of known critical technical issues, including Helmet Mounted Display, STOVL mechanization, handling characteristics, and afterburner “screech” on plans for flight test and fielding capability.
  4. Assure that there is explicit use of F-35 flight test for software integration before verification.
  5. Finalize plans to verify and validate the mission data load products through dedicated flight test.
  6. Complete VSIM development for OT&E in accordance with the operational testing requirements document and TEMP.
  7. Re-design the OBIGGS system to ensure that the fuel tank ullage volume oxygen concentrations are maintained below levels that sustain fire and/or explosion throughout the combat flight envelopes.