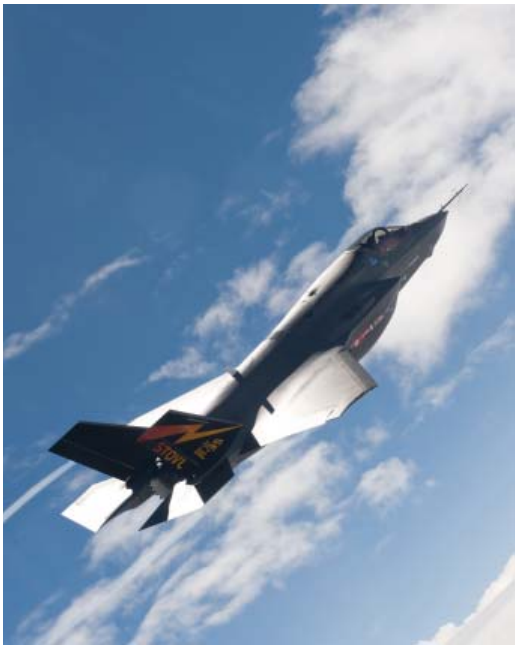
F-35 Lightning II Joint Strike Fighter (JSF)

Executive Summary

- F-35 verification and flight test did not reach the tempo planned for FY09 due primarily to late deliveries of the remaining 10 (of 13) System Design Demonstration (SDD) flight test aircraft. While other verification work continued in the hover pit, Cooperative Avionics Test Bed (CATB), and surrogate platforms, the Integrated Test Force accomplished only 16 of 168 flight test sorties planned for FY09. Completion of IOT&E of Block 3 capability could occur in early to mid-2016 provided the associated extension of SDD is supported with additional flight test aircraft, timely delivery of effective software, and an adequate pace of testing is maintained.
- Continued production concurrent with the slow increase in flight testing over the next two years will commit the DoD and Services to test, training, and deployment plans with substantial risk. Program management needs to emphasize maintaining robust engineering and test forces, early completion of detailed test plans, fully resourcing those plans, and rigorous accreditation of models and labs. Deliveries of assets for OT&E and initial training must be managed consistent with approved plans for OT&E.
- The mission capability of the low-rate initial production (LRIP) aircraft and support systems is unclear. This creates a problem for the Services as they plan for Initial Operational Capability. The process to accurately and credibly predict the mission capability of LRIP systems well before delivery needs to improve and LRIP contracts need to be tied explicitly to demonstrated progress in flight testing.
- The JSF Program Office (JPO) is executing a comprehensive, robust, and fully funded Live Fire test plan. However, the program's recent removal of shutoff fuses for engine fueldraulics lines, coupled with the prior removal of dry bay fire extinguishers, has increased the likelihood of aircraft combat losses from ballistic threat induced fires. At present, only the Integrated Power Plant (IPP) bay has a fire suppression system. Though the JSF Executive Steering Board (JESB) has approved the JPO's request to remove these safety systems as an acceptable system trade to balance weight, cost, and risk, DOT&E remains concerned regarding the aircraft's vulnerability to threat-induced fires.

System

- The F-35 Lightning II 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 a blend of advanced technologies. 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 air-to-air missiles, and AIM-9 infrared 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.

Prime Contractor

- Lockheed Martin, Aeronautics Division, Advanced Development Programs, Fort Worth, Texas

Activity

- F-35 Flight Test

  STOVL Flight Sciences, BF-1 and BF-2 Flight Test

  - SDD flight test operations added SDD STOVL test aircraft BF-2 in February 2009. First flight occurred 10 months later than envisioned in the 2007 mid-course risk reduction.
  - During FY09, the test team accumulated only 12 test flights with BF-2 and four flight test sorties for aircraft BF-1 for a total of 16 test flights of the approximately 5,000 total planned for SDD. The approved master schedule called for 168 test flights, including the completion of the first vertical landing, before the end of the fiscal year. Completion of the first vertical landing has slipped from mid-2009 to January 2010.
  - Aircraft BF-1 completed initial hover pit testing at the contractor's test facility in Fort Worth, Texas. While the testing concluded four months later than planned in the F135 engine recovery plan, all test objectives were completed and engineering staff concluded that the F135 provides sufficient thrust for STOVL operations. Discoveries included high temperatures in the shaft clutch, need for lift fan door seal change, and potential for hot gas ingestion under certain wind conditions. The test team continues to work towards achieving the full STOVL flight clearance.
  - The program planned to deploy BF-1 and BF-2 to the Navy flight test center at Patuxent River, Maryland, in mid-FY09. BF-1 ferried to Patuxent River in November 2009, and began activities towards the first vertical landing. BF-2 continued to undergo modifications and functional check flight activities in Fort Worth at the time of this report.

  CTOL Flight Sciences, AA-1 Flight Test

  - Aircraft AA-1 (the non-weight-optimized CTOL SDD test article) continued to mitigate risks for production aircraft, accumulating 36 flights during FY09.
  - AA-1 testing contributed to discoveries in air-starts, weapons bay door operations, air refueling, and noise levels. The test team also used AA-1 for training the flight test teams.
  - AA-1 deployed to Edwards AFB, California, in October 2008, to test engine-restart-in-flight and acoustic test points. AA-1 later deployed to Edwards AFB, California, in September 2009 to conduct risk mitigation ground roll hook engagements. The program plans to ferry AA-1 to China Lake, California, in FY10 for storage; it will eventually become a LFT&E asset.

- Modeling and Simulation

  Cooperative Avionics Test Bed (CATB)

  - The CATB accomplished two deployments to Edwards and a deployment to Eglin AFB, Florida during FY09. It began the first mission systems CATB test activity in March with Block 0.5 software, five months later than planned.
  - Testing included radar, electronic warfare, and communications/navigation/identification (CNI) systems. In 55 total flights during the fiscal year, the integrated test force resolved a total of seven missions systems success criteria of the 284 allotted to the CATB.

  Other Models and Corporate Labs

  - The JSF Program Office initiated a roadmap for the verification, validation, and accreditation (VV&A) of the labs and models intended to become test venues, per the mid-course risk reduction strategy of 2007. The roadmap serves as a gauge to measure the contractor's progress in completing the accreditation support packages needed before success criteria can be resolved using the models. The current roadmap indicates that 50 percent of models will be accredited during the final year of flight testing, an approach with substantial risk.

- Additional Test Venues
  - The F135 recovery path to support the first STOVL vertical landing progressed slowly as the contractor completed tests of modified engines in preparation for hover pit testing in Fort Worth. Although the full STOVL flight clearance was expected by February 2009, only the STOVL propulsion system flight clearance was available at that time. In September 2009, an F135 engine ground test encountered a broken blade in the compressor section. Root cause analysis was in progress as of the writing of this report, but flight test operations continued.
  - The first two F136 SDD engines entered ground testing. These tests accumulated approximately 40 hours of ground test time and yielded discoveries on bearing assemblies that were subsequently modified.
  - Contractor test teams conducted testing of situational awareness and attack sensors and subsystems (radar, electro-optical targeting system, distributed aperture system, and countermeasures systems) in labs and on surrogate aircraft. This was subsystem developmental testing. The JPO has not accredited these labs and surrogate aircraft for verification tasks. The test team employed the radar from a surrogate test aircraft in operational training exercise Northern Edge 09 in a multi-target, countermeasured environment.
  - The contractor successfully completed initial mission systems software stability testing in ground labs for Block 0.5 and Block 1. Contractor teams are working on stability deficiencies discovered in this testing. Impact to performance and schedule is unknown.
  - The JSF Operational Test Team (JOTT), comprised of the operational test agencies, concluded the fourth operational assessment, OT-2D, of the F-35 weapons system.
  - The contractor conducted initial structural loads testing on the STOVL test aircraft with loads up to 150 percent of the design load limit. The test team completed 92 percent of the test points approximately two months ahead of schedule. The test yielded production design changes to doors and a blade seal. STOVL flight test envelope expansion now progresses beginning with 64 percent allowable limit envelope (unmonitored), towards the mid-2011 goal

to release 80 percent of the allowable limit envelope (unmonitored). The test team placed the CTOL static test article in the test facility in the United Kingdom at the end of the fiscal year. The CV static test article had not entered static testing by the end of the fiscal year but was on track to begin in FY10.

- Activity Affecting Test Strategy and Resourcing
  - In August 2009, the JPO began the process of evaluating the impact of late delivery of the SDD flight test aircraft on completion of SDD and determining the capability that can be verified in the early production aircraft. Numerous concepts for recovering schedule were under consideration, ranging from content deferral to assuming a six-day work week for the test force through the remainder of SDD flight test.
  - The JOTT and JPO continued to refine plans for partner involvement in F-35 OT&E. Partner representatives received the program proposal on the OT&E Informed Participant process, which concludes planning for partner involvement in operational testing.
  - The contractor and Program Office continued to develop verification plans and flight test plans for the completion of SDD. The contractor re-organized senior test management to place verification activities within the purview of the Integrated Test Force.
  - The contractor continued to refine the Air System Capabilities Matrix and Capabilities Cross Reference Matrix, which are intended to present the goals for producing and increasing functionality, envelope, weapons loads, and autonomic logistics support to each LRIP lot of aircraft and support systems delivered to the Services.
  - The contractor continued product development of the Verification Simulation (VSIM) – a man-in-the-loop simulation for verification of mission effectiveness in a virtual operational environment. The JOTT identified the VSIM shortfalls that must be addressed in order for the simulation to be adequate for JSF OT&E.
  - Revision Three of the JSF Test and Evaluation Master Plan (TEMP) was completed and submitted for Service coordination. This revision of the TEMP is a significant improvement over prior versions and adequately describes content, measures, and resources for OT&E. The TEMP was approved December 11, 2009.
- Live Fire Test and Evaluation
  - The pilot-in-the-loop simulator test series of the F-35 with damage-induced failures was completed in FY09. The results from these tests provide the basis for predictions of results from full-up system-level tests using the AA-1 test article to be conducted in FY10.
  - A Live Fire ballistic test series to evaluate the potential for ballistically-induced electrical arcing to initiate fuel fires was completed and the report delivered by the end of 2QFY09 to DOT&E.

Assessment

- Concurrency of production, development, and testing increased in FY09 as verification and flight test did not attain the planned pace due to the failure to deliver SDD test aircraft. Only 16 test flights of 168 planned in FY09 and the 5,000 needed to complete SDD were accomplished and only 12 of over 3,000 SDD success criteria were verified. Flight test results, not modeling and simulation, pace the resolution of two issues: 1) when SDD will complete; 2) what capability the contractor will deliver to using commands/agencies, in the meantime.
  - This was a concurrent program with significant risk at the beginning of the FY09, during which development fell further behind and flight test did not start in earnest. Even assuming all the success that management plans to encounter in the remaining 5,000 flight test sorties, SDD flight test ends at least a year later than previously budgeted in late 2013.
  - In the last year, schedule pressure became manifest in software deliveries and flight testing. Program plans extended the end of flight test for blocks 0.5, 1, 2, and 3 each by 12 months. Missions Systems flight testing in F-35 aircraft does not begin until BF-4 ferries to Patuxent River, which experienced a delay from June 2009 to May 2010.
  - The Services and the JOTT must re-evaluate plans for IOT&E and Initial Operational Capability to account for the extension to SDD. The program must replace any aircraft originally intended for OT&E in a manner consistent with approved IOT&E plans and ensure IOT&E entrance criteria are met before the test readiness date.
  - Future extensions of SDD to complete Block 3 capability are likely if: 1) verification or test resources are cut; 2) shortcuts are taken in accreditation of labs and models intended as test venues; 3) the test team is not able to assimilate and respond to flight test data at the planned pace; 4) discoveries during flight test require pauses and modifications to aircraft that overcome schedule margins; 5) flight test events previously eliminated by the mid-course risk reduction turn out to be necessary to complete development.
- Though pace of flight test determines substantive progress towards completing SDD, the overall verification strategy still relies heavily on labs and models attaining accreditation as test venues.
  - The bulk of the VV&A effort is yet to be accomplished. Thus far, two of 35 accreditation support packages have been approved by the Program Office. Four more are in the draft/review process and 10 are needed to complete Block 1 testing in the next year.
  - However, data from F-35 hardware and software-in-the-loop ground tests and flight tests are needed to correctly implement the VV&A process. Accreditation of the labs and models needs to be event driven, subject to

disciplined oversight by the government and independent review. The program needs to protect against the tendency to use models before they are ready. The impact of not doing so will be to create more risk of discovery of deficiencies during flight test, which the reliance on models was intended to avoid.

- The mission capability of the LRIP systems is unclear. This creates an operational test planning problem for the JOTT and an IOC planning problem for the Services.
  - The process to accurately predict and verify the interim capabilities fielded with each LRIP lot is not yet complete and coherent. Expectations of capabilities provided in the early lots of LRIP aircraft need to be adjusted to the realities of what can be developed and verified before delivery.
  - The program's Air System Capability Matrix and the Capability Cross Reference Matrix focus on functionality, not levels of performance. The matrices lack necessary detail for Services and operational test agencies to determine precisely what mission capability will be delivered when the aircraft and support systems are procured and delivered.
  - Additionally, the Services and operational test agencies need to better understand when and how performance of LRIP deliveries is verified and reported. Given the developing lag in verification and test execution, closing on the capabilities planned for the first three (of eight) LRIP lots by the planned delivery dates is high risk. Lot 4 negotiations begin in early FY10. Beginning with LRIP 2, through LRIP 8, the program needs to provide to the Services and operational test agencies the intended schedule and content of verification (test venues, criteria, standards for evidence) of each contracted LRIP lot in flight sciences, missions systems, weapons integration, and autonomic logistics.
  - Because operational test assets intended for IOT&E are delivered in LRIP 3, 4, and 5, the Services and operational test agencies need to monitor the production-representative quality of these LRIP aircraft and support systems. Given the concurrency of development, production, and test, shortfalls in capability must be recognized early to ensure resources are available to modify these aircraft and support systems so they are production-representative and ready for a successful IOT&E.
- Flight sciences flight testing continues to warrant close monitoring to determine if the assumptions of the mid-course risk reduction test deletions can be validated; such as commonality of handling characteristics among the variants, structures testing predictions, and the skipping of build-up points. If not, additional schedule for flight sciences will be required and a ripple effect in SDD schedules will be further lengthened.
- Current resource plans reduce engineering staff and test personnel too rapidly in the FY10 through FY13 timeframe. Additional resource concerns include: reduced number of missions systems test aircraft, availability of spare engines for flight test, CATB spares for the sensors and basic aircraft, development of a man-in-the-loop full mission model that is also adequate for OT&E, autonomic logistics verification, and network resources for sharing data and integrating plans and activity of multiple test centers/agencies.
- The JOTT OT-2D operational assessment determined that the program is on track to achieve operational effectiveness requirements but not operational suitability requirements. The JOTT concluded that current shortfalls, if not addressed in a timely manner, will prevent the system from providing the required mission capability. The report acknowledged progress in several areas identified in the previous operational assessment. While the F-35 program has progressed in air vehicle, sensors, and support systems development, the report identified several items as continuing to pose substantial operational impact to F-35 mission capability:
  - Autonomic Logistics Information System architecture limits deployment of partial unit detachments and the recovery of diverted aircraft.
  - F-35 thermal management challenges hamper the ability to conduct missions in hot and cold environments.
  - Acoustic, thermal, and blast impacts on airfields and flight decks caused by the propulsion system pose risks to personnel and facilities.
  - Identified information assurance deficiencies have the potential to impact combat operations.
  - Low observable repair process requirements may exceed realistic operational environments.
  - F-35C predicted take-off speeds continue to increase and now exceed tire limits in hot and high density altitude environments.
  - Encryption and decryption timelines impact efficient operations and transfer of intelligence data.
- Block 2 OT&E and Block 3 IOT&E will not be adequate without a verification simulation (VSIM) capability that meets the minimum standards described by the JOTT. The shortfalls identified by the JOTT in the VSIM capability planned by the contractor for verification activities must be addressed in order for the simulation to be adequate for JSF OT&E.
- Ballistically-induced electrical arcing test results showed that, in some instances, circuit protection devices are not effective in preventing electrical arc induced fires initiated from threat induced fuel spillage.
- Pilot-in-the-loop flight simulations with control system damage-induced failures identified failure modes that could result in loss of aircraft and loss of pilot. The results of these tests will be validated with the full-up system-level tests using the AA-1 test article to be conducted in FY10.

Recommendations

- Status of Previous Recommendations. The JPO and Services have made satisfactory progress on 11 of 19 recommendations from FY06, FY07, and FY08. The remaining previous recommendations, which primarily addressed test resources and integration, are valid and merit immediate attention.

- FY09 Recommendations. The program should:
  1. Focus production and test team activities on the earliest possible delivery of SDD flight test aircraft to the test centers and assure these assets arrive ready to begin productive flight test.
  2. Assure adequate resources and plans to increase the pace of flight sciences testing through the completion of SDD in FY15. This includes manpower to increase the flight test sortie rate, analyze data, and direct the integration of all flight sciences test venues.
  3. Through an Operational Test Review Team, establish a schedule using realistic plans for the completion of SDD and IOT&E of Block 3 systems that incorporates the time and flight test aircraft needed to complete SDD. Assure that the JOTT receives aircraft, ground systems, and training consistent with approved TEMP and IOT&E plans. Plan the start of IOT&E based on the entrance criteria in the approved TEMP. Move Milestone C accordingly.
  4. Stabilize the production and deliveries of systems needed for OT&E and initial training for all three variants and assure any OT&E aircraft transferred to SDD flight test are backfilled in a manner consistent with OT&E plans. Assure the JOTT is involved in configuration decisions for these lots. Realize that reducing either developmental or operational test aircraft will increase, not reduce, risk. Link production decisions to performance demonstrated in flight test.
  5. Directly engage the Services, operational test agencies, and DOT&E when LRIP capability content negotiations begin in order to assure a transparent process. Improve the process by focusing LRIP documentation on performance needed to provide the mission capability desired for that lot. Provide the information needed to understand when and how the capabilities of each LRIP lot are verified. Assure resources are available to bring OT&E aircraft and support systems to final, production representative Block 3 configuration before the intended start of IOT&E.
  6. Establish that VV&A of labs and models as test venues will be event-driven, subject to disciplined oversight by the government and independent review. Assure labs and models are not used to close verification success criteria unless formally approved for that use.
  7. Improve the VSIM so that it meets all requirements for adequate verification and operational testing, as described by the JOTT.
  8. Restore the capability to minimize engine fueldraulics fluid spillage from threat-induced damage. Consider the addition of polyalphaolephin (PAO) shutoff valves for all variants.

DOD PROGRAMS