F-35 Lightning II Joint Strike Fighter (JSF)

Executive Summary

- The F-35 test effort increased in June with the addition of Short Takeoff and Vertical Landing (STOVL) test aircraft BF-1, the first of 12 weight-optimized flight test aircraft. While important discoveries improved the design and accomplishments in flight sciences testing occurred, the pace of flight test was slower than planned. The volume of lab and surrogate testing increased. This retired risks in air vehicle development and mission systems. Many of these efforts exceed those of legacy systems at this point in their respective development. Accreditation of all test assets is not complete.
- F135 engine deficiencies place STOVL operations at high risk until further testing demonstrates better performance from a new turbine blade design, intended to address deficiencies found in ground testing. Actual STOVL operations in the aircraft, which the test team plans for mid-FY09, will provide feedback for correction of deficiencies.
- The program incorporated a 12-month extension to System Design Demonstration (SDD) in order to complete Block 3. An updated Acquisition Strategy reflects appropriate operational test schedules and procurement profiles. However, further extension of SDD may be necessary to complete Block 3 due to the growing likelihood that insufficient flight sciences and missions system flight testing are planned. The prime contractor's plans for reducing manpower on the SDD contract do not support a realistic test tempo and should be re-examined.
- The 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 the shutoff fuses and defer consideration of installation of the PAO shutoff valves as an acceptable system trade to balance weight, cost, and risk, DOT&E concerns remain regarding the vulnerability to threat induced fires.
- High production rates concurrent with a relatively slow increase in flight test production over the next three years commit the DoD and Services to high risk test, training, and deployment plans. Program management needs to emphasize maintaining robust engineering/test forces, early completion of detailed test plans, linking fully resourced test venues, accreditation of test assets for assigned tasks, and sharing demonstrated performance in a transparent, shared-data environment. Production and deliveries of OT&E assets for all Services must stabilize.

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 takeoff and landing (CTOL)
  - F-35B STOVL
  - F-35C Aircraft carrier takeoff and landing (CV)
- It is designed to survive in an advanced threat (year 2012 and beyond) environment using a blend of advanced technologies with 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

Activity

- F-35 Flight Test

  BF-1

  - SDD flight test operations added SDD STOVL test aircraft BF-1 in June. First flight occurred four weeks later than planned.
  - By the end of September 2008, testers accumulated 14 test flights, of approximately 5,000 planned for SDD, and demonstrated the ability to fly twice in one day on one occasion.
  - Flight tests led to discoveries in wheel brakes and electrical battery fault isolation that resulted in modifications. BF-1 completed important handling qualities test points in STOVL configurations at medium altitude.

  AA-1

  - Aircraft AA-1 (the non-weight-optimized CTOL SDD test article) continued to mitigate risks for production aircraft, accumulating 54 flights by the end of September 2008. AA-1 experienced a three month down time due to engine bay nacelle vent fan malfunctions that were resolved.
  - AA-1 testing contributed to discoveries in landing gear door fitting, aerial refueling operations, and weapons bay functions, with design and/or production changes in development. Flight tests also demonstrated a portion of heavy gross weight handling characteristics.
  - AA-1 deployed to Edwards AFB, California, on October 1, 2008, to test engine restart in-flight and acoustic test points. AA-1 will return to Fort Worth, Texas, to enter storage for future live fire testing.

- Additional Testing
  - In February 2008, the F135 engine ground testing discovered deficiencies in blade design and manufacturing in the third Low Power Turbine section of the engine. Under STOVL mode conditions at high power setting, a blade fractured and damaged the engine. This failure is the second of its kind in the F135. The contractor is implementing design changes to improve blade performance. The test team plans full STOVL operations after further testing of modified engines in February 2009 at medium altitudes. The test team plans the first short takeoff and vertical landings in mid-2009.
  - The Cooperative Avionics Test Bird (CATB) flew its first four test missions with communications-navigation-identification software and hardware. The test team is preparing the CATB for test operations in November 2008 with mission systems software Block 0.5, the first mission systems software version that provides integrated sensor and processor operations, and the AESA radar. The verification team expects the CATB to maintain a minimum pace of 10 missions per month.
  - The test team conducted testing of electronic protection and attack sensors (radar, electro-optical targeting system, distributed aperture system, and countermeasures systems) in labs and on surrogate aircraft. These labs are not yet accredited for verification tasks.
  - The contractor successfully completed initial mission systems software stability testing in ground labs for Block 0.1, and portions of Block 0.5. Analysis of results is on-going.
  - The contractor investigated weapons bay fit checks and recorded the results for weapons integration engineering analysis. The test team plans initial tests of weapons bay door operations for FY09.
  - The Joint Strike Fighter (JSF) Operational Test Team (JOTT), comprised of the Operational Test Agencies, concluded the third operational assessment, OT-2C, of the F-35 weapons system. The Program Executive Officer assigned responsibility for resolving deficiencies identified in the assessment.
  - The contractor conducted initial structural loads testing on the STOVL test aircraft with loads up to 150 percent of the design load limit. Analysis of the results will support comparison of predictions with actual performance and continued flight sciences testing.
  - Service, Joint Program Office (JPO), contractor, and test teams conducted site surveys of LH and CVN class ships to assess ship suitability factors for the STOVL and CV variants.
- Activity Affecting Test Strategy And Resourcing
  - In April 2008, the Operational Test Review Team, comprised of the JOTT, Service representatives, DOT&E, and the JPO, recommended a minimum extension of 12 months to SDD in order to accumulate the necessary aircraft, train operators, and complete the development and testing needed for IOT&E of Block 3 capability. The Program Executive Officer updated the F-35 Acquisition Strategy accordingly, with the Milestone C/full-rate production decision now planned in FY15.
  - The Marine Corps and the Air Force are conducting reviews of Initial Operational Capability assumptions and criteria since their intended dates, 2012 and 2013, respectively, now occur prior to the completion of SDD and IOT&E of the required Block 3 capability.
  - The JOTT and JPO continued to refine plans for partner involvement in F-35 OT&E resulting in an amendment to the United States - United Kingdom IOT&E Memorandum of Understanding (MOU) that provided for the inclusion of the Netherlands and Italy as participants The Netherlands signed the MOU and associated Statement of Principles; Italy declined.
  - The prime contractor continued work on the Data Analysis Plans that may lead to a completion of the verification test plans. Formal test plan working groups have yet to convene and determine test content necessary to complete SDD. Linking accreditation support packages for verification labs and models to the expected verification activity is also a goal. The contractor is developing a new Air System Capabilities Matrix, which may show the relationship between requirements, test, and production during SDD.

- Lockheed Martin and Pratt & Whitney completed Estimate at Completion (EAC) activities for their respective SDD contracts. As product teams determined necessary increases to budgets, program management sought sources for offsetting funds. The JPO channeled resource needs to the DoD budget process for resolution.
- Lockheed Martin continued product development of the Verification Simulation (VSIM) – a man-in-the-loop model for verification of mission effectiveness in a virtual operational environment. The JOTT provided a document describing the shortfalls of the VSIM for adequate OT&E.
- The JOTT provided an updated operational test input to the Test and Evaluation Master Plan, Third Revision. The JPO plans to produce the final revision in 2QFY09.

• Live Fire Test and Evaluation
- DOT&E has recommended that the JPO reconsider their decision to remove shutoff fuses for engine fueldraulics.
- Live Fire ballistic tests conducted on electrical lines and data lines evaluated the potential for threat impact on wires to initiate fires.
- Live Fire ballistic tests conducted on electro-hydraulic actuators evaluated the capability of the aircraft to maintain flight control with threat damaged control surfaces.
- Flight simulations held in the F-35 Vehicle Integration Facility determined pilots' capability to fly and/or escape from an aircraft with threat damaged flight control systems.

Assessment

• The 12-month extension of SDD is a minimum schedule addition for the completion of Block 3 development. As the ability to avoid future extensions depends on the pace and success of verification test and evaluation, it is essential that: 1) SDD flight test aircraft are delivered on time and quickly integrated into a high pace of testing; 2) all ground and flight test venues become adequately staffed, accredited, and resourced beginning in FY09; and 3) production of OT&E and early training assets are stabilized for all three variants. Early, sufficient, and robust resourcing is critical for a successful SDD that leads to success in IOT&E.
- Flight sciences flight testing warrants close monitoring to determine if the assumptions of the FY07 test reductions 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 may be required and a ripple effect in SDD will occur.
- Current resource plans reduce engineering staff and test personnel too rapidly in the FY09 through FY13 timeframe. Additional resource concerns are: 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 VSIM that is also adequate for OT&E, autonomic logistics verification, and data network resources for sharing data and integrating plans and activity of multiple test centers/agencies.
- The deployed flight test operations at Edwards AFB, California, provided insight into the challenges ahead for the program to integrate multiple flight test operations that will sustain a combined tempo of 140 test flights per month. The analytical, scheduling, and decision-making power of the combined SDD force to discern an appropriate response to flight test data is crucial.

• The test team was not able to maintain the planned test tempo for BF-1 since first flight in June. The test team was able to execute 14 of 20 flights intended in the first 10 weeks. The pace has been affected by delays caused by the engine discoveries, weather, and additional discoveries resulting in minor design changes and electrical fault isolation corrections. However, the test team was able to accomplish the desired flight science test objectives before it was necessary to put BF-1 into modifications for STOVL operations.

• The impact of the contractor's adjustments during the latest EAC budget assessment on verification test and evaluation and planned OT&E is unknown. Program management intended to improve the contractor's management reserve through last year's "mid-course risk reduction," potentially offsetting budget pressures expected to result from this year's EAC. A limited amount of information regarding EAC impacts on testing is available: marginal improvement for flight test manpower at the government test facilities for FY09; reduced signature verification; reduced autonomic logistics verification; and reduced resources for the VSIM.

• Progress in completing high fidelity verification test plans and accreditation of test assets has been slow. Planning teams are behind schedule for completing Data Analysis Plans by nine months.
- The test team completed the Block 0.5 joint flight test plan without a formal test plan working group.
- Progress of accreditation support packages, needed to ensure adequate capability of labs and models to perform verification tasks, is behind the schedule revealed in August 2007.
- The extent of government oversight and specific roles in the process is not clear. In particular, the relationship between requirements documents, the system specification, and new capabilities reference matrices are not yet well defined.

• The JOTT OT-2C operational assessment determined that, while the F-35 program has progressed in air vehicle, sensors, and support systems development, the following items, if not adequately addressed, are likely to pose substantial or severe operational impact to F-35 mission capability or ability to conduct operational test:
- 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.

  - Information assurance deficiencies may place operating limits on the F-35.
  - Lack of cruise energy management functions increased pilot workloads in critical phases of flight.
- The Power Thermal Management System requires a new design to handle the currently known thermal loads on the F-35. A "cooler" main engine fuel pump design is under development but will not be available before low-rate initial production Lot 3, which is likely to impact integrated testing in Block 2 OT&E and, potentially, IOT&E. The test team aborted an AA-1 test sortie due to high fuel temperatures in June. Thermal management is a significant challenge for F-35 development, test, and fielded operations.
- Removal of engine fueldraulics shutoff fuses increases the likelihood of aircraft loss from in-flight ballistic threat induced fires.
- Ballistic tests showed that threat penetration of high voltage electrical wires could cause electrical short circuits, increasing the likelihood of fire in the presence of leaking fuel.
- Flight control system simulations showed that electro-hydraulic actuators were capable of operating threat damaged control surfaces under load.
- Flight simulations indicated that the F-35 might be able to operate with a variety of inoperable flight control components. Final full-up system-level testing planned for FY10 will determine how the aircraft flight control systems react to actual ballistic threat impacts.

Recommendations

- Status of Previous Recommendations. The JPO and Services have made satisfactory progress on six of 12 recommendations from FY06 and FY07. The remaining previous recommendations that primarily addressed test resources and integration are valid and merit immediate attention.
- FY08 Recommendations. The program should:
  1. Add resources and plan to increase the pace of flight sciences testing in FY09, FY10, and FY11. This includes manpower to increase the flight test sortie rate, analyze data, and direct the integration of all flight sciences test venues.
  2. Provide an explanation to DOT&E and the JOTT of all changes to any flight and ground test assets or plans (e.g. manpower, spares, test articles, modeling environments, integration plans) associated with the prime contractors' EAC actions.
  3. Initiate the Test Plan Working Groups using the Data Analysis Plans product; integrate the JOTT and DOT&E in these venues. Report and track the status of accreditation support packages for all test assets.
  4. Stabilize the production and deliveries of systems needed for OT&E and initial training for all three variants. Ensure the JOTT is involved in configuration decisions for these lots. Actions to reduce concurrency risk should not target test assets. Ensure production decisions rely on performance demonstrated in test.
  5. Complete the Third Revision of the Test and Evaluation Master Plan and ensure the developmental test section includes the System Verification Plans and the product of the associated Data Analysis Plans.
  6. Improve the VSIM so that it meets all requirements for adequate verification and operational testing, as described by the JOTT.
  7. Restore the capability to minimize engine fueldraulics fluid spillage from threat-induced damage. Consider the addition of polyalphaolephin (PAO) shutoff valves for all variants.