F-35 Lightning II Joint Strike Fighter (JSF)

Executive Summary

- Fourteen Systems Design and Development (SDD) test aircraft are in production as of the end of FY07.
- Aircraft AA-1, the first SDD flight test aircraft, accomplished 19 flight test missions in FY07, providing valuable data on subsystem reliability and flying qualities.
- Program leadership has taken actions to reduce test assets in order to restore contractor management reserve funds. This increases the likelihood that IOT&E will be unsuccessful and become a period of discovery of deficiencies late in program life.
- Ground labs and models continue to mature and are now planned to be part of the verification strategy.

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 Short takeoff and vertical landing (STOVL)
  - F-35C Aircraft carrier takeoff and landing (CV)
- It is designed to survive in an advanced threat (year 2010 and beyond) environment using a blend of advanced technologies with improved lethality compared to legacy multi-role aircraft.
- Using an Active Electronically Scanned Array 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 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 threat areas at the strategic, operational, and tactical levels of warfare.
- Targets include: fixed and mobile land targets, enemy surface units at sea, and air threats, including advanced cruise missiles.

Activity

- The program conducted 19 test flights with aircraft AA-1 in FY07. The test team reached a peak of eight flights in one month (April) and was also able to fly twice in one day. These activities demonstrated the team's ability to recover and turn to subsequent test missions. AA-1 flights began initial SDD validation of the helmet mounted display, flying qualities work, and flight envelope expansion.
- An electrical anomaly occurred in early May 2007 and flying has not yet resumed. The root cause was identified and a design change is being incorporated to the affected components. Testing is expected to resume in early FY08.
- Ground labs and test beds continue to mature as development and preparation continue for first flight of the first STOVL aircraft in May 2008, a key milestone as it is the first weight-optimized SDD aircraft. It is intended to increase the pace of flight sciences verification.
- The program activated an initial F-35 Autonomic Logistics Information System (ALIS) capability at the flight test operations center at Lockheed Martin, Fort Worth, Texas, in April, 2007. The system is intended to provide initial maintenance and sustainment capabilities in support of the flight test operations.
- Fourteen of 21 planned SDD test aircraft (flight and ground test articles) have entered production. Deliveries are currently forecast to be 2-3 months later than planned for the first 12 test articles. However, the program office and contractor team continue to re-work manufacturing plans and schedules to recover this delay.

- A turbine blade failure occurred on an F-135 test engine in late September 2007. The root cause is under investigation.
- The Operational Test Agencies conducted an operational assessment of the progress made by the F-35 program toward readiness for Block 2 operational testing and Block 3 IOT&E. The agencies will finalize their report in mid-FY08.
- The Cooperative Airborne Test Bed (CATB) completed air worthiness certification and is undergoing modifications to integrate mission systems hardware and software. Flight testing is expected to begin supporting SDD verification by late FY08.
- The Program Executive Officer initiated a Mid-Course Risk Reduction action in mid-FY07 that is intended to replenish the contractor's management reserve through reductions and restructures in the verification (SDD test) plan. The changes to the verification strategy include:
  - Foregoing build-up (intermediate) flight test points and going to end-points earlier in flight test sorties
  - Sharing more test sorties among multiple test disciplines to reduce the overall flight test effort required to complete SDD
  - Shifting verification events from F-35 flight test aircraft to existing ground labs and the CATB
  - Eliminating two SDD mission systems (avionics) flight test aircraft (one CTOL and one CV aircraft)
- Negotiations regarding participation in the operational testing of the F-35 continued with representatives of the interested partner governments. Agreements are expected to be finalized in early FY08.
- The Director of LFT&E approved the program's plan to replace BF-4 Full-up System Level (FUSL) LFT&E with an AA-1 FUSL ballistic test article and an addition of a STOVL full-scale structural test article (FSSTA) and stand-alone lift systems for ballistic testing.
- The program office removed five of six dry bay fire suppression systems. The Director of LFT&E sent a memo to the program office urging the reconsideration of this decision.
- The program conducted live fire composite panel ballistic tests, chemical/biological agent decontamination tests, and F-1 fuel tank ballistic tests.

Assessment

- The program greatly benefitted from the AA-1 flight test. Benefits range from discovering needed modifications to subsystem design to maturing the flight test planning, execution, and analysis process.
- The new verification strategy, resulting from the mid-course risk reduction actions, requires careful monitoring to determine if the changes have unintended consequences such as an inadequate or unsuccessful IOT&E.
  - The high volume of "build-up" points set aside from flight test could impact multiple areas if it is determined after analysis of end-point performance that build-up points must be flown to verify system performance after all.
  - The transition of the ground labs and CATB to verification assets requires analysis and action to ensure proper integration with flight test operations through:
    - Adequate resourcing for planned and surge tempo in manpower, data analysis tools, communications/links, and spares
    - Successful accreditation of high fidelity ground labs and CATB for three variants
  - Concurrent flight testing through "ride along" or "shared sortie" plans emphasizes unprecedented integration and real time coordination among the multiple flight test components. Impact of poor, incomplete/inaccurate communications will be significant. The flight test force must also be adequately resourced for planned and surge tempo throughout the SDD test program. The analytical, scheduling, and decision-making power of the combined SDD force to discern an appropriate response to flight test data is even more crucial as this program will peak near 140 test flights per month (as compared to 65 for peak months in F-22 development test and evaluation).
- Eliminating the last two SDD mission systems flight test aircraft increases the likelihood that IOT&E will be unsuccessful and become a period of discovery of deficiencies:
  - Mission systems flight testing will inevitably be in need of a higher than predicted pace of F-35 flight test operations as the program approaches IOT&E.
  - Important items were eliminated from the test:
    - Second CV flight test aircraft for ship suitability trials/ demos
    - Flight test of a second CTOL aircraft for signature
    - A significant portion of autonomic logistics input/ throughput and reliability data for missions systems test aircraft which may impact the ability to evaluate F-35 operational suitability
  - Fixes to problems identified through IOT&E and the follow-on development to IOT&E, Block 4, will need the planned full complement of mission systems flight test aircraft.
    - The improvements found necessary in IOT&E will need to be proven quickly through re-test
    - The follow-on development phase in legacy programs was poorly resourced and planned for very late
  - Attrition inventory is key to sustaining the intended tempo of F-35 verification plan. Eliminating two high-leverage test aircraft loses an important hedge against attrition or unavailability of mission systems assets.
- Some mitigation features intended to lessen negative consequences of changes made to the verification strategy are being examined or put in place (such as planning a dual-role mission systems and flight sciences aircraft, funding the CATB throughout SDD, reasonable re-fly/regression factors, potential use of early production aircraft in SDD verification flight test). However, it is unknown if these actions will be sufficient if available flight test resources are not adequate for the pace

required in the 12-24 month period prior to the planned IOT&E start date.
- The proposed chemical/biological agent decontamination methods successfully decontaminated F-35 ground support equipment.
- Removal of several vulnerability reduction features increased ballistic vulnerability of the F-35:
  - Threat impact on the F-1 fuel tank without the engine fuel ingestion suppression liner produced large fuel leakage rates into the engine. Testing with the liner demonstrated its effectiveness.
  - Ballistic damage to the STOVL propulsion system lift fan shaft can result in catastrophic failure upon transition to vertical landing. Detectable lift fan shaft vibrations occur from ballistic damage. The STOVL lift fan shaft vibration sensor is not part of the pilot caution and warning system.
  - Removal of five of six dry bay fire suppression systems increased the potential for aircraft loss from threat induced fires.
- Live Fire tests showed that threat penetration of composite material aircraft skin are more likely to start fires than predicted.
- The program is considering removal of shutoff valves for flammable liquid cooling system and engine fueldraulics. The removal of these valves will increase the likelihood of in-flight fires and possible aircraft loss.

Recommendations
- Status of Previous Recommendations. The joint program office and Services have made satisfactory progress on most of the FY05 and FY06 annual report recommendations. The following previous recommendations remain valid:
  - DOT&E recommended that the program identify all test resource shortfalls in opposing force/threats and present a solution that mitigates these (FY05).
  - DOT&E recommended that the program develop a predictive model to determine how test data on engine performance following "quick dump" fuel ingestion at the sea level test site could be extrapolated to predictions for higher operating altitudes (FY05).
  - DOT&E recommended that the program conduct additional full-up, system-level Live Fire ballistic tests to determine the vulnerability of the F-35 with only one dry bay fire suppression system (FY06). The program plans to conduct additional tests.
- FY07 Recommendations. The program should:
  1. Retain the last two SDD mission systems flight test aircraft.
  2. Ensure the ground labs, CATB, and flight test components are adequately resourced to execute the verification strategy (manpower, spares, connectivity) at planned and surge pace of operations.
  3. Ensure that metrics under development to monitor the effects of the changes to the verification strategy adequately predict the need to invoke mitigation plans to avoid failing to prepare the system for IOT&E.
  4. Develop an executable transition plan for IOT&E from the end of SDD, using detailed entrance criteria for IOT&E. Of significant concern are: weapons integration testing, mission systems verification, fully trained operators, and sufficient operating envelope for production representative aircraft.
  5. Reinstate five dry bay fire suppression systems, previously removed.
  6. Reinstate the engine fuel ingestion suppression liner in the F-1 fuel tank.
  7. Add cockpit warning indicators to alert the pilot of STOVL system ballistic damage prior to transition to vertical landing.
  8. Retain engine fueldraulics and liquid cooling shutoff valves to improve F-35 survivability.