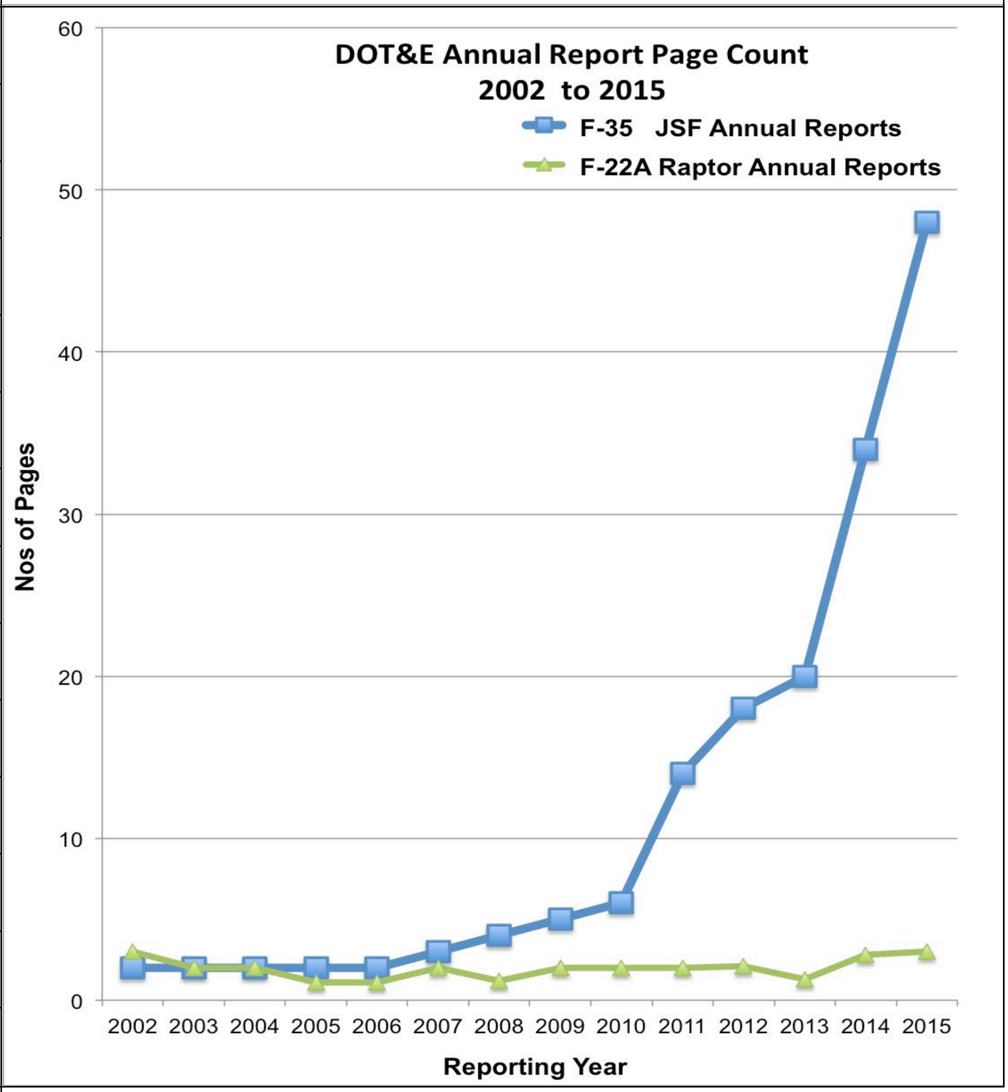
COMPENDIUM OF DOT&E ANNUAL REPORTS: F-35 JSF PROGRAM

Report Year	*Page Count*
2002**	2
2003**	2
2004	2
2005	2
2006	2
2007	3
2008	4
2009	5
2010	6
2011	14
2012	18
2013	20
2014	34
2015	48
Total:	162

Page Count Chart



** *Go to 'Attachments' to view these annual reports*

Notes:

1. DOT&E reports annually on all Major Defence Acquisition Programs (MDAP). The reports focus on major issues/problems discovered during the year, identifying areas of risk arising from these that are assessed as warranting further action.
2. A standard way for assessing the health of any MDAP is to read its latest DOT&E Annual Report in conjunction with preceding reports, then comparing the findings with the results and management plans from the MDAP Technical and Programmatic Risk Assessments since program approval and, importantly, those assessments and plans produced prior to DOT&E reporting of related issues/problems.
3. Data for another aircraft MDAP are provided for comparison.

F-35 Joint Strike Fighter (JSF)

SUMMARY

The program has spent the last year on efforts to reduce the aircraft weight and ensure the viability of the STOVL design.

- The F-35 Joint Strike Fighter (JSF) meets all the Services' needs for a strike fighter aircraft with a family of common aircraft. The three variants of this aircraft are:
  - Conventional Takeoff and Landing
  - Aircraft Carrier Suitable
  - Short Takeoff and Vertical Landing (STOVL)
- JSF will be capable of striking and destroying a broad range of targets, day or night, in adverse weather conditions. These targets include fixed and mobile land targets, enemy surface units at sea, and air threats ashore and at sea including anti-ship and land attack cruise missiles.
- The program has spent the last year on efforts to reduce the aircraft weight and ensure the viability of the STOVL design.
- The impact of the loss of commonality between the three variants, resulting from the weight reduction efforts, will require an increase in the scope of the flight test effort and will require a revision to the current Test and Evaluation Master Plan (TEMP).

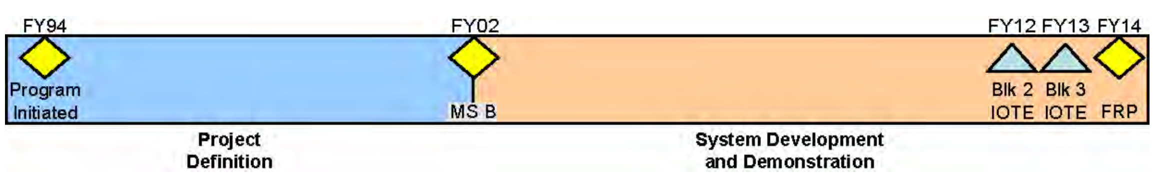
SYSTEM DESCRIPTION AND MISSION

JSF is a joint, multi-national program for the U.S. Air Force, U.S. Navy, U.S. Marine Corps, and eight cooperative international partners: the United Kingdom, Italy, the Netherlands, Turkey, Canada, Australia, Denmark, and Norway. This family of strike aircraft will consist of three variants: conventional takeoff and landing; aircraft carrier suitable; and STOVL.

The System Development and Demonstration (SDD) phase is a block program to develop, acquire, and test the JSF in a series of upgrades. To accommodate the phased integration of capabilities and functionality, the Integrated Test Force and the operational test agencies will test interim blocks. As the SDD phase progresses, the users will develop requirements for additional capabilities for future block upgrades to respond to new threats.

Biennial operational assessments (OAs) will determine potential operational effectiveness and suitability with a focus on programmatic voids, areas of risk, testability of requirements, significant trends in development efforts, and the ultimate ability of the program to support an adequate period of evaluation during the dedicated operational test and evaluation of Blocks 2 and 3. OAs will not replace the independent period of dedicated operational testing necessary to support a full-rate production.

TEST AND EVALUATION ACTIVITY



The Air Force Operational Test and Evaluation Center and the Navy's Operational Test and Evaluation Force conducted an OA of JSF and issued a report on their findings in mid-2004. This OA was the first in a series of five planned during the SDD phase. Although a limited amount of new data were available because of the redesign efforts, the report found that the JSF program is making satisfactory progress toward being an effective and suitable system. However, the following areas require attention:

- The base and ship infrastructure were not designed for the JSF security-operating environment. The JSF Program Office (JPO) and the Services are working to mitigate impacts.
- The JSF concept of operations requires performance in very hot climates. The predicted air vehicle thermal output in this environment will cause significantly degraded performance.
- JSF users have a requirement for future growth in the areas of power, volume, and cooling. Future growth allocations are in jeopardy for all three areas. The initial design requires excess capability in order to meet future requirements.

Insight from Live Fire Test and Evaluation (LFT&E) tests conducted during FY04 is part of the design effort.

TEST AND EVALUATION ASSESSMENT

This past year the JPO has focused on reducing the aircraft's vehicle weight. Aircraft weight is not a key performance parameter. However, weight reduction for the STOVL variant is critical to satisfy performance requirements. The Conventional Takeoff and Landing and Aircraft Carrier Suitable variants will benefit from weight reductions, but the current designs are low risk to satisfy key performance parameters. The JSF Program Office assesses that approximately 3,500 pounds of weight reduction is required for the STOVL variant in order to satisfy all key performance parameters. By the end of FY04, the JPO achieved approximately 2,700 pounds of weight savings/offsets through a three-step process.

- First, a STOVL variant weight attack team explored weight-savings design ideas. The most significant design change was a return to a thousand-pound weapon-capable bay.
- Second, the JPO made changes to the operating ground rules and assumptions for verifying requirements. These changes include reserve fuel requirements, ship landing patterns, and wave-off procedures.
- Third, the JPO conducted an analysis of requirements to determine where relief is prudent to balance warfighting needs and design realities. The most significant relief is a change to the mission profile to mirror that of the U.S. Navy's high altitude profile. Adopting the U. S. Navy profile permits the STOVL aircraft to satisfy the flat deck takeoff and range key performance parameters with a fuel weight 1,700 pounds less than the fuel capacity of the aircraft.

The STOVL weight reduction target of 3,500 pounds is optimistic.

- The JPO is utilizing a weight growth of three-percent during the SDD phase. DOT&E's weight threat assessment uses a six-percent growth value.
- DOT&E assesses there is an additional 800 to 1,000 pound threat to the STOVL design associated primarily with the difference in weight growth assumptions.
- Additionally, the cost to Force providers and warfighters of light-loading the STOVL aircraft with 1,700 pounds less fuel has yet to be determined.

DOT&E assesses the STOVL design is viable for the U.S. Air Force requirement for a short takeoff capability, but sees significant risk remaining in satisfying the U.S. Marine Corps shipboard operations requirements. The JPO must continue to reduce the weight of the STOVL design and should reassess their weight growth assumptions.

Another risk to the JSF program is the software development. The JSF requires an unprecedented amount of software. Block 3 delivers the majority of the capability. The slope of the learning curve and efficiencies required to execute Block 3 software development exceeds previous software development programs.

The scope of the flight test effort in the approved TEMP was acceptable when a high degree of commonality existed between the three variants. The weight reduction efforts have reduced the commonality between the variants - particularly in the area of weapons separation testing. The flight test program will have to grow to accommodate the new schedule and loss of commonality.

F-35 Joint Strike Fighter (JSF)

Executive Summary

- The program has resumed test planning following the replan action. DOT&E is reviewing a draft Test and Evaluation Master Plan (TEMP).
- Operational test resource shortfalls include instrumentation and adequate opposing forces/threats. These require plans and investment.
- Live Fire ballistic vulnerability testing:
  - Identified high performance dry bay fire extinguisher candidates
  - Demonstrated that the F-35 concept development aircraft engine is vulnerable to fuel ingestion

System

- The F-35 Joint Strike Fighter (JSF) is a joint, multi-national, single-seat, single-engine family of strike aircraft consisting of three variants:
  - Short takeoff and vertical landing (STOVL)
  - Conventional takeoff and landing (CTOL)
  - Aircraft carrier takeoff and landing
- 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 fielded air-to-ground, multi-role aircraft.
- Using an Active Electronically Scanned Array (AESA) radar and other sensors, the F-35 will 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.

Mission

- A force equipped with F-35 units is designed to 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 cruise missiles.

Activity

- Test planning resumed to support the FY05 replanning of the acquisition program.
- The program office provided DOT&E a draft TEMP in October 2005. In finalizing the TEMP, DOT&E will continue to work with the program office and operational test agencies to ensure: clear identification of capabilities for each block, linkage of test scenarios to Defense Planning Scenarios, and adequate numbers and types of operational test scenarios and correction of deficiencies.
- Live Fire ballistic vulnerability testing included:
  - Baseline dry bay fire suppression system and three alternative fire suppression technologies. The tests evaluated the fire suppression systems' performance against fires caused by ballistic penetration of high explosive incendiary rounds into the main landing gear.
  - The capability of the F-35 concept demonstration aircraft engine to operate during "quick dump" fuel ingestion that could accompany a ballistic penetration of the engine inlet duct.

Assessment

- Threat shortfalls are not addressed in the test plan. These shortfalls must be readdressed for realistic operational testing. The shortfalls include: opposing aircraft and surface threats that represent multi-spectral detection and engagement capability, threats with lethality projected in the FY11 timeframe, and threats with mobile and relocatable capabilities.
- Data collection capability will be inadequate to evaluate mission-level effectiveness and suitability. Instrumentation is needed to determine F-35 lethality and survivability in a complex, realistic operational test. The F-35 program does not currently plan to instrument operational test aircraft.
- The current user requirements document does not reflect the rebaselined program block capabilities.
- The Joint Program Office continues efforts to control weight of all variants, in particular that of the STOVL aircraft. Optimized designs are underway for the STOVL and CTOL variants. Actual weight of the first CTOL aircraft validated its weight predictions.

- Live Fire testing:
  - Identified a candidate fire suppressor that successfully demonstrated dry bay fire suppression in the main landing gear bay using less agent and longer time delays than the original design. This more robust design allows for the placement of redundant fire suppressors that could extinguish fires even if a single suppressor is destroyed by fragments from a ballistic threat.
  - Results from the "quick dump" fuel ingestion test showed significant damage to the concept demonstration aircraft engine. A new concept demonstration aircraft engine may be required to continue Live Fire testing. The program is disassembling the damaged engine to determine what components failed, and to evaluate whether the production configured engine could fail in a similar way due to fuel ingestion.

Recommendations

1. Develop an F-35 data collection and range interface capability that enables precise mission replay and data capture to evaluate mission-level effectiveness and suitability.
2. Identify all test resource shortfalls in opposing force/threats and present a solution that mitigates these.
3. Align the requirements for each block with the replanned program.
4. 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.
5. Reduce the fuel ingestion vulnerability. This could be done, for example, by improving the fuel bladders around the inlet ducts or improving the engine design to be more tolerant to "quick dump" fuel ingestion.

F-35 Lightning II Joint Strike Fighter (JSF)

Executive Summary

- The F-35 Lightning II program continues to make progress on the first System Design and Development aircraft. First flight is expected to occur in mid-December 2006.
- Work on a Test and Evaluation Master Plan revision continues. The revised document needs to incorporate more detail on test content and adequate resources for operational test and evaluation.
- The Air Force and Navy FY08 Program Objective Memoranda do not support an adequate full-scale aerial target replacement necessary for F-35 weapons integration testing. The operational test planning for the F-35 is not adequate without a credible full-scale aerial target.
- The Air Force and Navy operational test agencies completed an operational assessment of F-35 development in late 2005. Issues raised in the assessment are under review by the program office and require follow-up.
- Live Fire ballistic vulnerability testing:
  - Evaluated candidate dry bay fire extinguisher designs
  - Determined the extent of fire migration from the roll duct to the engine

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 cruise missiles.

Activity

- The program began using the F-35 ground lab system, which contains actual aircraft systems. The lab connects missions systems with air vehicle systems to operate as an aircraft allowing test and trouble shooting on the ground.
- Using the initial software as checked out in the ground lab system, the first System Design and Development aircraft completed engine operations from idle power to full afterburner and pre-mission power-on checks. First flight is expected to occur in mid-December 2006.
- Engine ground tests accumulated approximately 6,100 hours on 11 F135 engines and 240 hours on 2 F136 engines.
- Development of the Cooperative Avionics Test Bed continues; it is a structurally modified Boeing 737 commercial airline aircraft fitted with an F-35 simulator cockpit, mission systems sensors, and avionics. It includes 20 engineering workstations to assess mission systems performance. Flight testing with F-35 mission systems avionics is planned to begin in 2007.
- The operational test agencies completed an operational assessment in November 2005 and reported results to the program office and the Defense Acquisition Board in May 2006.

- DOT&E is reviewing the Test and Evaluation Master Plan revision completed by the program office. It has not been formally submitted to DOT&E for approval.
- Negotiations have begun with interested partner nations to define involvement in combined operational test and evaluation.
- Live Fire ballistic vulnerability testing and analyses included:
  - Dry bay fire suppression system tests to evaluate the fire suppression systems' performance against high explosive incendiary rounds
  - Roll duct fire migration testing to evaluate the extent of fire migration from the roll duct to the engine
- The Joint Strike Fighter program office made the decision to remove five of the six dry-bay fire suppression systems.

Assessment

- The Test and Evaluation Master Plan revision lacks details on test content, measures for performance, and does not establish specific resource requirements for adequate opposing forces and targets in open air and modeled test events.
- The Air Force and Navy FY08 Program Objective Memoranda do not support an adequate full-scale aerial target replacement necessary for F-35 weapons integration testing. The operational test planning for the F-35 is not adequate without a credible full-scale aerial target.
- The issues cited by the operational test agencies in the operational assessment warrant continued follow-up and further assessment. The program office is studying resolution of the helmet mounted display integration, thermal management issues, flight test schedule executability, instrumentation for operational testing, and maintainability issues.
- Given the high degree of concurrency in F-35 development, a commitment to event-driven decisions and ensuring readiness to begin operational test and evaluation is critical.
- Live Fire testing and evaluation revealed:
  - The fire suppression system successfully suppresses dry bay fires in the protected bays and successfully reduces fire migration into surrounding bays
  - Threat induced fires in the roll duct bay can migrate into the engine bay generating high temperatures
- The Joint Strike Fighter program office's recent decision to remove five of the six dry bay fire suppression systems from each variant will significantly increase the vulnerability of the aircraft to ballistic threat induced fires. It will also adversely affect the safety of the aircraft from non-ballistic induced fires.

Recommendations

- Status of Previous Recommendations. The joint program office and Services have made satisfactory progress on FY05 recommendations, with the exception of:
  FY05 #2: DOT&E recommended that the program identify all test resource shortfalls in opposing force/threats and present a solution that mitigates these. No progress has been made on this recommendation. The Test and Evaluation Master Plan revision should establish these test resource needs before being submitted for approval by DOT&E.
  FY05 #4: 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. No action has been taken.
- FY06 Recommendations. The program should:
  1. Ensure follow-up on the issues cited by the operational test agencies in the recent operational assessment.
  2. Consider opportunities to conduct IOT&E at an earlier point in initial production with operationally representative weapons systems.
  3. Follow the framework for partner operational test planning outlined by the Defense Acquisition Board in May 2006.
  4. Fund an adequate full-scale aerial target replacement in order to ensure the resources will exist to confirm F-35 operational effectiveness.
  5. 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.

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.

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.

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.

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.

F-35 Joint Strike Fighter (JSF)

Executive Summary

- The high level of concurrency of production, development, and test created several challenges for the program and the Services:
  - Preparing to begin flight training at the integrated training center with immature aircraft
  - Developing and resourcing structural modification plans for early production aircraft to meet service life and operational requirements
  - Developing and resourcing configuration upgrade plans to achieve final Block 3 capability
- The flight rate in flight sciences testing for all variants in 2011 matched or exceeded the new, restructured flight test plan for 2011. Measurements of progress based on test points accomplished indicate mixed results for flight sciences of the three variants: both the F-35B Short Take-Off/Vertical-Landing (STOVL) variant and the F-35A Conventional Take-Off and Landing (CTOL) variant are behind schedule (9 and 11 percent, respectively), and the F-35C Carrier Variant (CV) is 32 percent ahead.
- Very limited mission systems software flight testing took place in 2011. Additionally, concurrency between development and testing of mission systems blocks of capability is growing and this growth in concurrency increases risk. Development, integration, and flight testing of the most complex elements of mission systems lie ahead.
- In October 2011, the program successfully conducted initial amphibious ship trials with STOVL aircraft in accordance with the new, restructured plan for 2011; however, significant work and flight tests remain to verify and incorporate modifications to STOVL aircraft required to correct known STOVL deficiencies and prepare the system for operational use.
- Although it is early in the program, current reliability and maintainability data indicate more attention is needed in these areas to achieve an operationally suitable system.
- The program completed full-up system-level (FUSL) testing of the first flight test aircraft, as required under the LFT&E plan. Test results confirmed the ability of the airplane to isolate ballistic damage to targeted components, validating the robustness of both the flight control and electrical power systems. Nonetheless, live fire tests and analyses showed the fuel tank inerting system is incapable of providing protection from threat-induced fuel tank explosions during some critical segments of combat missions when the aircraft is most likely to be hit. The program is redesigning the system. Upon completion, the redesigned system will be evaluated to determine if it provides the required protection.

Actual versus Planned Test Flights and Points through November 2011

		ALL VARIANTS ALL TESTING		STOVL ONLY FLIGHT SCIENCES		CTOL ONLY FLIGHT SCIENCES		CV ONLY FLIGHT SCIENCES		MISSION SYSTEMS (MS)			OTHER MS TEST ACTIVITY
		Flights	Points	Flights	Points	Flights	Points	Flights	Points	Flights	Block 0.5 Points	Block 1.0 Points	Points[1]
CY11	ACTUAL	915	6,079	308	1,972	264	1,710	154	1,355	189	116	183	743
	PLANNED	812	5,509	268	2,175	263	1,925	148	1,023	133	111	125	150
Cumulative[2]	ACTUAL	1,371	11,612	564	4,848	426	3,474	181	2,151	200	203	183	753
	PLANNED	1,252	11,042	563	5,051	349	3,689	179	1,819	161	198	125	160
Estimated Quantities Remaining[3]		4,207	48,044	1,437	15,045	827	10,257	1,002	12,442	941	185	1,108	1,862
											8,438[4]		

Notes:
1. Other test activity requiring mission systems aircraft that was not mission systems software capability verification (i.e. maturity flights, survivability measurements).
2. Due to re-baselining in early 2011, "planned" test points are equal to the actual test points for activity prior to 2011.
3. Estimates of tests remaining include only the required number of successful flights and baseline test points. Discovery, regression, and re-fly factors are not included.
4. Mission systems estimate includes total remaining Test Points to complete System Design and Development test plans for Blocks 0.5 through Block 3.0.

System

- The F-35 Joint Strike Fighter (JSF) program is a tri-Service, 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/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 in this environment 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 provides mission capability in three increments: Block 1 (initial training), Block 2 (advanced), and 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

Test Strategy, Planning, and Resourcing

- The program applied the recommendations of last year's Technical Baseline Review (TBR) to the System Design and Development (SDD) phase test and verification plans. The program established a new integrated master schedule for the 2011 calendar year, and rebaselined all test metrics beginning January 2011.
- In November 2011, the program implemented the changes to the SDD flight test schedule recommended by the TBR. These changes included lowering planned flight rates, increasing planned downtime for modifications of test aircraft, changing roles for some SDD test aircraft, adding production aircraft as developmental test aircraft, lengthening software development spans, increasing the number of flights dedicated to weapons integration, and adding sustainment support for flight test.
- Throughout 2011, the program developed a new integrated master schedule (IMS) for the remainder of SDD. In December 2011, the program incorporated the new SDD flight test schedule (which included the TBR recommendations) in the new, draft IMS. The final IMS is expected to be available in early 2012.

F-35 Flight Test

F-35A Flight Sciences, Flight Test with AF-1, AF-2, and AF-4 Test Aircraft

- The program achieved the full complement of planned F-35A flight sciences SDD test aircraft with the delivery of aircraft AF-4 in January 2011. F-35A flight sciences testing focused on expansion of the flight envelope in transonic and supersonic flight regimes, improving handling qualities by reducing the impact of transonic roll-off, and accomplishing the test points required for the initial training capability flight clearance.
- As of the end of November 2011, the test team was able to accomplish the planned sortie rate of 7.7 flights per aircraft per month (264 flights accomplished, 263 planned). However, the number of test points accomplished lagged the planned baseline productivity by 11 percent (1,710 test points accomplished of 1,925 planned). The program discovered a test point metrics accounting error in November and adjusted the CY11 planning numbers accordingly. The error caused a projection of an additional 590 F-35A flight sciences test points than were actually called for in the test plans for 2011.
- In addition to the content of the approved baseline test plans, the program discovered requirements for additional testing. The test team accomplished an additional 358 test points per the program's flight test request process, which is the formal process for adding flight tests that are not part of the existing, approved test plan.

F-35B Flight Sciences, Flight Test with BF-1, BF-2, BF-3, BF-4, and BF-5 Test Aircraft

- In accordance with the post-TBR re-planning guidance, the program modified two mission systems F-35B test aircraft, BF-4 and BF-5, as flight sciences aircraft and modified the original three flight sciences test aircraft (BF-1, BF-2, and BF-3) to improve their STOVL-mode capabilities and instrumentation. BF-4 and BF-5 may accomplish either type of testing: flight sciences or mission systems. In 2011, BF-4 and BF-5 focused on flight sciences. This brought the number of F-35B flight science test aircraft to five, which is the full complement in the new plan.
- F-35B flight sciences focused on preparation for the first developmental test trials on a large deck amphibious ship, which began on October 3, 2011, as planned in the new master schedule for 2011. The test team also worked to

expand the flight envelope for F-35B pilot training (planned to begin in early 2012), conducted air refueling testing, and surveyed handling characteristics in transonic flight regimes.
- As of the end of November 2011, the test team was able to exceed the planned flight rate of 5.1 flights per aircraft per month, exceeding the total flight goal by 15 percent (308 flights accomplished, 268 required). By the end of November 2011, overall test point progress against planned baseline productivity was slightly behind (9 percent). The program also identified additional F-35B flight sciences test requirements and accomplished 213 of these test points added by flight test requests.

F-35C Flight Sciences, Flight Test with CF-1, CF-2, and CF-3 Test Aircraft
- The production team delivered test aircraft CF-2 and CF-3 to the Patuxent River, Maryland, test center in May and June 2011, respectively. CF-3 is primarily a mission systems test aircraft, but is capable of limited flight sciences activity, such as ship trials. The program plans to deliver the final F-35C flight sciences aircraft, CF-5, in late 2012.
- F-35C flight sciences focused on preparing for and executing carrier landing and catapult launch testing in the simulated carrier environment at the Lakehurst, New Jersey, test facility. The test team also began envelope expansion in the transonic regime, weapons bay environment testing, and evaluation of handling qualities with weapons bay doors open.
- As of November 2011, the test team exceeded the planned flight rate of 4.3 flights per aircraft per month, accomplishing 154 flights against a planned total of 148. Test point production exceeded the goal by 32 percent. The program also identified additional flight test requirements for F-35C flight sciences and accomplished 132 of these points added by flight test requests.

Mission Systems, Flight Tests with AF-3, AF-6, and AF-7 Test Aircraft and Software Development Progress
- The program successfully added F-35A production lot 1 aircraft AF-6 and AF-7 as mission systems test assets at the Edwards flight test center, California, in June and May 2011, respectively. Because the program plans for these aircraft to eventually be operational test aircraft, they contain instrumentation that makes them useful as mission systems test aircraft. This brings the total number of dedicated mission systems test aircraft at present to three; this number may be augmented by aircraft BF-4 and BF-5 at the Patuxent River test center, as they have a primary role as F-35B flight sciences assets. For example, aircraft BF-4 accomplished eight mission systems flights early in the year before entering modifications for F-35B flight sciences ship trials. The program plans to provide three more operational test aircraft from production lots 3 and 4 to the mission systems test fleet – F-35B aircraft BF-17 and BF-18 (in late 2012) and F-35C aircraft CF-8 (in early 2013).
- The test team attempted mission systems test points needed for acceptance and delivery of the lot 2 and lot 3 aircraft to the training center. The test team also accomplished other flight test activity requiring the use of mission systems aircraft, such as signature tests and "maturity" flights designed to determine the readiness of the F-35A air vehicle for the start of pilot training.
- As of the end of November 2011, mission systems test aircraft exceeded the planned flight rate of 5.2 flights per aircraft per month by 42 percent. The team exceeded the combined Block 0.5 and Block 1 test point goal of 236 by 27 percent. The program identified additional mission systems flight test requirements and accomplished 67 of these points added by flight test requests. The team had not completed any of the 60 Block 2 flight test points, which the program intended to begin in November 2011.
- Block 0.5, Block 1A, and Block 1B Initial Training Capability for Lot 2 and Lot 3 Aircraft
  - **Block 0.5.** Most of the Block 0.5 test points (78 percent) remained to be accomplished after the end of 2010. In 2011, the test team planned to accomplish 130 of the 301 remaining Block 0.5 test points concurrently with Block 1 testing. Block 1 capability has two parts: Block 1A for lot 2 aircraft and Block 1B for lot 3 aircraft (retrofit to lot 2).
  - **Block 1A.** The program and the Air Force determined that the initial Block 1A capability and the F-35A air vehicle required additional testing and deficiency resolution in order to be suitable for unmonitored flight at the training center. Early in 2011, plans for the airworthiness certification process initially anticipated that 200 to 400 hours would need to be accumulated in order to have sufficient flight hours to facilitate a maturity decision. The Edwards test team added a "maturity" flight test plan and used the instrumented lot 1 mission systems test aircraft, AF-6 and AF-7, which were delivered in May (five months later than previously planned), to accomplish these flights. The results of these flights, along with other flight test data, are inputs to the Air Force's airworthiness decision and official military flight release for the lot 2 aircraft at the training center. Through mid-October 2011, the test team accomplished 34 F-35A maturity flights flown in the initial training syllabus mission profile, accumulating 58.6 hours on AF-6 and AF-7 combined. Between early July and early November, an additional 10 sorties and 19.9 hours were flown in AF-6 and AF-7 with the initial Block 1A software configuration in flights accomplishing other mission systems flight test objectives. By the end of November 2011, the program accumulated a total of 44 sorties and 78.5 hours on the Block 1A software in the F-35A air vehicle for consideration in the Air Force airworthiness decision.
  - **Block 1B.** Software integration tasks for Block 1B mission capability were 90 percent complete by the end of September 2011 when it began flight test, three months late based on the new plan. This increment includes new functionality for sensor fusion, electronic

warfare, and onboard imagery, as well as system security provisions. As of the end of November 2011, less than half of the Block 1B capabilities (12 of 35) had met full lot 3 production contract verification requirements for aircraft delivery. Five of the remaining capabilities were under consideration to be deleted from the requirements since they were associated with weapons capabilities not available until lot 5 in the new IMS. The remaining 18 capabilities have some degree of variance from the expected performance.
  - Tests of two systems integral to Block 1 (and later) capability, the Identification Friend-or-Foe Interrogator (IFFI) and the laser in the Electro-Optical Targeting System experienced delays in 2011. This was due to delays in obtaining clearances from the government agencies that oversee their use. While limited testing of the IFFI system has been conducted off-shore in non-restricted airspace, clearance for testing in national airspace (planned for May) had not been received as of this report. Clearance for testing the laser did not occur until November, while testing was planned to start in June 2011. These delays affected the ability of the test team to accomplish the 192 Block 1 test points assigned for laser and IFFI testing during the year.
- Block 2 and Block 3 Software Development Progress
  - The program intends to provide Block 2 capability for production lot 4 and lot 5 aircraft; lot 4 aircraft should begin to deliver in mid-2012. In the new plan, the program intends Block 2 to contain the first mission systems combat capability – including weapons employment, electronic attack, and interoperability.
  - Concurrent with Block 1 development and integration, the program began integration of initial Block 2A software using the Cooperative Avionics Test Bed (CATB) in early October 2011. The development team augmented the mission systems integration lab, which was busy supporting Block 1 tasks, with the CATB as an integration resource. The new plan calls for the beginning of Block 2A flight test on F-35 mission systems aircraft before the end of November 2011. However, initial Block 2 integration task execution has fallen behind the new plan, having completed approximately half of the planned schedule, and leaving approximately 70 percent of integration tasks to go.
  - Block 3 development is slightly behind the new plan with only 30 percent of initial Block 3 having completed the development phase. In the new plan, the program simplified Block 3 to two production releases instead of three in prior planning and schedules. The program plans the first release, Block 3i, to contain no substantive increase in functions or capability. It will re-host the final Block 2 capability on the upgraded "Technical Refresh 2" processor hardware set. The program intends Block 3i capability for production lot 6 and lot 7 aircraft. Block 3f, the final increment, includes new capability. The program intends to deliver Block 3f for IOT&E and the final lots of low-rate production.

Modeling and Simulation

Verification Simulation (VSIM)

- The program determined that the man-in-the-loop verification simulation that will meet the operational test agencies' intended use would be located at Marietta, Georgia, for both Block 2 and Block 3 testing.
- The contractor worked through validation of the requirements of the simulated battlespace environment and the F-35 own-ship modeling with the program office, the verification team, and the JSF Operational Test Team.
- The Lockheed Martin VSIM verification and validation team provided inputs to the Block 2 flight test plan that will begin execution in late 2011. The program continues to work to source the data that will be needed to validate this simulation for operational testing.
- The program began a technical assessment of simulation validation challenges that have been identified by the operational test community, and is exploring these in a series of detailed technical reviews that began in 2011 and will continue into 2012.

Other Models and Corporate Labs

- Of the 28 models and simulations currently planned to support verification of the F-35, the program office has accredited four. In 2011, the program accredited use of the finite element models contained in the National Aeronautics and Space Administration (NASA) Structural Analysis (NASTRAN) model in verification of F-35 structures. NASTRAN solves large structural stress analysis problems and predicts strength and durability. The program plans to accredit two more models before the end of 2011.
- The changes to the program master schedule enabled several accreditation need dates to move from 2011 to later years. About half of the models and simulation in the verification plan must be accredited in the next 24 months, with the remainder due between 2014-2016.

Static Structural and Durability Testing

- The program halted F-35B durability testing at the end of last year when a wing carry-through bulkhead cracked before 2,000 hours of airframe life. The required airframe lifetime is 8,000 hours. Repair of the bulkhead on the test article was completed in November 2011, and F-35B durability testing is scheduled to restart in January 2012.
- Following the bulkhead crack in the F-35B test article, analysis verified the existence of numerous other life-limited parts on all three variants. The program began developing plans to correct these deficiencies in existing aircraft by repair/modifications, and designing changes to the production process. The most significant of these in terms of complexity, aircraft downtime, and difficulty of the modification required for existing aircraft is the forward wing root rib on the F-35A and F-35B aircraft.

All production aircraft in the first five lots will need the modification before these aircraft reach 1,000 hours.
- The program also halted F-35A durability testing after the F-35B bulkhead crack and restarted it at the end of May 2011. The test article restarted testing in November 2011, after completing inspections subsequent to accomplishing 3,000 effective flight hours of testing. During the second 1,000-hour block of testing, the wing root rib failed, as predicted. The test team is able to continue airframe fatigue testing in the near-term, while analysis determines when and how to repair the test article.
- F-35C structural testing completed all structural test objectives in August 2011, including planned "drop tests" in preparation for simulated carrier trials. Durability testing is scheduled to begin in Spring 2012.

Training System
- The program continued to develop training systems for use at the Integrated Training Center, Eglin AFB, Florida. The Air Force's training command approved courseware and the syllabus for the initial familiarization flight training (a six-mission syllabus) portion of the F-35A transition syllabus. From July through October, the six F-35A lot 2 aircraft ferried to Eglin on a one-time ferry-flight clearance from the production plant in Fort Worth, Texas. The aircraft have been used for verification of Joint Technical Data – the technical directives delineating F-35 maintenance and servicing procedures – while awaiting the military flight release permitting unmonitored flight.
- The program worked with the Air Force's airworthiness authority to determine the data requirements for the military flight release needed to begin flying production aircraft at the training center. Engineering teams cannot monitor these aircraft like they can flight test aircraft. Though planned to be complete by August, the military flight release had not occurred by the end of November 2011. At the time of this report, the program and the Air Force were in the process of examining numerous risks in starting unmonitored flight and training relatively early in, and concurrent with, development. The program and the Air Force have stated an intention to follow an event-driven plan to start training.
- In August 2010, the JSF Program Executive Officer (PEO) asked the JSF Operational Test Team to assess the initial training mission capability intended for the integrated training center. The JSF Operational Test Team developed an Operational Utility Evaluation (OUE) plan and submitted it for approval to DOT&E. In October 2011, DOT&E identified the need to resolve specific safety-related deficiencies in the F-35A and sustainment systems, as well as the need to build-up maturity in the air system, before the OUE test plan would be approved.

Air System-Ship Integration and Ship Suitability Testing
- **F-35B.** The program accomplished the first of two STOVL developmental test ship trials on the USS *Wasp* in October with test aircraft BF-2 and BF-4. The testing focused on developing initial short take-offs and vertical landings in the initial flight envelopes for deck operations, performing initial ship compatibility assessments, and collecting environmental data from instrumented ship locations. Seventy-two short take-offs and vertical landings were completed during the 19-day deployment in conditions of up to 33 knots of wind-over-deck and 10 knots of starboard crosswind. Some standard deck operations and maintenance activities were demonstrated, including fueling and defueling, aircraft tiedown, jacking, tire replacement, augmenter boost pump and door actuator replacements, and hydraulic servicing. Environmental data were collected to assess thermal stress to landing sites and shielded areas, and acoustic effects to ship personnel. Current plans place the second set of trials in August 2013.
- **F-35C.** The program began F-35C carrier landings, catapult take-offs, and jet blast deflector testing at the Lakehurst, New Jersey, test facility in July.

Live Fire Testing
- FUSL testing conducted on the first flight test aircraft (CTOL aircraft AA-1) provided aircraft flight control, electrical, propulsion, and fuel system vulnerability data. Due to commonality of the three variants, these results are extendable to the STOVL and CV variants as well.
- Contractor Fuel System Simulator tests showed the On-Board Inert Gas Generation System (OBIGGS) performance to be inadequate to support the vulnerability reduction requirements of the aircraft. A two-phase redesign effort is underway to provide protection against threat-induced fuel tank explosion across the entire flight envelope. Engine test articles have been delivered and structural test articles have been identified.

Assessment

F-35A Flight Sciences
- The test team was able to complete the F-35A flight sciences testing needed to provide flight envelope for the initial training mission capability and make progress toward other flight sciences goals needed to complete the SDD phase.
- An error in the test point planning metrics was discovered in November and the planned number of flight science test points were adjusted accordingly (590 test points removed from the planned metric). After this correction, test point completion lagged the planned level for the year by 11 percent. This lag was a result of accomplishing fewer test points per flight than planned. Contributing factors included deficiencies in the air vehicle's air data system as well as in-flight data indicating different structural loads than that predicted by computer modeling. These departures from model prediction of loads led to the addition of more build-up points, which are incremental, "stepping stone" expansions of the flight envelope. Additionally, planned air refueling testing did not take place because the instrumented tanker was not available at the expected time.
- The test team worked to overcome two obstacles to progress: test point constraints and aircraft reliability. Aircraft

operating limitations and inadequate instrumentation often constrained the available test points to a small subset of those planned. Aircraft reliability and parts shortages also negatively affected flight generation.

- While the lag is not a significant shortfall at this point in flight sciences testing, the program needs to continue to address the obstacles to flight and test point productivity to avoid a compounding effect. Weapons integration, high angle of attack testing up to 50 degrees, and completion of elevated g-loads testing are significant challenges of traditionally difficult test regimes that lie ahead.
- Discoveries included:
  - An Integrated Power Package failure during ground start on aircraft AF-4 in early August resulted in grounding all aircraft, all variants, for two weeks. A malfunctioning valve in the power and thermal management system created the conditions for the failure. Flights resumed after putting new procedures in place to monitor the valve with instrumentation on SDD flight test aircraft. The program also created a procedural change for production aircraft to manage the risk of failure on aircraft that engineering personnel cannot monitor. The program completed testing of a software change that has since been installed on the F-35A lot 2 aircraft at Eglin in November 2011.
  - The F-35A flight sciences tested evaluated handling characteristics and performance in a larger, more stressful flight envelope than the other two variants (e.g. up to 20 degrees angle-of-attack, with 50 degrees being the required maximum, and 9 g-load factor, which is the planned maximum load factor). The program worked to improve handling characteristics in transonic flight regimes through changes to flight control software, resulting in acceptable handling characteristics at high and medium altitudes (software version R25.0.7). However, the structural loads on the vertical tail fins of the F-35A aircraft, which stem from sideslip occurring in this regime, are higher than predicted and may require modifications to the tails or further changes to flight control software to reduce these effects. Additionally, flight tests of the magnitude and effects of buffet during elevated g-load and angle-of-attack revealed characteristics that need to be further examined. Testing in the regime where buffet is expected to be most pronounced had not occurred by the time of this report, due to load-factor flight envelope limitations. Fixes for handling characteristics must be balanced with other aircraft performance factors to find an acceptable, optimized solution. The program plans to continue this testing into 2012; more discoveries of performance trade-offs or adverse effects to structures are possible.
  - The program previously discovered deficient aircraft braking performance during landing on wet runway surfaces. The program tested new brake control unit hardware and software intended to improve performance. The program accelerated testing of the capability to stop the aircraft after landing on wet runway surfaces to 2011 to support the military flight release for aircraft ferried to the training center. Changes to the wheel brake controller improved this capability, but the program has not determined if the deficiency is resolved. Effective use of the latest design depends on the adequacy of simulations used to train pilots in maintaining directional control while activating differential braking. This requires precise control of brake pedal deflection, which will be difficult if not impossible during non-instrumented flight.
  - Fuel dump tests found that fuel migrated back into the aircraft, similar to results discovered on F-35B test aircraft. This has the potential to create an unsafe condition.
  - Engine airstarts require sufficient revolutions-per-minute of the engine for a successful re-start. The Integrated Power Package and the engine starter generator combine to provide additional torque to achieve the needed revolutions-per-minute in a flamed-out engine during an assisted airstart procedure. Ground tests recently indicated that the power output from the Integrated Power Package and the torque supplied by the starter-generator are lower than expected and may result in a failed start at speeds below 320 knots. Pilot procedures have been written requiring the airspeed to be maintained between 320 and 350 knots for an assisted airstart, which produces a high descent rate. Airstart flight tests have not begun. Software changes are under consideration to reduce the likelihood of failed start. This will affect all variants.
  - The horizontal tail of aircraft AF-1 was discovered to have sustained heat damage at the inboard trailing edge area after long duration afterburner operations on a flight test mission. The damage consisted of blistering of the surface and missing pieces of the trailing edge. Restrictions are in place and the test team is adding instrumentation to gain more accurate data on the conditions and cause of the problem.

F-35B Flight Sciences

- The test team was able to improve the tempo of STOVL-mode flight test early in the year in order to open sufficient flight envelope and accomplish other shore-based build-up for the ship trials in October 2011. Test and engineering teams accomplished a significant amount of modifications to the test aircraft to bring about this needed increase in the pace of STOVL-mode flight test. To accomplish 2011 goals, the test team also worked to overcome the challenges of low aircraft reliability and parts shortages.
- The test team was able to conduct safe flight tests of the STOVL-mode and successfully completed initial ship trials using flight monitoring systems in SDD test aircraft. The program has not completed the final re-designs and plans to correct deficiencies through modifications of F-35B production aircraft intended for the fleet, which cannot be monitored in-flight because these aircraft are not instrumented. Production aircraft will be restricted from STOVL-mode flight operations until Service airworthiness authorities grant a flight clearance. A significant amount

of flight test and development of system maturity of the final STOVL-mode door and propulsion system designs remains to be accomplished. A system mature enough for unmonitored STOVL-mode flight may be needed as early as late 2012 to coincide with the delivery of lot 4 F-35B aircraft to the Marine Corps at Yuma, Arizona. If testing of the changes is not complete and needed modifications are not installed by late 2012, aircraft at Yuma will fly in CTOL-mode only.

- The following table describes the door and propulsion problems by component, and identifies the production cut-in, if known.

F-35B Door and Propulsion Problems				
Category	Component	Problem	Design Fix and Test Status	Production Cut-In
Subsystems	Upper Lift Fan Inlet Door Actuators	Actuator redesigns due to high actuator failure rates.	New actuator under development. Interim design will be tested during SDD, planned for late CY12.	BF-38 LRIP 6
Structure	Auxiliary Air Inlet Door	Problems included inadequate life on door locks, excessive wear and fatigue due to the buffet environment, inadequate seal design.	Redesign currently being installed on BF-1, including associated structural longeron repair. Flight testing to begin in mid-December 2011.	BF-38 LRIP 6
Structure	Lift Fan Door Actuator Support Beam	Cracks occurring earlier than predicted. Root cause analysis showed fastener location incorrectly inserted in design.	BF-1 and BF-2 modifications are complete. BF-3 will not to be modified (will not be used for STOVL Mode 4 operations). BF-4 has resumed Mode 4 operations. Potential design fix is on BF-5; however, limited STOVL mode testing has been done on BF-5 to date (less than 30 total hours as of November 2011).	BF-5 LRIP 2
Structure	Roll Post Nozzle Doors	Doors separated from aircraft BF-2 and BF-3 during flight; door loads not well understood, aero pressures higher than expected. Impact not limited to STOVL mode operations – flight not to exceed 400 KCAS below 18K ft and 0.5 minimum g-load.	BF-3 is being instrumented. All SDD F-35B aircraft have an interim fix with door stiffeners/clips and strengthened torque tube fasteners. Final design is still to be determined (TBD).	Not known
Structure	3 Bearing Swivel Nozzle Door	Door attachment wear/damage found on BF-1 (6/11) requiring new inspection interval every 25 mode-4 flights. During Slow Landing flight testing, measured door loads exceeded limits.	Interim mod on BF-1 (01/12), instrumentation added. Final design and retrofit plan is TBD. Slow Landings now prohibited below 100 knots pending the results of flight testing.	Not known
Structure	Main Landing Gear Doors	Door cracking observed on BF-1, 2, 4 aft door adjacent to aft lock.	Final design is TBD. Instrumentation added to BF-2.	Not known
Propulsion	Drive Shaft	Lift fan drive shaft undergoing a second redesign. Original design inadequate due to shaft stretch requirements to accommodate thermal growth, tolerances, and maneuver deflections.	Analysis of failure of 2nd design and corrective action is ongoing. Additional spacers needed – uniquely fitted for each aircraft – to ensure proper lift fan performance.	BF-44 LRIP 7
Propulsion	Clutch	Lift fan clutch has experienced higher than expected drag heating during conventional (up and away) flight.	Temperature data from the clutch housing is being collected on the test aircraft to determine risk and a path forward.	BF-44 LRIP 7
Propulsion	Roll Post Nozzle Actuator	Roll post nozzle bay temperatures exceed current actuator capability. Actuator failure during Mode 4 operations.	Insulation between the roll post nozzle bay and the actuator is being installed and tested to provide interim solution for LRIP 2 – 4 STOVL aircraft. Increased temperature actuator is scheduled to be available for test in early 2012.	TBD

- The status of F-35B door and propulsion deficiencies follows.
  - Redesign of the auxiliary air inlet doors continued, this being needed to reduce deflection under actual flight loads that have proven to exceed design and modeling predictions. The program plans flight testing of the new design in early 2012. These doors conflicted/jammed during operation on newer F-35B test aircraft, necessitating special attention to door rigging.
  - Analysis continued on the three-bearing swivel nozzle doors and the lower lift fan door as a result of flight tests indicating higher than predicted loads. The program plans to modify the design of the three-bearing swivel nozzle doors and test concurrently with the modified auxiliary inlet door in early 2012. This testing is expected to generate the dynamic loads data required to assess whether any further design changes to the three-bearing swivel nozzle doors will be required to achieve full-life capability.
  - Temperatures in the roll control nozzle actuator area exceeded the heat tolerance of the current actuator design during flight test, necessitating a redesign. The program is

changing the insulation in the nozzle actuator area as an interim fix and redesigning the nozzle actuator to improve heat tolerance. The program plans new hardware by the end of 2011 for testing.

- Roll control nozzle doors separated in-flight from a test aircraft twice, drawing attention to door rigging and the potential for redesign. The program plans to conduct flight test on a new door in early 2012 to support the redesign effort.
- The interim solution to unacceptably high clutch temperatures is to add a temperature sensor and display page so that the pilot can be aware of increasing temperature inside the clutch housing. Fuel and operational conditions permitting, changing flight regimes (e.g. configuration, altitude, and airspeed) may cool the clutch so that the pilot can engage STOVL modes. Such a cooling procedure may be untenable in combat conditions.
- The program added spacers to the lift fan driveshaft to address unanticipated expansion/stretching that takes place during flight. This is an interim solution while the program redesigns the driveshaft for better performance and durability.

- The vertical lift bring-back requirement is a primary STOVL-mode attribute and is a Key Performance Parameter (KPP). It is the weight of a minimum fuel quantity and other necessary payload needed to safely recover the aircraft on the ship after an operational mission, plus a representative weapons payload. Managing aircraft empty weight growth is essential to being able to meet the vertical lift bring-back requirement. The F-35B aircraft weight management challenge is complicated by balancing available lift, thrust required, and vertical descent rates in the vertical landing mode. Current and projected F-35B aircraft weight growth threatens the ability to meet this vertical lift bring-back requirement. The November 2011 weight data show only 230 pounds of margin between the current weight and the intended not-to-exceed weight of 32,577 pounds, which is the program's technical performance measurement threshold for empty aircraft weight currently programmed for January 2015. This weight margin represents 0.71 percent of the current weight and allows for only 0.22 percent weight growth per year until the technical performance measurement assessment deadline, which is prior to the end of SDD. The program recently determined that allowing a greater descent rate to touchdown (7 feet per second) plus possible positive thrust margins available from the lift fan may add an additional 142 pounds of weight tolerance to the technical performance measure not-to-exceed weight. This additional weight increases the margin to 1.2 percent of current weight and allows for 0.36 percent weight growth per year. Managing weight growth with such tight margins for the balance of SDD will be a significant challenge, especially with over 70 percent of the scheduled F-35B flight sciences test flights remaining to be accomplished in the next 60 months. For comparison, weight growth on the F/A-18 E/F was approximately 0.69 percent per year for first the 42 months following first flight.
- Other discoveries included:
  - The program found that later models of upper lift fan door actuators caused the door to stop moving as commanded. The program intends to redesign the actuator in time to begin flight test in late 2012, and introduce the new actuator into production aircraft in lot 6.
  - The fuel dump system causes fuel to migrate back into the aircraft structure, where it is retained until after landing. While some improvement was noted with modifications to the vent area on test aircraft, the program plans more work to correct this deficiency.
  - Flight test teams discovered cracks in landing gear doors on STOVL aircraft. Analysts determined that gear door stresses were within tolerance. Root cause analysis of the cracks continued through the time of this report.
  - Using the version of flight control software available at the beginning of 2011, undesirable wing roll-off, airframe buffet, and sideslip occurred in transonic flight regimes. Through changes to flight control software, the program improved these handling qualities. By the end of November 2011, testing of the latest flight control software change (version R25.0.7) indicated the handling qualities did not meet the current criteria. No further software modifications specific to transonic roll-off are planned. The program is examining the handling characteristics criteria for operational relevance. Two options remain: a) consideration of structural modifications to improve handling characteristics, or, b) relaxation of the handling characteristics criteria. Testing also began to survey the magnitude and effect of buffet during elevated g-load and increasing angle-of-attack; e.g. up to 16 degrees angle-of-attack, of the 50 degrees required maximum, and 7.5g load factor, which is the required maximum. Testing in the regime where buffet is expected to be most pronounced had not occurred by the time of this report. As with the CTOL aircraft, the test and engineering teams must balance improvements to handling qualities with other performance factors to find an acceptable, optimized solution. This testing will continue into 2012.
  - Aircraft BF-2 experienced damage to coatings on the horizontal tail following afterburner use similar to that found on F-35A aircraft AF-1. Restrictions are in place and the test team is adding instrumentation to gain more accurate data on the conditions and cause of the problem.

F-35C Flight Sciences

- As F-35C flight sciences focused on preparation for and execution of carrier launch and landing testing at Lakehurst, a limited amount of other envelope expansion occurred in 2011. The F-35C flight sciences test points accomplished thus far are approximately 15 percent of the total expected in SDD.
- The lack of available flight envelope in the transonic regime currently constrains testing of F-35C aircraft handling

qualities. In limited testing using flight control software that benefitted from F-35A and F-35B testing, the F-35C aircraft performance in the transonic flight regime demonstrated the predicted intensity of uncommanded rolls but higher buffet levels. The F-35C aircraft was expected to have the greatest challenge of the three variants in the transonic flight regime, which led to the decision to incorporate structural provisions for the installation of external spoilers in one test aircraft.

- The carrier launch and landing testing at Lakehurst provided valuable lessons regarding the impacts of these dynamic environments on the aircraft early in the testing. Corrections and regression testing are needed as a result of the discoveries listed below. The program is also working to correct other performance problems such as excessive nose gear oscillations during taxi, excessive landing gear retraction times, and overheating of the electro-hydrostatic actuator systems that power the flight controls. The program will subsequently evaluate the need for modifications of production aircraft for these items.
- Discoveries included:
  - Flight test aircraft could not engage the arrestment cable during tests at the Lakehurst, New Jersey, test facility. The tail-hook point is undergoing a redesign and the hold-down damper mechanism requires modifications to enable successful arrestments on the carrier. Resolution of these deficiencies is needed for testing to support F-35C ship trials in late 2013.
  - Hold-back bar and torque arm components, which keep the F-35C aircraft from moving forward when tensioned on the catapult at full power, require a redesign due to the use of incorrect design load factors. Actual loads are greater than predicted. The impact of these greater-than-predicted loads on strength and fatigue characteristics is under analysis by the program.
  - Loss of inertial navigation and GPS inputs to pilot displays occurred during a catapult launch. Root cause analysis was in progress at the time of this report.
  - The test team conducted initial testing in the transonic flight regimes with one version of air vehicle software on aircraft CF-2. Problems similar to the other variants were observed, such as excessive buffeting and roll-off, at times making the helmet-mounted displays unreadable.
  - Higher than predicted temperatures exist in the electro-hydrostatic actuator system during flight testing of the aircraft in a landing configuration. This component provides the force to move control surfaces.

Mission Systems

- Assessing mission systems progress requires a review of the allocation of flight test activity so far, and an understanding that the total mission systems verification to date is only approximately 4 percent of that planned to complete SDD mission systems software testing.
  - Operating only one test aircraft for the first six months, and three total aircraft for the remainder of the year, the Edwards test team was able to exceed the planned mission systems flight rate and limited test point productivity for mission systems capability. However, the majority of this year's mission systems test point accomplishment was for F-35A maturity (37 percent) and other non-software verification tasks (34 percent). This occurred partially because of the constraints on test operations caused by delays in obtaining clearances to test the Electro-Optical Targeting System laser and operate the Identification Friend-or-Friend Interrogator. F-35A maturity flights more than offset these test constraints in consuming mission systems aircraft flight test productivity. The need to add maturity flights is a manifestation of highly concurrent production of aircraft and development of the air vehicle. To accomplish these flights, the program had to use the mission systems test aircraft from production lot 1as they represented the low-rate initial production (LRIP) aircraft that would be flying unmonitored at the training center. Even though these aircraft were mission systems test assets, these flights evaluated the overall maturity of the air vehicle, not just the effectiveness of the limited mission systems capability for initial training.
  - Overall, the program has demonstrated very little mission systems capability thus far in flight test on F-35 aircraft. In fact, the program has not delivered some of the intended initial training capability, such as effective and consistent radar performance. Only very limited F-35 flight testing of sensor fusion took place this year. In accordance with the test plans to build up to operationally relevant flight test scenarios, flight tests to date largely focused on verifying correct sensor contributions to sensor fusion, with limited stressors on the system. The program plans more stressing flight test scenarios in upcoming flight testing. It is too early to determine the effectiveness of the fusion design. Knowledge of mission systems performance is extremely limited until the measure of fusion performance is oriented to operationally relevant weapons employment, electronic warfare, threat location, and threat identification.
- The limited progress in demonstrating mission systems capability so far causes increasing concurrency among the first three increments of mission systems software capability.
  - If the program introduces Block 2 into flight test in early 2012 as it plans to do, there will be a significant amount of overlap of the remaining Block 0.5 and Block 1.0 test execution with Block 2 development, integration, and flight testing. Per the status of execution of the test plans at the end of 2011, 40 percent of the Block 0.5 and over 85 percent of Block 1 test points will remain unaccomplished; these are demonstrations of functions and capability that are largely foundational to Block 2 capability. This situation creates uncertainty as to what capability will be provided to production lots 3 and 4 and how this capability will be verified before release to the field.
  - The inherent and growing concurrency in the mission systems flight test plan is a source of risk in the program.

The difficulty of managing multiple configurations on test and operational flight lines to assure use of appropriate software, increasing rework of software, and the potential for greater than expected regression flight tests are significant challenges to the program.

- This creates an uncertain starting point for the next two years, during which the program plans to evaluate Block 2 capability. Significant challenges come with correcting the current known deficiencies and evaluating weapons delivery capability, interoperability with other platforms, and electronic warfare capability. A significant risk area for the program during this time is the absence of mission systems testing with an operationally representative mission data file, which is the compilation of threat and other system data needed for track identification and appropriate threat countermeasures.

- Discoveries included:
  - The helmet-mounted display system is deficient. It is meant to display key aircraft handling/performance information as well as tactical situational awareness and weapons employment information on the pilot's helmet visor, replacing conventional heads-up display systems.
    - Deficiencies include integration of the night vision capability, integration of Distributed Aperture System video for night vision, symbology jitter or swimming, and latency. These stem in turn from poor acuity with night vision camera hardware, limited computer processing power, inaccurate head position tracking, and poor helmet fit, complicated by vibration-inducing airframe buffet experienced at high angles-of-attack in some dynamic maneuvering regimes.
    - The program began pursuing a dual path to resolve the technical shortfalls and provide a system that will enable flight test to proceed and meet operational mission needs. One path is to complete development of the original helmet-mounted display system by the end of SDD Block 3. The alternate path is to integrate a technically mature, existing helmet-mounted display system that addresses the symbology stability problems that have been discovered, but requires an additional night vision system (such as existing night vision goggles) to provide night combat capability, and does not display Distributed Aperture System imagery on the pilot's visor. The impacts of these two paths on mission systems schedule cannot be measured until plans are integrated into the master schedule.
    - The program made several modifications to the helmet to be useful in daytime flight test and the benign initial training environment. Shimming and visor alignment changes have corrected some of the virtual heads-up display deficiencies for flight test and initial training; however, more work is needed for the existing helmet to support certain flight test missions in the near future (e.g. high angle-of-attack, elevated g-loading, weapons employment) and combat operations.
  - Panoramic cockpit displays in the mission systems aircraft overheat during flight test. The program is pursuing modifications to test aircraft to increase cooling and decrease heat load so that testing can continue.
  - While mission systems software has been stable during flight tests so far, startup time and startup stability is poor, usually taking more than 30 minutes to complete. The most recent Block 1B software improved startup times, but more improvement is needed for suitable operations.
  - Radar anomalies in flight included loss of air target tracks without indicating radar faults or failure to the pilot. Root cause analysis was in progress at the time of this report.

Operational Assessment

- The JSF Operational Test Team completed an operational assessment of the F-35 program and determined that it is not on track to meet operational effectiveness or operational suitability requirements. The JSF Operational Test Team assessed the program based on measured and predicted performance against requirements from the JSF Operational Requirements Document, which was re-validated in 2009.
- The primary operational effectiveness deficiencies include poor performance in the human systems integration (e.g. helmet-mounted display, night vision capability) and aircraft handling characteristics, as well as shortfalls in maneuvering performance (e.g. F-35A combat radius, which is a KPP, and F-35C acceleration).
- The driving operational suitability deficiencies include an inadequate Autonomic Logistics Information System (ALIS) for deployed operations, excessive time for low observable maintenance repair and restoration capability, low reliability and poor maintainability performance, and deficient crypto key management and interface compatibility.
- The assessment was completed prior to release of an updated program integrated master schedule. While additional time and resources in development may aid the program in resolving some deficiencies, several requirements are not going to be met given current, known program plans. After the new master schedule is available, along with documentation of the application of the additional resources applied to SDD plans, an updated operational assessment may be provided.

Air System-Ship Integration and Ship Suitability Testing

- The F-35B initial ship trials on USS *Wasp* supported initial short take-off and vertical landing envelope expansion efforts for shipboard operations with data collected as planned across a portion of the wind-over-deck conditions. As expected, high starboard crosswinds produced the most challenging environment. One approach to hover prior to a vertical landing was waved off by the pilot due to turbulence in the ship's airwake. A minimal nozzle clearance of 2 inches was observed at rotation during a short take-off with high starboard crosswinds when the pilot made an aggressive correction to maintain centerline. The test team demonstrated deck and hangar operations.

Although maintenance was completed while aboard the ship, limited support equipment was positioned on USS *Wasp* and no ALIS equipment supported the deployment aboard the ship. The test team created a virtual private network connection between the ship and the prime contractor in Fort Worth such that they were able to process maintenance actions as if operating at Patuxent River. Aircraft BF-2 diverted to Patuxent River twice during the deployment for maintenance – once for a fuel leak that could not be addressed at sea and once when the team elected to have upper lift fan door actuators replaced ashore. The upper lift fan door actuators on BF-4 had to be replaced twice during the trial period, once at Patuxent Rive and once at sea with an embarked maintenance team.

Ground Structural Testing and Analysis

- The fatigue cracks that occurred in November 2010 in a F-35B wing carry-through bulkhead early in durability testing were the result of unpredicted high stress concentrations. The finite element modeling previously conducted by the program to analyze the airframe was not adequate and did not predict these stress concentrations.
- As a result of the bulkhead crack, the program completed a detailed analysis of the full structural design for all variants, which identified more life-limited parts. A total of 58 parts were identified across all three variants. The most significant of these in terms of complexity, aircraft downtime, and difficulty of the modification for existing aircraft is the forward wing root rib on the F-35A and F-35B aircraft. All production aircraft in the first four lots will need the forward root rib modification before these aircraft reach 1,000 hours.
- The risks of concurrent development, testing, and production are highlighted by the experience with structural testing. Since most flight testing remains to be completed, the potential for more discoveries exist. The program predicts another 22 major discoveries and 43 moderate discoveries within SDD. The program plans to continue durability testing through two airframe lives (16,000 hours). Current schedules indicate the completion of the second airframe life will occur in early 2015 for F-35A and late 2014 for F-35B and F-35C. This means a total of nine aircraft production lots will be procured before completion of durability testing.

Issues Affecting Operational Suitability

- Flight test and lot 1 aircraft demonstrated low reliability compared to the operational requirement (i.e., the reliability required at 50,000 total flight hours for each variant) and compared to where program plans expect reliability to be at this point in system maturity. Based on data at the end of September 2011, the mean flight hours between critical failures were measured to be 2.65 hours for the F-35A, 2.05 hours for the F-35B, and 2.06 hours for the F-35C. These values range between 21 to 31 percent of the planned mean flight hours between critical failure for each variant given the flight hours accumulated so far. However, the rolling three-month trend of this measure is not stable for any of the variants, indicating continued discovery in reliability. Due to the initial low reliability experienced so far in all variants, the program has a significant challenge to provide sufficient reliability growth to meet the operational requirement. The program is working to update the reliability growth plan, last produced in 2006. Significant contributors to low reliability include the following:
  - F-35A wheel and tire assemblies, thermal management system, flight control actuators, fuel systems, and electrical power systems/connectors
  - F-35B lift fan system, thermal management, fire protection system, electrical power system/converters, wheel and tire assemblies, access doors/covers, lower inlet lip, wing and fuselage repairs, panoramic cockpit displays, doors, and actuators
  - F-35C landing gear wiring, wheel and tire assemblies, thermal management system, wing and fuselage repairs, engine nozzle segment, electrical power system, and fuel system.
- Maintenance of flight test and production lot 1 aircraft is taking longer than required for the mature system. For example, mean corrective maintenance time for critical failures for F-35A and F-35B aircraft is approximately twice that required of the mature system. The F-35C air vehicle is currently maintained at the required threshold for this requirement. Mean time to repair data show that all three variants currently are experiencing approximately twice the required time for the mature system. Current maintenance repair times are driven largely by immature health management and autonomic logistics information systems; however, the potential exists for discoveries in flight test and early operational fielding to further reduce maintainability. Timely maturation of these systems, completing and verifying technical order data are critical to improving maintainability for operational units. It is too early to predict whether the required maintainability thresholds can be met.
- The program failed to design the unit-level ALIS hardware for deployability. The squadron operating unit weighs 2,466 pounds and measures 79 inches high by 40 inches deep and 24 inches wide. It also requires climate-controlled environments. The program worked through late 2010 and 2011 to redesign the system and provide improved deployability by late 2014. However, there is no plan for end-to-end testing of the system, and funding of retrofits or changes to the units that will be purchased in the meantime. The problem needs correction in order to take advantage of F-35 capability in forward operating locations expected in combat.
- Data Quality and Integration Management (DQIM) is a vital part of the autonomic logistics global sustainment plan for the F-35. The ALIS version 1.0.3 is supposed to incorporate DQIM; however, missing data elements (e.g. part number, logistics control number, serial number) of vendor supply databases have prevented timely testing and fielding of ALIS version 1.0.3. This results in the development of manual

data tracking processes for early LRIP aircraft. The program expects to have DQIM data products available to support ALIS 1.0.3 fielding in May 2012.

Modification of Low-Rate Initial Production (LRIP) Aircraft

- The aircraft produced in the first five production lots will require significant numbers of structural modifications and configuration upgrades to attain the planned service life and the intended Block 3 capability. The program office worked with the Services this year to organize a funding and scheduling strategy. These are known as concurrency modifications because ground and flight tests concurrent with production identified the need to change the design after production began in order to achieve acceptable performance. These modifications include corrections to airframe parts discovered to have limited life during structural durability testing conducted so far. Additionally, the program has always planned a significant hardware and software upgrade from Block 2 to Block 3 mission systems capability; this will affect the first five lots of aircraft.
- Service plans, particularly in regards to throughput at the training center equipped with the initial production aircraft, must account for the planned downtime, which will be 45-60 days. For example, the program plans the F-35A and F-35B forward wing root rib modification to take a depot repair team 45 days to complete. All of the aircraft intended for operational testing require many of these modifications and the Block 3 upgrade in order for the JSF Operational Test Team to conduct an adequate IOT&E.

Training

- The JSF Operational Test Team developed an OUE test plan to provide the PEO the assessment he requested of the initial F-35A training mission capability, initially planned to begin in August 2011. The readiness-to-test and readiness-to-begin training processes highlighted several issues that have led to delays to the start of pilot flight training.
- Based on the flight schedule planned in April 2010, the program expected to have completed over 1,100 sorties and over 1,980 flight hours on the F-35A SDD aircraft (including the two lot 1 aircraft) by the end of November 2011. Actual numbers were 622 flights and 1,175 hours. The lower than expected flight rate and hours created schedule pressure to start training activities with a less mature aircraft system than planned.
- The primary problem for the program and the Air Force has been determining the acceptable level of risk involved with starting training in immature aircraft. The key event anticipated by the program office and the training center is obtaining a suitable military flight release from the Air Force airworthiness authorities, which is needed before pilots can fly the aircraft at the training center. The results of the maturity flights on the production lot 1 mission systems test aircraft were that approximately half required intervention by flight test control room personnel, an indication of low system maturity and likely mission abort in a non-flight test environment. The abort rate was measured at three times the measure of success set by the program and the airworthiness authority.
- As of the end of November 2011, the program had made progress on some of the safety-related items identified by DOT&E in October. Although the program and the training center leadership had officially committed to an event-driven start of flight training, they had provided no explicit plan for building maturity in the F-35A aircraft in order to safely conduct the OUE and begin F-35A pilot training. As of the end of November 2011, there were less than 80 total flight hours on the training mission software configuration and less than 1,200 hours on the F-35A variant. Historically, more than 2,500 fleet hours have been needed to reduce risk of beginning training in a new aircraft to an acceptable level.

Live Fire Test and Evaluation

- Live Fire FUSL testing of the first flight test aircraft consisted of 25 ballistic tests. Testing confirmed the ability of the airplane to isolate the damage to targeted components. Testing validated the robustness of both the Flight Control and Electrical Power Systems. Further analysis of the data will take place to compare with the pilot-in-the-loop simulations completed in FY09, which provided the basis for FUSL pre-test predictions, and to ensure that test limitations did not obscure potentially significant vulnerabilities.
- Analyses of OBIGGS fuel system simulator tests showed that the system is incapable of providing protection from threat-induced fuel tank explosions during some critical segments of combat missions when the aircraft is most vulnerable. Program focus is currently on the immediate need to meet requirements to protect the aircraft from lightning-generated fuel tank explosions and on redesigning OBIGGS to provide protection throughout all combat mission segments.

Recommendations

- Status of Previous Recommendations. The program and Services are satisfactorily addressing four of seven previous recommendations. The remaining three recommendations concerning use of objective criteria for evaluating flight test progress, integrating flight test of an operational mission data load, restoring shut-off valves, and redesigning the OBIGGS are outstanding.
- FY11 Recommendations. The program should:
  1. Conduct an integrated test review of the final flight test schedule to ensure the new integrated master schedule matches flight test schedule sequencing and content, and that both comply with the TBR-recommended planning factors.
  2. Use a criteria-based event-driven strategy to reduce risk before beginning flight operations with early, immature production aircraft at the training center or elsewhere.

3. Determine the impact of the alternate path for the helmet-mounted display on the integrated master schedule, including potential for cockpit and pilot systems redesigns.
4. Ensure operationally relevant criteria are used to evaluate handling characteristics in transonic flight regimes and in buffet testing.
5. Produce and implement a realistic reliability growth plan.
6. Evaluate and reduce the risk of later than intended completion of structural durability testing given concurrent production.
7. Improve spares efficiency/resupply and test aircraft reliability at the flight test centers.
8. Survey the test plans for certifications required by government agencies outside program and Service control and plan appropriate lead-time for these certifications.

F-35 Joint Strike Fighter (JSF)

Executive Summary

- The F-35 Joint Strike Fighter (JSF) program continues to have a high level of concurrency among production, development, and test. Approximately 34 percent of the total planned flight testing, based on test points completed through November 2012, has now been accomplished as the program initiates the fifth of 11 initial production lots. Durability testing is ongoing on all three variants, with only the F-35A test article having completed a full lifetime of testing. The program will not complete the two lifetimes of durability testing currently planned on any variant until the last quarter of 2014.
- Through November 2012, the flight test teams were able to exceed the flight rate planned for flight sciences in the F-35B and F-35C variants, but were slightly behind the plan for the F-35A. The program did not accomplish the intended progress in achieving test objectives (measured in flight test points planned for 2012) for all variants. Certain test conditions were unachievable due to unresolved problems and new discoveries. The need for regression testing of fixes (repeat testing of previously accomplished points with newer versions of software) displaced opportunities to meet flight test objectives.
- The flight rate of the mission systems test aircraft also exceeded the planned rate during the year, but overall progress in mission systems was limited. This was due to delays in software delivery, limited capability in the software when delivered, and regression testing of multiple software versions (required to fix problems, not add capability). Test points accomplished for the year included Block 1 verification, validation of limited capabilities for early lot production aircraft, baseline signature testing, and Block 2 development. No combat capability has been fielded.
- The lag in accomplishing the intended 2012 flight testing content defers testing to following years, and in the meantime, will contribute to the program delivering less capability in production aircraft in the near term.
- The tables on the following page present the actual versus planned test flights and test points conducted as of the end of November 2012.
- The program submitted Revision 4 of the Test and Evaluation Master Plan (TEMP) for approval, which included changes to the program structure brought about by the previous year's Technical Baseline Review and subsequent re-planning of testing. However, the TEMP contained an unacceptable overlap of development with the start of operational test activity for IOT&E.
- The Air Force began the F-35A training Operational Utility Evaluation (OUE) in September 2012 and completed it in mid-November. During the OUE, four pilots completed training in the system familiarization portion of the syllabus, which included no combat capabilities. Because of the immaturity of the system, which is still largely under development, little can be learned about operating and sustaining the F-35 in combat operations from this evaluation.

- The program completed two of the eight planned system-level ballistic test series.
  - The first series confirmed the built-in redundancies and reconfiguration capabilities of the flight-critical systems. The second series indicated that ballistic damage introduced no measurable degradation in the F-35B propulsion system performance and that the damage would be undetectable by the pilot. Ongoing analysis will evaluate whether these tests stressed the vulnerabilities unique to ballistic damage to the F-35 (e.g., interference or arcing between 270 Volt, 28 Volt, and signal lines and/or damage to lift fan blade sections).
  - The first test series confirmed Polyalphaolefin (PAO) coolant and fueldraulic systems fire vulnerabilities. The relevant protective systems were removed from the aircraft in 2008 as part of a weight reduction effort. A Computation of Vulnerable Area Tool analysis shows that the removal of these systems results in a 25 percent increase in aircraft vulnerability. The F-35 Program Office may consider reinstalling the PAO shutoff valve feature based on a more detailed cost-benefit assessment. Fueldraulic system protection is not being reconsidered for the F-35 design.
- The program's most recent vulnerability assessment showed that the removal of fueldraulic fuses, the PAO shutoff valve,

and the dry bay fire suppression, also removed in 2008, results in the F-35 not meeting the Operational Requirements Document (ORD) requirement to have a vulnerability posture better than analogous legacy aircraft.
- Tests of the fuel tank inerting system in 2009 identified deficiencies in maintaining the required lower fuel tank oxygen levels to prevent fuel tank explosions. The system is not able to maintain fuel tank inerting through some critical portions of a simulated mission profile. The program is redesigning the On-Board Inert Gas Generating System (OBIGGS) to provide the required levels of protection from threat and from fuel tank explosions induced by lightning.

Actual versus Planned Test Metrics through November 2012

TEST FLIGHTS					
	All Testing	Flight Sciences			Mission Systems
	All Variants	F-35B Only	F-35A Only	F-35C Only	
2012 Actual	1,092	374	263	233	222
2012 Planned	927	244	279	211	193
Difference from Planned	+18%	+53%	–6%	+10%	+15%
Cumulative Actual	2,533	963	709	425	436
Cumulative Planned	2,238	820	651	404	363
Difference from Planned	+13%	+17%	+9%	+5%	+20%

TEST POINTS								
	All Testing	Flight Sciences			Mission Systems			
	All Variants	F-35B Only	F-35A Only	F-35C Only	Block 1*	Block 2	Block 3	Other
2012 Baseline Accomplished	4,711	1,075	1,338	1,060	358	457	0	423
2012 Baseline Planned	6,497	1,939	1,923	1,327	336	448	0	524
Difference from Planned	–28%	–45%	–30%	–20%	+7%	+2%	0	–19%
Added Points	1,720	292	565	253	0	610	0	0
Points from Future Year Plans	2,319	992	431	896	0	0	0	0
Total Points Accomplished**	8,750	2,359	2,334	2,209	358	1,067	0	423
Cumulative SDD Actual***	20,006	7,480	5,664	4,330	899	457	0	1,176
Cumulative SDD Planned	19,134	7,057	6,102	3,748	667	488	0	1,072
Difference from Planned	+5%	+6%	–7%	+16%	+35%	–6%		+10%
Test Points Remaining	39,579	12,508	8,321	10,316	8,434 (All Blocks and Other Mission Systems Activity)			

* Includes Block 0.5 and Block 1 quantities
** Total Points Accomplished = 2012 Baseline Accomplished + Added Points + Points from Future Year Plans
*** SDD – System Design and Development

System
- The F-35 JSF program is a tri-Service, 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/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 in this environment 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 (JDAM) and Joint Standoff Weapon, AIM-120C radar-guided Advanced Medium-Range Air-to-Air Missile (AMRAAM), and AIM-9 infrared-guided short-range air-to-air missile.
- The program provides mission capability in three increments: Block 1 (initial training), Block 2 (advanced), and 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, and in highly defended areas of joint operations.
- F-35 will be used to attack fixed and mobile land targets, enemy surface units at-sea, and air threats, including advanced cruise missiles.

Major Contractor
Lockheed Martin, Aeronautics Division – Fort Worth, Texas

Test Strategy, Planning, and Resourcing

- The JSF Program Office, in coordination with the operational test agencies, worked to develop Revision 4 of the TEMP. As part of the Milestone B recertification in March 2012, the USD(AT&L) tasked the program to submit a revised TEMP for approval prior to the September In-Progress Review by the Defense Acquisition Board.
- The TEMP included a schedule for IOT&E that assumed the final preparation period prior to IOT&E could fully overlap with the air-worthiness certification phase of development, which occurs after the final developmental test events. DOT&E identified to the program and the JSF Operational Test Team that without analysis showing this overlap is feasible, the TEMP could not be approved. DOT&E concluded that this final preparation period should be scheduled to begin at a later point, no earlier than the Operational Test Readiness Review, and budgets should be adjusted accordingly.
- This report reviews the program by analyzing the progress of testing and the capability delivered as a function of test results. The program plans a specific set of test points (discrete measurements of performance under specific test conditions) for accomplishment in a given calendar year. In this report, test points planned for a given calendar year are referred to as baseline test points. In addition to baseline test points, the program accomplishes test points added for discovery and regression. Cumulative System Design and Development (SDD) test point data refer to the total progress towards completing development at the end of SDD.

F-35A Flight Sciences

Flight Test Activity with AF-1, AF-2, and AF-4 Test Aircraft

- F-35A flight sciences testing focused on:
  - Expanding the flight envelope (achieved 700 knots calibrated airspeed [KCAS]/1.6 Mach test point in March and achieved 50,000 feet, the designed altitude limit, in November)
  - Evaluating flying qualities with internal stores (GBU-31 JDAM, GBU-12 Laser-guided Bomb, and AIM-120 AMRAAM) and external stores (AIM-9X short-range missile)
  - Characterizing subsonic and supersonic weapons bay door and environment
  - Expanding the air-refueling envelope and investigating tanker-to-F-35A connection/disconnection problems
  - Engine air-start testing
  - High (greater than 20 degrees) angle-of-attack testing
- The test team began weapons separation testing in October with the first safe separation of an inert GBU-31 JDAM, followed by the first AIM-120 safe separation later in the month.
- The program released two revisions of the air vehicle systems software (R27.1 and R27.2.2) in 2012 to improve flying qualities, correct air data deficiencies observed during F-35A envelope expansion, and to address various software deficiencies.
- Through the end of November 2012, the test team was able to sustain a sortie rate of 8.0 flights per aircraft per month, compared to the goal of 8.5 sorties per month. The overall annual sortie total was only 6 percent short of the goal (263 sorties completed, 279 planned).

Flight Sciences Assessment

- By the end of November, the progress against planned baseline test points for 2012 lagged by over 30 percent (accomplishing 1,338 baseline F-35A flight sciences test points of 1,923 planned through November 2012, for a completion rate of 70 percent). The test team could not execute this portion (30 percent) of planned 2012 baseline test points for the following reasons:
  - Aircraft operating limitations, which prevented the extended use of afterburner needed to complete high-altitude/high-airspeed test points.
  - Higher than expected loads on the weapon bay doors, which required additional testing and thus limited the amount of testing with weapons loaded on the aircraft.
  - Deficiencies in the air-refueling system, which reduced testing opportunities.
- To compensate for not being able to achieve the baseline test points planned for 2012, the test team moved up test points planned for completion in later years, and was thereby able to nearly keep pace with overall cumulative SDD test point objectives. For example, the Block 2B flight envelope includes operations with the weapons bay doors open. The program discovered dynamic flight loads on portions of the open doors were higher than expected, requiring additional instrumentation and testing. The test team substituted other test points, which were available from Block 3 envelope plans for 2013 that did not require the doors open. For F-35A flight sciences, the test team had accomplished 93 percent of the overall planned number of cumulative test points scheduled for completion by the end of November (5,664 cumulative points accomplished against a goal of 6,102 points).
- Weight management of the F-35A variant is important for meeting air vehicle performance requirements. The program generates monthly aircraft weight status reports for all variants and computes weights as a sum of measured weights of components or subassemblies, calculated weights from approved design drawings released for build, and engineering weight estimates of remaining components. The program has managed to keep F-35A weight estimates nearly constant for the last year. The latest F-35A weight status report from November 2012 showed the estimated weight of 29,098 pounds to be within 273 pounds (0.94 percent) of the projected maximum weight needed to meet the technical performance required per contract

specifications in January 2015. This small margin allows for only 0.42 percent weight growth per year for the F-35A. The program will need to continue rigorous weight management through the end of SDD to avoid performance degradation and operational impacts.
- The program announced an intention to change performance specifications for the F-35A, reducing turn performance from 5.3 to 4.6 sustained g's and extending the time for acceleration from 0.8 Mach to 1.2 Mach by 8 seconds. These changes were due to the results of air vehicle performance and flying qualities evaluations.
- Discoveries included:
  - Delayed disconnects during air refueling required the program to implement restrictions on the F-35A fleet and conduct additional testing of the air refueling capability. The program added instrumentation to isolate root causes.
  - Horizontal tail surfaces are experiencing higher than expected temperatures during sustained high-speed/high-altitude flight, resulting in delamination and scorching of the surface coatings and structure. All variants were restricted from operations outside of a reduced envelope until the test team added instrumentation to the tailbooms to monitor temperatures on the tail surfaces. The program scheduled modification of one flight sciences aircraft of each variant with new skin coatings on the horizontal tail to permit flight testing in the currently restricted part of the high-speed/high-altitude flight envelope. The test team is adding more flight test instrumentation to help quantify the impacts of the tail heating to support necessary design changes. The program scheduled modifications on one aircraft (AF-2) to be completed in early 2013 to allow flight testing of the new skin design on the horizontal tails to proceed.

F-35B Flight Sciences

Flight Test Activity with BF-1, BF-2, BF-3, BF-4, and BF-5 Test Aircraft
- F-35B flight sciences focused on:
  - Expansion of the vertical-lift operations envelope testing of the newly designed auxiliary air inlet door
  - Engine air-start testing
  - Expansion of the flight envelope with weapons loaded on the aircraft
  - Fuel dump operations
  - Regression testing of new vehicle systems software
- The test team accomplished radar signature testing on BF-5 after the aircraft was returned to the plant for four months for final finishes.
- The test team began weapon-separation flight tests in August when BF-5 accomplished a successful safe separation of an inert GBU-32 JDAM.
- As of the end of November, the sortie rate for the F-35B flight sciences test aircraft was 6.8 sorties per aircraft per month, compared to the goal of 4.4. The program accomplished 153 percent of the planned F-35B flight sciences sorties, completing 374 vice 244 planned.

Flight Sciences Assessment
- Although the program exceeded the objectives planned for sortie rate through the end of November, the progress against planned baseline test points for 2012 lagged by 45 percent with 1,075 test points accomplished against 1,939 planned. This was primarily a result of higher-than-expected loads on weapon bay doors, which prevented planned envelope expansion test points and required additional unplanned testing.
- To compensate for not being able to accomplish the planned envelope expansion test points, the test team pulled an additional 992 points from testing planned for 2013 back into 2012 and added 292 points for regression testing of new software. As of the end of November, the program had accomplished 2,359 total test points for the year. By pulling test points to 2012 that were originally planned for execution in later years, the test team was able to keep pace with the program's overall cumulative SDD test point objectives. Like the F-35A, loads on the weapons bay doors prevented test point accomplishment for internally-loaded weapons; test points with external stores were accomplished instead. For F-35B flight sciences, the test team had completed 106 percent of the planned quantity of cumulative SDD test points scheduled for completion by the end of November (7,480 cumulative points accomplished against a goal of 7,057 points).
- The test team continued investigations into the impact of transonic roll-off and transonic buffet in the F-35B; these investigations are not complete. The program introduced new F-35B vehicle systems software to reduce rudder and flaperon hinge moment in the transonic/supersonic region. The program expected to see improvements in transonic wing roll-off with these changes, but results were not available at the end of November 2012.
- The following table, first displayed in the FY11 Annual Report, describes the observed door and propulsion problems by component and identifies the production cut-in, if known. A significant amount of flight test and validation of an adequate final STOVL-mode configuration (doors and propulsion system) remains to be accomplished.

F-35 B Door and Propulsion Problems				
Category	**Component**	**Problem**	**Design Fix and Test Status**	**Production Cut-In**
Subsystems	Upper Lift Fan Inlet Door Actuators	High actuator failure rates.	Root cause analysis is complete and failure modes are limited to open position (i.e., failure to close); the doors have not failed to open when commanded, which allows lift fan operations. New actuator design is complete and testing is entering final stage of qualification.	BF-38 Low-Rate Initial Production (LRIP) 6 2014
Structure	Auxiliary Air Inlet Door (AAID)	Inadequate life on door locks, excessive wear and fatigue due to the buffet environment, inadequate seal design.	Redesigned door undergoing testing on BF-1. Loads testing completed and verified. Static testing on ground test article (BG-1) is complete, fatigue testing started in November.	BF-38 LRIP 6 2014
Structure	Lift Fan Door Actuator Support Beam	Cracks occurring earlier than predicted. Root cause analysis showed fastener location incorrectly inserted in design.	BF-1, BF-2, and BF-4 modifications are complete. BF-3 will not be modified (will not be used for STOVL Mode 4 operations). BF-4 has resumed Mode 4 operations. Design fix is on BF-5 and subsequent aircraft and new configuration is to full life.	BF-5 LRIP 2 2012
Structure	Roll Control Nozzle (RCN) Doors	Doors separated from aircraft BF-2 and BF-3 during flight; door loads not well understood, aero pressures higher than expected. Impact not limited to STOVL mode operations – flight not to exceed 400 KCAS below 18K ft and 0.5 minimum g-load.	BF-2 and BF-3 were modified with an interim design, instrumented, and flown to verify the updated loads used to develop the interim and final design doors. The Program Office is reviewing a redesign to support production in LRIP 6.	BF-38 LRIP 6 2014
Structure	3 Bearing Swivel Nozzle Door	Door attachment wear/damage found on BF-1 (6/11) requiring new inspection interval every 25 Mode-4 (vertical-lift-fan-engaged) flights. During Slow Landing flight testing, measured door loads exceeded limits.	Interim mod complete on BF-1 and BF-2, instrumentation added and flight test is ongoing. Production redesign is in progress.	BF-44 LRIP 7 2015
Structure	Main Landing Gear (MLG) Doors	Door cracking observed on BF-1, -2, and -4 aft door adjacent to aft lock.	Instrumentation added to BF-2 and flight loads testing complete. Models correlated and root cause confirmed. Modification of the rest of the SDD fleet is in work; production redesign is in progress. MLG door modification will be concurrent with AAID modification.	BF-44 LRIP 7 2015
Propulsion	Drive Shaft	Lift fan drive shaft undergoing a second redesign. Original design inadequate due to shaft stretch requirements to accommodate thermal growth, tolerances, and maneuver deflections.	Full envelope requirements are currently being met on production aircraft with an interim design solution using spacers to lengthen the early production drive shaft. Due to the heavy maintenance workload associated with the spacers, the Program Office is pursuing an improved design that does not require class spacers. The initial improved driveshaft design failed qualification testing. A new design is under development.	BF-44 LRIP 7 2015
Propulsion	Clutch	Lift fan clutch has experienced higher than expected drag heating during conventional (up and away) flight.	Testing completed to determine root cause of drag heating. Fix includes clutch plate width reduction on LRIP 5 and 6 aircraft, at the expense of reduced life (engagements) to the clutch. The Program Office is investigating alternate plate material to meet engagement requirement on subsequent LRIPs.	BF-44 LRIP 7 2015
Propulsion	Roll Post Nozzle Actuator	Roll post nozzle bay temperatures exceed current actuator capability. Actuator failure during Mode 4 operations.	Insulation between the roll post nozzle bay and the actuator has been installed and testing completed through the STOVL flight envelope. All LRIP aircraft have been fitted with insulation to reduce heat transfer into the bay and wear on current actuator. A newly designed, more heat tolerant actuator is scheduled to begin testing in early 2013.	TBD, depending on testing and production of redesigned actuator; retrofit of early production fleet will occur by attrition.
Propulsion	Bleed Air Leak Detectors	Nuisance overheat warnings to the pilot are generated because of poor temperature sensor design; overheats are designed to be triggered at 460 degrees F, but have been annunciated as low as 340 degrees F.	More accurate temperature sensors in the bleed air leak detectors have been designed and delivery for production aircraft started in January 2012.	Detectors on early LRIP aircraft will be replaced by attrition.
Propulsion	Auxiliary Air Inlet Door Aft down-lock seal doors (aka "saloon doors")	Doors are spring-loaded to the closed position and designed as overlapping doors with a 0.5 inch gap. The gap induces air flow disturbance and make the doors prone to damage and out-of-sequence closing. Damage observed on BF-5.	Seal doors are being redesigned with non-overlapping doors and stronger spring loads to ensure proper sequencing and full closure of the doors.	TBD

- The status of F-35B door and propulsion deficiencies follows.
  - The upper lift fan inlet doors continue to fail to operate correctly due to poor actuator design. Crews have observed failure of the doors to close on flight test aircraft and the early LRIP aircraft at Eglin AFB during ground operations. Ground maintenance workaround procedures are in place to ensure correct door operation; however, standard maintenance procedures for fleet operations are not yet in place. Newly designed actuators will not be available for production cut-in until BF-38, a Lot 6 delivery in 2014.
  - Redesign of the auxiliary air inlet doors is complete. The test team accomplished flight testing of the aerodynamic loads on the BF-1 doors early in 2012, and modified the F-35B static test article with the new auxiliary air inlet doors in August 2012 in preparation for static and durability testing. The static load testing was completed in mid-November, followed by the start of durability testing. Results of the testing were not available as of the time of this report.
  - Testing and analysis continued on the three-bearing swivel nozzle doors. The test team added instrumentation on BF-1 in January to assess the dynamic loads on the door to support an engineering redesign. BF-2 was modified and flight testing of the design is ongoing as of the time of this report. Redesign for both the production cut-in and the retrofit plans is in review at the Program Office. Fleet restrictions will remain in effect (slow landings below 100 KCAS are prohibited) until the program modifies the nozzle doors.
  - Temperatures in the roll control nozzle actuator area exceeded the heat tolerance of the current actuator design during flight test, necessitating a redesign. The program is changing the insulation in the nozzle actuator area as an interim fix and redesigning the nozzle actuator to improve heat tolerance. The program plans to begin testing the newly designed nozzle actuator in early 2013.
  - After roll control nozzle doors separated in-flight in 2011, additional testing of the aerodynamic loads on the doors led to a door redesign. A production redesign currently under review with the Program Office increases the closing forces on the door to prevent aerodynamic loads opening and possibly damaging doors or causing door separation.
  - The material solution to unacceptably high clutch temperatures observed during developmental testing is to reduce the width of the clutch plates in later LRIP aircraft with the expectation of reducing the drag and associated heating during all modes of flight. Clutch temperatures are monitored by aircraft sensors, which alert the pilot when normal temperature limits are exceeded. The associated pilot procedures to reduce high clutch temperatures require changing flight regimes to a cooling envelope of lower altitude (below 11,000 feet) and lower airspeed (less than 280 knots); such a procedure during combat missions would likely increase the vulnerability to threats and cause the pilot to abort the mission. Further, a vertical landing under high clutch temperature conditions needs to be avoided if possible, making return to forward basing or ship-borne operations in the combat zone, where a vertical landing would be required, not practical.
  - The program added spacers to the lift fan driveshaft to address unanticipated expansion/stretching that takes place during flight. This is an interim solution while the program redesigns the driveshaft for better performance and durability.
- Weight management of the F-35B aircraft is critical to meeting the Key Performance Parameters (KPPs) in the ORD, including the vertical lift bring-back requirement. This KPP requires the F-35B to be able to fly an operationally representative profile and recover to the ship with the necessary fuel and balance of unexpended weapons (two 1,000-pound bombs and two AIM-120 missiles) to safely conduct a vertical landing.
  - Weight reports for the F-35B have varied little in 2012, increasing 14 pounds from either changes in the manufacturing processes or more fidelity in the weight estimate. Current estimates are within 231 pounds (0.71 percent) of the not-to-exceed weight of 32,577 pounds – the target weight of the aircraft in January 2015 to meet specification requirements and ORD mission performance requirements for vertical lift bring-back. The small difference between the current weight estimate and the not-to-exceed weight allows for weight growth of 0.32 percent per year.
  - Managing weight growth with such small margins will continue to be a significant program challenge. Since the program will conduct the technical performance measurement of the aircraft in January 2015, well before the completion of SDD, continued weight growth through the balance of SDD will affect the ability of the F-35B to meet the STOVL mission performance KPP during IOT&E. Additionally, production aircraft are weighed as part of the government acceptance process, and the early LRIP lot F-35B aircraft were approximately 150 pounds heavier than the predicted values found in the weight status report.
- The program announced an intention to change performance specifications for the F-35B, reducing turn performance from 5.0 to 4.5 sustained g's and extending the time for acceleration from 0.8 Mach to 1.2 Mach by 16 seconds. These changes were due to the results of air vehicle performance and flying qualities evaluations.
- Other discoveries included:
  - As with the F-35A, horizontal tail surfaces are experiencing higher than expected temperatures during sustained high-speed/high-altitude flight, resulting in delamination and scorching of the surface coatings and structure. The program modified the tail surfaces of BF-2 in September to permit flight testing at higher airspeeds. The coatings delaminated during flight,

however, suspending further flight testing in the higher airspeed envelope until a new plan for the coatings can be developed.
  - Fuel dump testing is ongoing on BF-4 after a redesign of seals on the lower trailing edge flaps. Previous testing with the original seals resulted in fuel penetrating the cove area behind the flaps and wetting the fuselage, allowing fuel to pool near the Integrated Power Package exhaust where the fuel is a fire hazard. Testing with the new seals has shown less fuel penetration with flaps fully retracted and with flaps extended to 20 degrees; however, fuel traces inside the flaperon cove were observed during post-flight inspections. The test team is also testing redesigned exit nozzles of different shape and cross-sectional areas. As of the end of November 2012, 11 relevant test flights have been accomplished; more flights will be necessary to resolve the deficiency.
  - Planned wet runway testing, required to assess braking performance with a new brake control unit, has been delayed due to the inability to create the properly degraded friction conditions at the Patuxent River Naval Air Station (NAS), Maryland. The F-35B training aircraft at Eglin will be restricted to dry runway operations only until the wet runway testing is completed.

F-35C Flight Sciences

Flight Test Activity with CF-1, CF-2, and CF-3 Test Aircraft

- F-35C flight sciences focused on:
  - Verification of the basic flight envelope for the first production F-35C aircraft
  - Expansion of the flight envelope with external weapons loaded on the aircraft (AIM-9X short-range missile in subsonic flight)
  - Testing of arresting hook system modifications
  - Preparing for executing carrier landings in the simulated carrier environment at Lakehurst Naval Test Facility, New Jersey, including handling qualities at approach speeds at carrier landing weights
  - Surveying handling qualities in the transonic flight regimes
  - Regression testing of new air vehicle systems software
- As of November, the test team executed a sortie rate of 7.1 sorties per aircraft per month compared to the goal of 6.4. The program accomplished 110 percent of the planned F-35C flight sciences sorties, completing 233 vice 211 planned through the end of November.
- The program plans to deliver the final F-35C flight sciences aircraft, CF-5, in late 2012, followed soon by the first production F-35C from Lot 4. CF-5 flew its first company acceptance flight at the end of November.

Flight Sciences Assessment

- The program completed 80 percent of the baseline test points planned though November 2012, accomplishing 1,060 test points of a planned 1,327. Flight restrictions blocked accomplishment of a portion of the planned baseline test points until a new version of vehicle systems software became available.
- The test team flew an additional 253 test points from flight test requests and pulled 896 test points forward from work planned for 2013.
- By accomplishing envelope test points planned for completion in later years, the test team was able to keep ahead of the cumulative SDD test point objectives, as was the case in F-35A and F-35B flight sciences. While awaiting new vehicle systems software required to complete planned envelope testing in 2012, the test team accomplished points in other areas of the flight envelope. For F-35C flight sciences, the test team had accomplished 116 percent of the planned number of cumulative test points scheduled for completion by the end of November (4,330 cumulative points accomplished against a goal of 3,748 points).
- Weight management of the F-35C variant is important for meeting air vehicle performance requirements. F-35C weights have generally decreased in the monthly estimates during 2012. The latest weight status report from November 2012 showed the estimated weight of 34,522 pounds to be within 346 pounds (1.0 percent) of the projected maximum weight needed to meet technical performance requirements in January 2016. This margin allows for 0.31 percent weight growth per year. The program will need to continue rigorous weight management through the end of SDD to avoid performance degradation and operational impacts.
- The program announced an intention to change performance specifications for the F-35C, reducing turn performance from 5.1 to 5.0 sustained g's and increasing the time for acceleration from 0.8 Mach to 1.2 Mach by at least 43 seconds. These changes were due to the results of air vehicle performance and flying qualities evaluations.
- Discoveries included:
  - Due to the difference in wing design, transonic buffet becomes severe in different portions of the flight envelope and is more severe in the F-35C than the other variants. The program is making plans for investigating how to reduce the impact of transonic roll off in the F-35C with the use of wing spoilers; however, detailed test plans are not complete.
  - As with the F-35A and F-35B, horizontal tail surfaces are experiencing higher than expected temperatures during sustained high-speed/high-altitude flight, resulting in delamination and scorching of the surface coatings and structure. In August, the test team installed new coatings on CF-1 horizontal tails, designed to prevent scorching and delaminating during prolonged use of afterburner pursuing high airspeed test points. However, portions of the coatings dis-bonded during flight, suspending further testing of the high airspeed portion of the envelope.
  - The test team investigated alternative trailing edge flap settings to improve flying qualities during carrier landing approach. While pilot surveys showed handling qualities were improved with a 15-degree flap setting, flight test data to date have shown that 30 degrees of flaps are required to meet the KPP for maximum approach speed of 145 knots at required carrier landing weight.

Mission Systems

Flight Test Activity with AF-3, AF-6, AF-7, BF-17, and BF-18 Test Aircraft and Software Development Progress

- Mission systems are developed and fielded in incremental blocks of capability.
  - Block 1. The program designated Block 1 for initial training capability and allocated two increments: Block 1A for Lot 2 (12 aircraft) and Block 1B for Lot 3 aircraft (17 aircraft). No combat capability is available in either Block 1 increment. (Note: Remaining development and testing of Block 0.5 initial infrastructure was absorbed into Block 1 during the program restructuring in 2011.)
  - Block 2A. The program designated Block 2A for advanced training capability and associated this block with Lots 4 and 5. No combat capability is available in Block 2A.
  - Block 2B. The program designated Block 2B for initial, limited combat capability for selected internal weapons (AIM-120C, GBU-32/31, and GBU-12). This block is not associated with the delivery of any production aircraft. Block 2B software will be used to retrofit earlier production aircraft.
  - Block 3i. Block 3i is Block 2A capability re-hosted on an improved integrated core processor for Lots 6 through 8.
  - Block 3F. The program designated Block 3F as the full SDD capability for production Lot 9 and later.
- The Patuxent River test site accepted two early production aircraft from Lot 3 (BF-17 and BF-18) to support mission systems development and testing, in accordance with guidance following the Technical Baseline Review (TBR) in October 2010. Aircraft BF-17 ferried to Patuxent River on October 4th and BF-18, on November 8th. BF-17 began radar signature testing soon after arrival; BF-18 has yet to fly test sorties.
- The four mission systems flight test aircraft, three assigned to the Edwards AFB test center, and one BF-17 assigned to Patuxent River, flew an average rate of 5.0 sorties per aircraft per month through November, exceeding the planned rate of 4.4 by 14 percent. Mission systems test aircraft flew 115 percent of the test flights planned through the end of November (222 sorties completed compared to 193 planned).
- The test team accomplished 95 percent of the planned 2012 baseline test points by the end of November (1,238 baseline test points accomplished, 1,308 planned). The team also accomplished an additional 610 test points for regression testing of additional revisions of Block 2A software.

Mission Systems Assessment

- The program made limited progress in 2012 in fielding capability, despite relatively high sortie and test point completion rates.
  - Software delivery to flight test was behind schedule or not complete when delivered.
    - Block 1 software has not been completed; approximately 20 percent of the planned capability has yet to be integrated and delivered to flight test.
    - The first version of Block 2A software was delivered four months late to flight test. In eight subsequent versions released to flight test, only a limited portion of the full, planned Block 2A capability (less than 50 percent) became available and delivered to production. Block 2A has no combat capability.
    - Block 2B software was planned to be delivered to flight test by the end of 2012, but less than 10 percent of the content was available for integration and testing as of the end of August. A very limited Block 1B software version was delivered to the Cooperative Avionics Test Bed aircraft in early November for integration testing.
    - The program made virtually no progress in the development, integration, and laboratory testing of any software beyond 2B. Block 3i software, required for delivery of Lot 6 aircraft and hosted on an upgraded processor, has lagged in integration and laboratory testing.
  - The test team completed 1,238 (95 percent) of the planned 1,308 baseline test points by the end of November. The team also completed an additional 610 points for regression of multiple versions of software. Although the test team accomplished test points in 2012 as planned, little flight testing of advanced mission systems capability has taken place. Additionally, current planning of baseline test points results in shortfalls in production aircraft capabilities that will persist into 2014. Only 2,532 (23 percent) of the 10,966 total mission systems test points planned for SDD have been accomplished as of the end of November 2012. Of those completed, 54 percent supported testing of basic mission systems capabilities, such as communications, navigation, and basic radar functions, with the remaining 46 percent being comprised of radar signature testing (which does not involve or require any mission systems capability), software maturity demonstrations, and verification of capabilities for early production aircraft delivery.
- Although all Lot 2 and Lot 3 aircraft – in the Block 1 configuration – were either delivered to the Services or awaiting final delivery as of the time of this report, the test team had accomplished only 54 percent (738) of the 1,371 test points in the original Block 1 test plan. This resulted in the Lot 2 and Lot 3 aircraft being accepted by the Services with major variances against the expected capabilities and added to a bow wave of test points that will have to be completed in the future.
  - For example, when six F-35A and six F-35B Lot 2 aircraft were delivered to the training center in the Block 1A configuration, only 37 of 51 Block 1A capabilities on contract were delivered. Subsequently, the program delivered ten Lot 3 aircraft to the training center in 2012 in a partial Block 1B configuration (three F-35As, five F-35Bs, and two F-35Bs produced for the United Kingdom).

- The Block 1B configuration was designed to provide an additional 35 capabilities; however, the program delivered only 10 prior to the delivery of the first Lot 3 aircraft. The program is in the process of upgrading Block 1A aircraft to the 1B configuration; however, no additional capabilities were delivered with the Block 1B configuration. Examples of expected capabilities that were not delivered include air vehicle and off-board prognostic health management tools, instrument landing system (ILS) for navigation, distributed aperture system (DAS) video displaying in the helmet, corrosion data recording capability, and night vision imaging integration with the helmet.

• The Services began accepting Lot 4 aircraft in the Block 2A configuration in November with major variances against the expected capabilities. The program plans to continue to develop and test the incomplete and remaining Block 2A capabilities using incremental versions of Block 2A software and update the aircraft previously delivered with partial capabilities in late 2013. The continued development and testing of Block 2A software will be accomplished concurrently with the Block 2B software capabilities.

• Simultaneous development of new capabilities, associated with the next blocks of software, competes with the flight test resources needed to deliver the scheduled capability for the next lot of production aircraft.
  - For example, the testing needed for completion of the remaining 20 percent of Block 1 capabilities and 50 percent of Block 2A capabilities will have to be conducted while the program is introducing Block 2B software to flight test. Software integration tasks supporting Block 2B (and later increments) were delayed in 2012 as contractor software integration staff were needed to support Block 2A development, test, and anomaly resolution.
  - This process forces the program to manage limited resources, including the software integration labs, the cooperative avionics test bed aircraft, and the mission systems test aircraft, to address the needs of multiple versions of software simultaneously. The demand on flight test to complete test points for verification of capability for production software releases, while simultaneously accomplishing test points for expanding development of capability will continue to challenge the test team and add to the inherent concurrency of the program. The program intends Block 3i to enter flight test in mid-2013, which will be conducted concurrently with the final 15 months of Block 2B flight test. The program intends for Block 3F to enter a 33-month developmental flight test period in early 2014.

• Recognizing the burden and challenges caused by the concurrency of production and flight test, the Program Office is developing a capability management plan and review board to evaluate priorities and trades of capabilities within blocks and for deferral out of SDD if necessary.

• Shortfalls in the test resources required to test mission systems electronic warfare capabilities under operationally realistic conditions were identified by DOT&E in February. The needed resources and funding were being considered by the Department at the time of this report.

• Discoveries included:
  - The test team continued to work through technical problems with the helmet-mounted display system, which is deficient. The program was addressing five problems at the time of this report. Jitter, caused by aircraft vibrations and exacerbated by aircraft buffet, makes the displayed information projected to the pilot hard to read and unusable under certain flight conditions. Night vision acuity is not meeting specification requirements. Latency of the projected imagery from the DAS is currently down to 133 milliseconds, below the human factors derived maximum of 150 milliseconds, but still requires additional testing to verify adequacy. Boresight alignment between the helmet and the aircraft is not consistent between aircraft and requires calibration for each pilot. Finally, a recently discovered technical problem referred to as "green glow" has been experienced when light from the cockpit avionics displays leaks into the helmet-mounted display and degrades visual acuity through the helmet visor under low ambient light conditions. The test team is planning additional, dedicated ground and flight testing to address these technical problems.
  - Electronic warfare antenna performance of the first three production lots of aircraft was not meeting contract specification requirements. Poorly designed connectors created signal distortion in the six antenna apertures embedded in the aircraft. The Program Office determined that 31 aircraft are affected and require additional testing of each antenna. Testing of the apertures began on SDD aircraft at Edwards AFB in November. Progress in verifying the performance of the electronic warfare system will be affected until additional testing of the apertures in the aircraft is completed and any necessary retrofits accomplished on the mission systems test aircraft.
  - Helmet-mounted display video imagery needed to successfully analyze and complete portions of the mission systems test plans cannot be reliably recorded on either the portable memory device or the data acquisition recording and telemetry pod. The program began testing fixes in August. Until resolved, the overall impact is 336 total mission systems test points that are not achievable.
  - The program projects utilization rates for the two processors that support the panoramic cockpit display to be greater than 100 percent when assessed against Block 3 capabilities. The program initiated plans to optimize the core processor software to reduce these rates.
  - The program is tracking mission system software stability by analyzing the number of anomalies

observed as a function of flight time. Current program objectives for early mission system software in flight test are to have integrated core processor and Communications/Navigation/Identification Friend or Foe (CNI) anomaly rates be 15 hours or more between events. Recent reports for the latest mission systems software in flight test – version 2AS2.8 – show a rate of 6.3 hours between anomalies based on 88 hours of flight test.

Weapons Integration

- Weapons integration includes flight sciences, mission systems, and ground maintenance support. Testing includes measuring the environment around the weapon during carriage (internal and external), handling characteristics of the aircraft, safe separation of the weapon from the aircraft, and weapons delivery accuracy events.
- In 2012, the program conducted detailed planning of the weapons integration events necessary to complete SDD. This planning yielded a schedule for completing weapons integration for Block 2B and Block 3F combat capability.
- The test team conducted the flight sciences loads, flutter, and environmental testing necessary to certify a limited Block 2B carriage envelope of the F-35A and F-35B aircraft for Joint Direct Attack Munition, GBU-12 laser guided bomb, and the AIM-120 air-to-air missile to enable the start of active flight testing. As of the end of October, this testing had achieved captive carriage and first safe separation of an inert AIM-120 missile (on the A model) and inert Joint Direct Attack Munition (on both the A and B model). However, to date, weapons integration has been limited by the following deficiencies:
  - Instrumentation
  - Data recording shortfalls
  - Deficient mission systems performance in radar, Electro-Optical Targeting System (EOTS), fusion, and the helmet
  - Lack of radar fusion support to the AIM-120 air-to-air missile
  - EOTS inability to accurately track and designate targets for the air-to-ground munitions,
  - Deficient fused situational awareness presentation to the pilot
- The successful execution of the detailed schedule developed this year was dependent on:
  - The ability of the program to deliver mission systems capability required to start weapons integration in April 2012
  - Adequate margin in the test schedule to accommodate repeated testing, cancellations due to weather, range assets, and operational support
  - Reliable instrumentation and range support
- None of these assumptions have proven true, adding risk to the execution of the overall schedule. Deferrals of mission systems capabilities to later blocks and delays for corrections to test instrumentation and data recording have removed the schedule margins. The impact of these delays will potentially require an additional 18 months added to the schedule for weapons integration events.

Static Structural and Durability Testing

- Durability testing on the ground test articles of all three variants continued in 2012; progress is measured in aircraft lifetimes. An aircraft lifetime is defined as 8,000 Equivalent Flight Hours (EFH), which is a composite of time under different test conditions (i.e., maneuver and buffet for durability testing). In accordance with the SDD contract, all three variants will complete two full lifetimes, or 16,000 EFH of durability testing. The completion dates for the second aircraft lifetimes are late 2014 for the F-35B and early 2015 for the F-35A and F-35C. Plans for a third lifetime of durability testing for all three variants are under development.
- The F-35A ground test article, AJ-1, completed the first of two planned aircraft lifetimes in August, as planned. F-35A durability testing continued into the second planned aircraft lifetime at the time of this report, completing 9,117 EFH as of December 5, 2012.
- F-35B durability testing on BH-1 was restarted in January after a 16-month break caused by the discovery, analysis, and repair of a crack in a wing carry-through bulkhead at 1,055 EFH. Since restarting, an additional 5,945 hours of testing had been completed by the end of October, bringing the total test time to 7,000 EFH and putting the testing ahead of the restructured 2012 plan to complete 6,500 hours by the end of the year.
- F-35C durability testing began in March and the test article, CJ-1, had completed 4,000 EFH of fatigue testing as of October, as scheduled.
- Component durability testing for two lifetimes of the vertical tails was completed for the F-35A and F-35B during 2012. This testing was started in August for the F-35C. Component testing of the horizontal tail for the F-35C completed 8,000 EFH, or one lifetime, in May, and an additional 2,000 EFH by the end of October. (Component testing of the horizontal tails for the F-35A and F-35B completed two lifetimes of testing in 2011.)
- The program redesigned the F-35B auxiliary air inlet doors, required for STOVL operations, and began flight testing in 2012. Redesigned doors have been installed on the static loads test article (BG-1) and completed static loads testing in early November, followed by the start of durability testing. The report from the static testing is scheduled to be completed by the end of 2012; however, the results of the durability testing are not scheduled to be available until mid-2013. The program has already ordered, received, and begun installing retrofit kits for the auxiliary air inlet door modifications on fielded Lot 4 aircraft.
- Discoveries from durability testing included significant findings in both the F-35A and F-35B ground test articles.
  - In the F-35A, a crack was discovered on the right wing forward root rib at the lower flange (this is in addition to the crack found and reported in the FY11 Annual Report).

Also, a crack was found by inspection in the right hand engine thrust mount shear web in February. Testing was halted while the crack was inspected and analyzed, then restarted to complete subsequent blocks of testing.
- In the F-35B, the program halted testing in December 2012 after multiple cracks were found in a bulkhead flange on the underside of the fuselage during the 7,000-hour inspection. Root cause analysis, correlation to previous model predictions, and corrective action planning were ongoing at the time of this report. Other cracks were previously discovered in the B-model test article; one on the right side of the fuselage support frame in February and one at a wing pylon station in August, both of which were predicted by modeling. Another crack in the shear web tab that attaches to the support frame was discovered in March. Also, excessive wear was found on the nose landing gear retractor actuator lugs and weapons bay door hinges. All of these discoveries will require mitigation plans and may include redesigning parts and additional weight.

• The results of findings from structural testing highlight the risks and costs of concurrent production with development. The Program Office estimates of the weight changes to accommodate known limited life parts discovered so far from structural testing are shown in the table below. These weight increases are in the current weight status reports for each of the variants. Discoveries during the remaining two years of structural testing will potentially result in more life-limited parts and associated impacts to weight and design.

Variant	Number of Life Limited Parts	Retrofit Weight Increase to Early LRIP Aircraft (prior to production cut-in)	Production Weight Increase (cut-in varies from LRIP 4 to LRIP 7)
F-35A	19	38 pounds	20 pounds
F-35B	20	123 pounds	33 pounds
F-35C	7	5 pounds	1 pound

Modeling and Simulation

Verification Simulation (VSim)

• The Verification Simulation (VSim) is a man-in-the-loop, mission software-in-the-loop simulation developed to meet the operational test agencies' requirements for Block 2B OT&E and Block 3 IOT&E.

• The program continued detailed technical reviews of the VSim with the contractor and subcontractors supplying its component models during 2012. Sensor model reviews took place for the electronic warfare, radar, and DAS infrared sensors. The program held similar detailed reviews for the inertial navigation system (INS) and Global Positioning System (GPS) models, as well as for the VSim Battle Space Environment (BSE), a collection of background environment models with which the sensor and navigation system models interact.

• At the time of this report, the program was tracking 11 formal risks with regard to VSim, 4 of them characterized as high risk, the other 7 characterized as moderate. These 11 risks fall into 4 general categories:
- Risks associated with timeliness of VSim software delivery, completeness with regard to modeled capabilities, and discrepancies between VSim and aircraft software due to mismatches in the software versions that are current in VSim and those that are current in the aircraft at any given time.
- Risks associated with the timeliness, completeness, and production-representativeness of data from flight testing and other testing used to verify and validate VSim.
- Risks regarding the time and manpower needed to analyze VSim validation data and perform accreditation assessments.
- Fundamental risks regarding the ability of VSim to faithfully replicate all aspects of F-35 and threat systems performance.

• In addition to the risks cited by the Program Office, DOT&E has highlighted shortfalls in the test resources needed to gather key elements of data required for validation of the VSim for IOT&E, in particular for electronic warfare performance. These shortfalls are a function of limitations in the test assets currently available to represent threat systems. DOT&E has made formal recommendations to address the shortfalls.

Other Models and Corporate Labs Activity

• The Program Office has accredited 7 of the 28 models and simulations currently planned to support verification of the F-35.

• The program accredited three models intended for use in contract specification verification in 2012. These are the Ejection Seat Model, the Support Enterprise Model (SEM), and the Automatic Dynamic Analysis of Mechanical Systems (ADAMS) model. A fourth model, Prognostic Health Management (PHM) Coverage Analysis Tool (PCAT), is in final accreditation review at the Program Office at the time of this report.
- The Ejection Seat Model is used to verify the terrain clearance requirements of the F-35 ejection seat under different flight conditions.
- SEM is used to assess the logistics infrastructure requirements of the fielded F-35 Air System.
- ADAMS is used to assess weapon store-to-aircraft clearances and interfaces during loading, carriage and separation, evaluating weapon arming and de-arming, and other weapons system separation functions.
- PCAT is a spreadsheet-based application that rolls-up probabilities of fault isolation and fault detection to various line replaceable units.

• The program plans to accredit 6 models and simulations intended for use in requirements verification plan in 2013, with the remaining 15 accreditations due between 2014 and the end of SDD in 2017.

• The Program Office has identified challenges for 2013 with respect to obtaining and analyzing, in a timely fashion, the validation data needed to accredit the GPS System Model Simulation (GSMS) and Modeling System for Advanced Investigation of Countermeasures (MOSAIC) infrared countermeasures effectiveness models.

- In 2011, the Air Force airworthiness authorities identified the pilot escape system installed in the early LRIP aircraft as a serious risk. Validation of expected performance of the F-35 escape system is supported by modeling the ejection seat as well as the effectiveness of the transparency removal system for the canopy during the ejection sequence.
  - For the ejection seat model, the program used data from sled testing under straight and level conditions to predict performance of the ejection seat under non-zero angle-of-bank (including inverted) conditions. Interactions between the pilot, the ejection seat, and the canopy during the ejection sequence, however, are not well understood, particularly during other than straight and level ejection conditions.
  - Testing of the transparency removal system under off-nominal conditions to better understand these interactions was scheduled for March 2012. The program expects this testing to take place in December 2012.

Training System

- The program initiated flight operations at the Integrated Training Center, Eglin AFB, Florida, in 2012 with both the F-35A and F-35B aircraft.
  - The Air Force accepted six F-35A aircraft from production Lot 2 in 2011 at Eglin in the Block 1A configuration, but did not commence flight operations until March 2012 when the Air Force airworthiness authorities provided the necessary flight clearance, which limited operations to previously qualified F-35 pilots. In July, the Air Force changed the flight clearance to allow pilots not previously qualified to fly at Eglin, which paved the way for F-35A pilot training to begin later in the year.
  - The program delivered six F-35B aircraft from production Lot 2 to Eglin between January and May 2012. Also in May, Navy airworthiness authorities provided a flight clearance for F-35B flight operations to begin at Eglin.
  - The program added 10 production Lot 3 aircraft – all in the Block 1B configuration – to Eglin by the end of October 2012 to support flight training: 3 F-35A aircraft between July and August and 7 F-35B aircraft (5 for the Marine Corps and 2 for the United Kingdom) between July and October. These deliveries were later than planned due to late availability of an adequate Autonomous Logistics Information System (ALIS) at Eglin to support the Block 1B aircraft configuration.
- In July 2012, DOT&E recommended to the Air Force, the operational test agencies, and the JSF Program Office that the training OUE be delayed until the system matures and possesses some combat capability relevant to an operational evaluation.
  - DOT&E identified seven indicators which highlighted a lack of overall system maturity: abort rates higher, and trending flat, than the Air Force risk assessment identified for a maturing system; the trend in discovery as indicated by the rate of new Deficiency Reports; the high number of "workarounds" needed to support maintenance and sortie generation activities (including engineering support from the contractor); lack of a water-activated parachute release system (qualification testing is delayed until 2013); incomplete testing of the escape/ejection system; low overall availability rates; and no new information or plans to address deficiencies in the Integrated Caution and Warning System.
  - The Air Force elected to begin the training OUE in early September 2012, and concluded it in mid-November 2012. The system under test had no combat capability. Flight training events were limited to basic aircraft maneuvers called for in the "familiarization" pilot transition syllabus, which is a six-flight module of training. Pilots were trained in basic ground procedures, take-off, approach/landing, and formation flight. Radar, electronic warfare, countermeasures, and weapons capabilities were not included in the syllabus as they were either restricted from being used or were not available. Flight maneuvering was restricted to 5.5 g's, 550 knots, 18 degrees angle-of-attack, and below 39,000 feet altitude, and was further constrained by numerous aircraft operating limitations that are not suitable for combat. The maintenance environment and support systems are still immature. Sortie generation was dependent on contractor support personnel, maintenance personnel had to use workarounds to accommodate shortfalls in ALIS, and the Joint Technical Data was incomplete. DOT&E will provide an independent report on the evaluation in early 2013.
- As of the end of OUE in November, 276 sorties and 366 hours had been flown in the F-35A aircraft at Eglin, with the first flights in March, and 316 flights and 410 hours flown in the F-35B, since starting in May.
  - Aircraft availability rates for the F-35A varied from less than 5 percent to close to 60 percent in a given week from the first flights in March through October, with an average availability of less than 35 percent, meaning three of nine aircraft were available on average at any given time. For the F-35B, availability rates varied monthly as well from less than 5 percent to close to 50 percent, with similar average rates over the six months of flying.
  - Cumulative air abort rates over the same time period were also similar between the two variants with approximately five aborts per 100 flight hours observed (4.7 for the F-35A and 5.3 for the F-35B). In 2010, the Air Force used air abort rate as an objective metric for assessing the maturity needed to start flight training, with a goal of 1.0 air abort per 100 flight hours as a threshold to start an evaluation of the system's readiness for training. Ground abort rate was one ground abort in seven scheduled sorties (0.14) for the F-35A and one in eight (0.13) for the F-35B.
- The center conducted maintenance training for experienced maintenance personnel for both the F-35A and F-35B

during 2012. As of the end of November, 542 personnel had completed training in one or more of the maintenance courses. Graduates from the maintenance courses at the training center will support initial service bed down and training locations.

Air System-Ship Integration and Ship Suitability Testing

F-35B

- The Program Office continued planning efforts to support the next F-35B developmental testing deployment to USS *Wasp* in August 2013. Through the middle of November, the test team had accomplished 79 vertical landings in 2012 (358 total to date) and 212 short takeoffs (631 to date). Control law changes were made to the vehicle system software as a result of flying qualities observed during the first deployment to USS *Wasp* in 2011. Regression testing of the control law changes was accomplished in 2012.
- Discoveries affecting F-35B operations on L-class ships include:
  - Assessment of ship capabilities were inconclusive in determining whether there would be adequate storage requirements for lithium battery chargers and spares, gun pods, and the ejection seat carts as some of the support equipment and spares from legacy systems may no longer be required. Additional data are required to determine a path forward.
  - Propulsion system module containers do not meet all shipboard requirements. Due to the fragility of certain propulsion system components, there is significant risk to engines during transport to and from ships, using the current containers. The Program Office is coordinating a propulsion system fragility analysis which is expected to lead to a container redesign.
  - Concept of operations for managing and using the classified materials area remains to be resolved.

F-35C

- A redesign of the arresting hook system for the F-35C to correct the inability to consistently catch cables and compensate for greater than predicted loads took place in 2012. The redesign includes modified hook point shape to catch the wire, one-inch longer shank to improve point of entry, addition of damper for end-of-stroke loads, increased size of upswing damper and impact plate, addition of end-of-stroke snubber. In 2012, the following occurred:
  - Initial loads and sizing study completed showed higher than predicted loads, impacting the upper portion of the arresting hook system (referred to as the "Y frame," where loads are translated from the hook point to the aircraft) and hold down damper (January 2012)
  - Risk reduction activities, including cable rollover dynamics testing at Patuxent River (March 2012), deck obstruction loads tests at Lakehurst (April 2012)
  - Flight tests with CF-3 using new hook point and new hold down damper design at Lakehurst (August 2012)
  - 72 of 72 successful roll-in tests with MK-7 and E-28 gear
  - 5 of 8 successful fly-in tests; 3 of 8 bolters (missed wire)
  - Preliminary design review of updated design completed (August 15, 2012)
- Analysis by Service and program ship integration teams identified several aircraft-ship interface problems for resolution.
  - Deficient capability to transfer recorded mission data to ship intelligence functions for analysis, in particular video data recorded by the JSF.
  - Ships are unable to receive and display imagery transmitted via Link 16 datalink by JSF (or other aircraft).
  - The design of the JSF Prognostic Health Maintenance downlink is incomplete, creating concerns for sufficient interfaces with ship systems and Information Assurance.

Live Fire Test and Evaluation

System-Level Test Series

- The program completed two of the eight system-level test series. The first, LF-19D Flight-Critical System-Level test series, was conducted on the first F-35A flight test aircraft to assess the ballistic tolerance of the flight control system and its supporting systems (e.g., power thermal management, vehicle management, and electrical power systems).
- This test series targeted components of the redundant vehicle management and electrical power systems, demonstrating their ability to automatically reconfigure after damage, and to continue to operate with no obvious effect on the ability of the aircraft to remain in controlled flight.
- The Live Fire Test team is assessing the aircraft vulnerability damage thresholds and whether testing properly explored the intended ballistic damage modes (e.g., interference or arcing between 270 Volt, 28 Volt, and signal lines; loss of flight actuator stiffness; and/or impact to singularly vulnerable components such as the flight actuator ram cylinder).
- One test in this series, LF-19D-27, demonstrated aircraft vulnerabilities to fires associated with leaks from the PAO system. The aircraft uses flammable PAO in the avionics coolant system, which has a large footprint on the F-35. The threat in this ballistic test ruptured the PAO pressure line in the area just below the cockpit, causing a sustained PAO-based fire with a leak rate of 2.2 gallons per minute (gpm).
  - The program assessed that a similar event in flight would likely cause an immediate incapacitation and loss of the pilot and aircraft. The test article, like the production design, lacks a PAO shutoff system to mitigate this vulnerability.
  - In 2008, the JSF Executive Steering Board (JESB) directed the removal of PAO shutoff valves from the F-35 design to reduce the aircraft weight by 2 pounds. Given the damage observed in this test, the JESB directed the program to re-evaluate installing a PAO shutoff system through its engineering process based on a cost/benefit analysis and the design performance capabilities. The ballistic test results defined the significance of this vulnerability. However, the test also showed that a shutoff system needs

to outperform other fielded systems. To be effective, it must trigger on smaller leak rates, down to 2 gpm versus the 6 gpm typical of other aircraft designs, without causing excessive false alarms.
    - The program is currently working to identify a low leak rate technical solution. The Program Office will consider operational feasibility and effectiveness of the design, along with cost, to decide if PAO shutoff valves will be reinstated as part of the production aircraft configuration.
- Another test in this series, LF-19D-16, identified the vulnerability associated with fuel fires from fueldraulic system leaks. The fueldraulic system is a fuel-based hydraulic system used to control the engine exhaust nozzle. It introduces a significant amount of fuel plumbing to the aft end of the engine and, consequently, an increased potential for fire.
    - This test confirmed the increase in vulnerability. The original aircraft design included flow fuses, also known as excess flow check valves, to cutoff fuel flow when a leak is sensed due to downstream fuel line damage or failure. As a result of the weight-reduction initiative, the JESB directed removal of fueldraulic fuses from the production design in 2008 to provide weight saving of 9 pounds. Fuses, however, were still part of the non-weight-optimized F-35A test article used in this test.
    - While a ballistic test with fragment threats demonstrated that the fueldraulic system poses a fire-related vulnerability to the F-35, the leak rates generating the fire were insufficient to trigger the fuses. Since the fuses did not shut off the flow, the result was a sustained fuel-based fire.
    - The Program Office is accepting the increased vulnerability associated with the fueldraulic system and is currently not considering reinstating the fueldraulic fuses in the production aircraft configuration.
- A Computation of Vulnerable Area Tool analysis shows that the removal of the PAO coolant and fueldraulic systems results in a 25 percent increase in aircraft vulnerability.

Ballistic Analysis

- The program used a computational analysis, supported by single fragment test data, to evaluate the vulnerabilities of the F-35 to multiple missile warhead fragment hits for several encounter geometries.
    - Multiple missile warhead fragment hits are more combat-representative and will result in combined damage effects that need to be assessed. For example, aircraft may not be lost due to a fuel leak from a single missile fragment impact, but combined leakage from multiple impacts could prevent the aircraft from returning to base.
    - There are potentially other such combined effects that are not known or expected and that, due to the analysis limitations, cannot be identified. These limitations will introduce a level of uncertainty in the F-35 vulnerability assessment.
- The program used the results of the completed tests to assess the effects of ballistic damage on the capability of the aircraft to maintain controlled flight.
    - These estimates are typically expressed as a function of time intervals, i.e., 0 minutes (“catastrophic kill”), 30 seconds (“K-kill”), 5 minutes (“A-kill”), 30 minutes (“B-kill”), etc.; however, the program categorized them in terms that supported their specification compliance, i.e., “Loss of Aircraft” or the ability to “Return to Forward Line of Troops (FLOT).”
    - These limited categories do not provide detailed insight into the vulnerability of the aircraft. For example, with a Return to FLOT criterion of 55 minutes, if the aircraft could fly for 45 minutes it would still be classified as a Loss of Aircraft and no understanding is provided concerning the aircraft’s actual capability to maintain controlled flight for those 45 minutes. Such an assessment does not provide insight into the actual operational survivability of the aircraft because it only focuses on the ability of the aircraft to fly for 55 minutes even though, in some instances, the pilot might need much less time to return to friendly territory.

STOVL Propulsion System Test Series

- The program completed most of the STOVL propulsion system test series. The Program Office temporarily suspended this test series due to budget constraints without notifying DOT&E. The remaining lift fan-to-clutch drive shaft and lift fan clutch static and dynamic tests have been postponed until FY13.
    - The LFT&E STOVL propulsion system tests confirmed that back-ups to hydraulic systems that configure the STOVL propulsion system for its various operating modes worked as intended.
    - The completed test events targeted the lift fan rotating and stator components while the fan was static. The program assumed that the lift fan would most likely be hit while in forward flight and that hits during STOVL flight were less likely. In most test events, the system was then run up to simulate a STOVL landing sequence.
    - The results indicated that test damage introduced no measurable degradation in STOVL propulsion performance, including cascading damage effects, and would be undetectable by the system and the pilot. However, due to concerns for catastrophic lift fan or drive train damage that would risk loss of the test article for subsequent tests, this test series did not include dynamic tests to the inboard portion of the lift fan blade, where the cross section is smaller and centrifugal forces are higher, making failure more likely.
    - The engine manufacturer is providing damage tolerance estimates for these threat-target conditions, which still need to be evaluated.

Vulnerability Assessment

- The program completed an intermediate vulnerability assessment (the previous one was in 2008) incorporating results from ballistic tests conducted to date, a higher-fidelity target model, and modified blast and fire curves.
  - The ORD requires an analysis of two types of fragments, a 30 mm high explosive incendiary (HEI) round and a Man-Portable Air Defense System (MANPADS) missile. The analysis showed that none of the F-35 variants met the operational requirements for the HEI threat. The analysis also showed that the F-35A and F-35C have shortfalls to the two fragment threats. The F-35B variant is more resistant to these two threats, primarily due to less fuel carried and some additional shielding provided by the lift fan.
  - Reinstatement of the dry bay fire extinguishing system, in combination with the PAO shutoff valve, and the fueldraulic fuses could make all F-35 variants compliant for all four specified ballistic threats, as currently defined in the ORD.

OBIGGS Redesign

- The program is redesigning OBIGGS to address deficiencies identified in earlier fuel system simulator test series (LF-09B) to meet the vulnerability requirements during all critical segments of a combat mission and to provide an inert tank atmosphere for internal lightning protection.
- The program reported several design changes during the Phase II Critical Design Review to:
  - Fix the vent-in-during-dive problem, wherein fresh oxygen-laden air is drawn into the fuel tanks in a dive
  - More uniformly distribute the nitrogen enriched air (NEA) throughout the fuel tanks
  - Ensure NEA quality
  - Inform the pilot when the system is not inerting the ullage
- The program will conduct verification and certification testing and analyses to confirm the performance of the new OBIGGS design on all three aircraft variants. These tests are expected to begin in FY13.
- Additionally, the current fuel tank venting design is inadequate to vent the tanks during a rapid descent. As a result of the related OBIGGS and tank venting deficiencies, flight operations are currently not permitted within 25 miles of known lightning conditions. Moreover, below 20,000 feet altitude, descent rate is restricted to 6,000 feet/minute. Dive rates can be increased to up to 50,000 feet/minute but only if the maneuver includes 4 minutes of level flight for fuel tank pressurization purposes. Neither restriction is acceptable for combat or combat training.

Chemical/Biological Survivability

- The F-35 Chemical Biological Warfare Survivability Integrated Product Team built and demonstrated a prototype full-scale shelter-liner for chemical/biological containment. The demonstration did not evaluate effectiveness, and the program determined the design was too complex for field use.
- The team is working on a lighter, more robust and less complex redesign. The integration of the new shelter-liner with the chemical and biological agent decontamination support system is ongoing with a full-up demonstration test planned for FY14.

Issues Affecting Operational Suitability

- Overall suitability performance demonstrates the lack of maturity in the F-35 as a system in developmental testing and as a fielded system at the training center.
- Reliability requirements are identified for system maturity (50,000 fleet hours), but the program predicts a target at each stage of development that projects growth toward the maturity requirement.
  - Analysis of data through May 2012 shows that flight test and Lots 1 through 3 aircraft demonstrated lower reliability than those predictions. Demonstrated Mean Flight Hours Between Critical Failure for the F-35A was 5.95 hours, for the F-35B was 4.16 hours, and for the F-35C was 6.71 hours, which are 60, 70, and 84 percent of the level predicted by the program for this point in development of each variant, respectively.
  - Although reliability results appear to indicate improvement over those reported in last year’s report (2.65 for F-35A, 2.05 for F-35B, and 2.06 for F-35C, reflecting data through September 2011), too few flight hours have accrued (approximately 1.5 percent of the flight hours required to achieve reliability maturity) for these results to be predictive, and although they are based on a rolling three-month measure of reliability, have shown great variation between measurement periods.
- In 2012, the program updated the reliability growth plan for the first time since 2006. Significant contributors to low reliability by variant are:
  - F-35A – power and thermal management system, CNI, lights, fuel system, landing gear, fire control and stores, integrated air vehicle architecture, and electrical power system
  - F-35B – electrical power system, power and thermal management system, integrated air vehicle architecture (which includes the Integrated Core Processing system and the cockpit displays including the HMDS), access doors and covers, landing gear, oxygen system, stabilizers, lift fan system, crew escape and safety, and flight control system
  - F-35C – engine controls, power and thermal management system, electrical power system, landing gear, and integrated air vehicle architecture
- The amount of time spent on maintenance, or measures of maintainability, of flight test and Lots 2 and 3 aircraft exceeds that required for mature aircraft.

- Mean corrective maintenance time for critical failures by variant are:
  - F-35A – 9.3 hours (233 percent of the requirement of 4.0 hours)
  - F-35B – 8.0 hours (178 percent of the requirement of 4.5 hours)
  - F-35C – 6.6 hours (165 percent of the requirement of 4.0 hours)
- Mean times to repair by variant are:
  - F-35A – 4.2 hours (168 percent of the requirement of 2.5 hours)
  - F-35B – 5.3 hours (177 percent of the requirement of 3.0 hours)
  - F-35C – 4.0 hours (160 percent of the requirement of 2.5 hours)
- Maintainability of the system hinges on improvements and maturation of Joint Technical Data (JTD), and the ALIS functions that facilitate flight line maintenance.

- The program is developing and fielding the ALIS in incremental capabilities, similar to the mission systems capability in the air vehicle. It is immature and behind schedule, which has had an adverse impact on maintainability, and delays delivery of aircraft.
  - ALIS 102 is a limited capability and is the version fielded only at the Eglin training center. It was required for receiving and operating the early Lot 2 and Lot 3 aircraft, as well as for conducting initial aircrew and maintenance training. This version of ALIS operates with independent subsystems and requires multiple workarounds to support sortie generation and maintenance activities.
  - ALIS 103 is intended to provide the initial integration of ALIS subsystems. The program intended to make it available for the fielding of Lot 3 and Lot 4 production aircraft at new operating locations in 2012: Edwards AFB, California, and Yuma Marine Corps Air Station (MCAS), Arizona. The program discovered problems with ALIS security in February 2012, which in turn delayed the delivery of Lot 3 and Lot 4 aircraft from July to late in 2012. A formal evaluation of ALIS 103 was delayed until September 2012, and was completed in October. The first F-35B was delivered to Yuma MCAS on November 16, 2012, and the first F-35A to Edwards AFB is delayed to December 2012. These aircraft were ready for delivery as early as July 2012. A version of ALIS 103 has been fielded at Yuma MCAS for use with ground operations of the three Lot 4 F-35Bs delivered in November. Flight operations at Yuma are expected to start in early 2013. Similarly, ALIS 103 has been fielded at Edwards AFB and is expected to provide support delivery of aircraft and flight operations in early 2013.
  - Future versions of ALIS will complete the integration of subsystems. In 2012, the program made limited progress toward the development of a deployable unit-level version of ALIS by demonstrating only half of the unclassified functionality on representative hardware. The deployable version will weigh approximately 700 pounds less than the existing 2,466-pound system, and will be modular to enable transportation. Funding for development is being secured by the Program Office.
- The program continued the process of verifying JTD, the set of procedures used to operate and maintain the aircraft.
  - As of the end of September 2012, the program had verified 38 percent of the technical data modules (6,879 out of an estimated 17, 922), which is close to the planned schedule. The program plans to have approximately 11,600 (65 percent) of all the modules verified by the end of FY13.
  - Although the program has improved plans and dedicated effort for verifying and fielding JTD, the lack of JTD causes delays in maintenance actions that consequently affect the availability of aircraft.
- Data Quality and Integration Management (DQIM) are essential parts of the overall Autonomic Logistics Global Sustainment process for the F-35. Experiences with early production aircraft indicate an immature database that contains missing or incorrect part numbers, serial numbers, and missing scheduling rules for inspections. Effective data quality and integration management require that part numbers, serial numbers, and inspection requirements for each aircraft be loaded into ALIS for mission debrief or maintenance actions to occur.

Progress in Plans for Modification of LRIP Aircraft

- The program and Services continued planning for modifications of early LRIP aircraft to attain planned service life and the final SDD Block 3 capability.
  - In January, the aircraft assembly plant received the first production wing parts, which the program redesigned as a result of life limits imposed by structural analyses. The assembly plant received the first F-35A forward root rib in January for in-line production of AF-31, the first Lot 5 F-35A aircraft, which is scheduled to deliver in 2013.
  - The operational test agencies worked with the Services and the Program Office to identify modifications required. Due to the extension of the program, which resulted in very early procurement (relative to the end of SDD) of the aircraft planned for IOT&E, there is high risk that the Service plans for updating the aircraft intended for IOT&E will not be production-representative. Activities to study the depth of the problem occurred in 2012; however, a comprehensive, funded plan that assures a production-representative set of aircraft for OT&E is not yet available. This is a significant and fundamental risk to an adequate IOT&E.
  - The first set of depot-level modifications for the F-35A aircraft are scheduled to begin at Hill AFB in early 2014. Initial F-35B modifications will be completed at the initial operating base at Yuma MCAS, Arizona. Modification of the Auxiliary Air Inlet Door, which is required for vertical landings, has begun on the first F-35B delivered to Yuma in November.

Recommendations

- Status of Previous Recommendations. The program and Services are satisfactorily addressing four of seven previous recommendations. The remaining three recommendations concerning use of objective criteria for evaluating flight test progress, integrating flight test of an operational mission data load, restoring shut-off valves, and redesigning the OBIGGS are outstanding.
- FY12 Recommendations. The program should:
  1. Make the corrections to Revision 4 of the JSF TEMP, as described by DOT&E September 2012 memorandum disapproving the TEMP
     - Include the electronic warfare test annex that specifically required operationally-realistic threats
     - Include adequate criteria for entering the final preparation period prior to IOT&E
     - Schedule the start of the final preparation period prior to IOT&E to begin no earlier than the Operational Test Readiness Review, approximately 90 days prior to the end of the air-worthiness certification phase of development
  2. Conduct dedicated ALIS end-to-end developmental testing of each incremental ALIS version that supports the production aircraft.
  3. Assure modification and retrofit plans for OT aircraft make these aircraft fully production-representative.
  4. Ensure the contractor is meeting VSim requirements for operational testing and is addressing data requirements to support the validation, verification, and accreditation during developmental testing.
  5. Assure the schedules of record for weapons integration, VSim, and mission data load production/verification are consistent with the Integrated Master Schedule.
  6. Continue with the OBIGGS redesign efforts to ensure the system has the capability to protect the aircraft from threat and lightning induced fuel tank explosions while on the ground and during all phases of a combat mission without compromised maneuver limits.
  7. Continue the PAO system redesign efforts and reinstall a PAO shutoff valve to protect the aircraft from PAO-based fires.
  8. Reconsider the removal of the fueldraulic fuses. The program should design and reinstate an effective engine fueldraulic shutoff system to protect the aircraft from fuel-induced fires.
  9. Reconsider the removal of a dry bay fire extinguisher system from other than the Integrated Power Package dry bay. Prior F-35 Live Fire testing showed that the fire suppression system could be designed to successfully extinguish fires from the most severe ballistic threats.
  10. Provide a higher-resolution estimate on how long the aircraft could continue to maintain controlled flight after a ballistic event. Remaining flight time, expressed in smaller time intervals (e.g., 30 seconds, 5 minutes, 30 minutes, etc.) is a more informative metric than the current “Loss of Aircraft” or “Return to FLOT” metric.

F-35 Joint Strike Fighter (JSF)

Executive Summary

- Flight test teams operating the 18 test aircraft assigned to the developmental flight test centers nearly matched or exceeded flight test sortie goals through October 2013. This occurred despite loss of several government employee work days due to furloughs and sequestration, and two fleet-wide grounding instances. Flight sciences testing made the planned progress in envelope expansion and handling qualities for the year; however, mission systems and weapons integration testing made little progress and continued to fall behind test point execution goals driven by upcoming fleet release and Services' Initial Operational Capability plans.
- Mission systems development and test teams focused on getting Block 2B capability into flight test, which began several months later than planned in the integrated master schedule. Block 2B capability is the next major increment planned to be released to the fleet of production aircraft, and the first planned to have combat capability. A considerable amount of testing was necessarily devoted to completing development of prior-block capabilities, attempting to complete fixes to known problems, and regression testing of new versions of software. As a result, through October 2013, little progress was made in completing flight testing required by the baseline Block 2B joint test plan. This creates significant pressure on development and flight test of the remaining increments of Block 2B, with approximately 12 months remaining on the program timeline before final preparations are planned to begin for an operational utility evaluation of the combat effectiveness and suitability of Block 2B.
- Weapons integration, which includes both flight sciences and mission systems test events, did not make the planned progress in CY13. Weapons integration is recognized by the program as a critical path to both Block 2B completion and the end of Block 3F development.
- Flight operations of production aircraft and upcoming operational testing of Block 2B capability depend on the functionality of the Autonomic Logistics Information System (ALIS), which has been fielded with significant deficiencies. The current ALIS capability forces maintenance operations into numerous workarounds and causes delays in determining aircraft status and conducting maintenance. The program expects improvements in the next ALIS version, scheduled in time for the release of Block 2B capability to the fleet, but there is no margin in the development and test schedule.
- F-35B flight test aircraft completed 10 days of testing aboard USS *Wasp* as planned in August 2013. Testing included evaluating changes to control laws, expanding the operational flight envelope, and flight operations at night.
- Overall suitability performance continues to be immature, and relies heavily on contractor support and workarounds unacceptable for combat operations. Aircraft availability and measures of reliability and maintainability are all below program target values for the current stage of development.
- The program is now at significant risk of failing to mature the Verification Simulation (VSim) and failing to adequately verify and validate that it will faithfully represent the performance of the F-35 in the mission scenarios for which the simulation is to be used in operational testing.
- The program completed F135 engine vulnerability test series that demonstrated:
  - The engine can tolerate a range of fuel leak rates ingested through the inlet to simulate and assess ballistically induced fuel tank damage effects. System-level live fire tests using a structural F-35C test article with an operating engine will determine the engine tolerance to the fuel quantity ingested as a result of actual ballistic damage.
  - The engine is tolerant of mechanical component damage from single-missile fragments, while fluid-filled engine components are vulnerable to fire. Results from two tests demonstrated engine vulnerabilities against more severe threats and were consistent with results from prior legacy engine tests.
- The program examined the F-35 vulnerability to ballistically induced damage to the F-35 gun ammunition. Missile fragment ballistic testing on single PGU-32 rounds demonstrated that a propellant explosive reaction and sympathetic reaction of adjacent rounds in multiple round tests were unlikely. The F-35 is, however, vulnerable to ballistically-induced propellant fire from all combat threats.
- The vulnerability of the F-35 to electrical system ballistic damage remains an open question. Based on the F-35A aircraft (AA:0001) in-flight incident in 2007, electrical arcing

in 2009, and the flight-critical system-level test events in 2012, DOT&E recommended that the program conduct additional analyses to address the likelihood and consequence of arcing from the 270-volt to 28-volt system. The Lockheed Martin electrical power system team is currently working on a response to these concerns.

- The program provided no update on the decision to reinstate the Polyalphaolefin (PAO) shut-off valve, a 2-pound vulnerability reduction system that could reduce crew casualties and the overall F-35 vulnerability by approximately 12 percent, averaged across all threats and F-35 variants.
- The program redesigned the On-Board Inert Gas Generation System (OBIGGS) to meet vulnerability reduction and lightning requirements. The program is currently planning the tests for FY14 to ensure that the system is able to maintain fuel tank inerting throughout all mission profiles. The system should protect the F-35 from threat-induced or lightning-induced fuel tank explosions.

Actual versus Planned Test Metrics through October 2013

TEST FLIGHTS					
	All Testing	Flight Sciences			Mission Systems
	All Variants	F-35B Only	F-35A Only	F-35C Only	
2013 Actual	993	284	226	181	302
2013 Planned	985	287	241	171	286
Difference from Planned	+0.8%	-1.0%	-6.2%	+5.8%	+5.6%
Cumulative Actual	3,601	1,269	963	612	757
Cumulative Planned	3,284	1,127	910	584	663
Difference from Planned	+9.7%	+12.6%	+5.8%	+4.8%	+14.2%

TEST POINTS									
	All Testing	Flight Sciences			Mission Systems				
	All Variants	F-35B Only	F-35A Only	F-35C Only	Block 1*	Block 2A	Block 2B	Block 3	Other
2013 Baseline Accomplished	5,464	1,418	1,713	1,032	326	168	461	0	346
2013 Baseline Planned	7,180	1,701	1,836	1,165	1,755			0	723
Difference from Planned	-23.9%	-16.6%	-6.7%	-11.4%	-45.6%				-52.1%
Added Points	1,776	178	193	211	1,194			0	0
Points from Future Year Plans	720	320	0	400	0			0	0
Total Points Accomplished**	7,960	1,916	1,906	1,643	2,149			0	346
Cumulative SDD Baseline Actual	26,689	9,356	7,636	5,859	1,166	614	860	0	1,198
Cumulative SDD Baseline Planned	27,075	9,256	7,735	5,564	2,663			0	1,857
Difference from Planned	-1.4%	+1.1%	-1.3%	+5.3%	-0.9%			0.0%	-35.5%
Program Office Estimated Test Points Remaining	31,218	9,726	6,057	7,493	350	606	3,226	1,739	2,021

* Includes Block 0.5 and Block 1 quantities
** Total Points Accomplished = 2013 Baseline Accomplished + Added Points
SDD = System Development and Demonstration

System

- The F-35 Joint Strike Fighter (JSF) program is a tri-Service, 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/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 in this environment 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 (JDAM) and Joint Standoff Weapon, AIM-120C radar-guided Advanced Medium-Range Air-to-Air Missile, and AIM-9 infrared-guided short-range air-to-air missile.
- The program provides mission capability in three increments:
  - Block 1 (initial training)
  - Block 2 (advanced training and initial combat)
  - Block 3 (full combat)
- 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, and in highly-defended areas of joint operations.
- F-35 will be used to attack fixed and mobile land targets, enemy surface units at-sea, and air threats, including advanced cruise missiles.

Major Contractor

Lockheed Martin, Aeronautics Division – Fort Worth, Texas

Test Strategy, Planning, and Resourcing

- The JSF Program Office, in coordination with the Services and the operational test agencies, submitted Revision 4 of the Test and Evaluation Master Plan (TEMP) for approval in late CY12.
  - DOT&E approved the TEMP in March 2013, under the condition that the schedule in the TEMP be revised such that no overlap exists between the final preparation period for IOT&E and the certification period required for the Services' airworthiness authorities to issue flight clearances.
  - DOT&E required that the final preparation for the IOT&E could not begin any earlier than the Operational Test Readiness Review, a point in time when the JSF Program Executive Officer certifies the system ready for IOT&E.
- This report reviews the program by analyzing the progress of testing and the capability delivered as a function of test results. The program plans a specific set of test points (discrete measurements of performance under specific test conditions) for accomplishment in a given calendar year. In this report, test points planned for a given calendar year are referred to as baseline test points. In addition to baseline test points, the program accomplishes test points added for discovery, regression of new software, and regression of fixes to deficiencies identified in flight test. Cumulative System Development and Demonstration (SDD) test point data refer to the total progress towards completing development at the end of SDD.

F-35A Flight Sciences

Flight Test Activity with AF-1, AF-2, and AF-4 Test Aircraft

- F-35A flight sciences testing focused on:
  - Accomplishing clean-wing (no external stores or weapons) flutter testing of the full Block 2B flight envelope with weapons bay doors closed and open
  - Evaluating flying qualities with internal stores (GBU-31 JDAM, GBU-12 laser-guided Bomb, and AIM-120 Advanced Medium-Range Air-to-Air Missile) and external stores (AIM-9X short-range missile)
  - Characterizing the subsonic and supersonic weapons bay door and environment
  - High angle-of-attack (above 20 degrees) testing in clean configuration and in landing configuration
- F-35A flight testing was affected by two directives to halt testing in early CY13.
  - The entire F-35 fleet was grounded on February 21, 2013, after a crack was discovered on February 19, 2013, in one of the third-stage, low-pressure turbine blades in the engine of AF-2, a flight sciences test aircraft at Edwards AFB, California. The cause of the crack was determined to be a rupture due to thermal creep, a condition in which deformation of material forms from the accumulated exposure to elevated temperatures at high-stress conditions. The stop order was lifted one week later, on February 28, 2013, with the requirement for additional inspections of the engines to ensure the effects of creep, if they occur, are within tolerances.
  - Discovery of excessive wear on the rudder hinge attachments on AF-2 in early March 2013 also affected availability of test aircraft. As a result, the test fleet was grounded for inspections and maintenance actions, including replacing part of the hinge on AF-2 and adding wear-preventing washers to the hinges of the rest of the test fleet.
  - In total, AF-2 was down for six weeks for replacement of the engine and rudder hinge repair.
- The test team completed supersonic clean wing flutter testing with the weapons bay doors open and closed, clearing the F-35A Block 2B envelope to 1.6 Mach/700 knots calibrated airspeed.
- The team began testing F-35A controllability at high angles of attack and high yaw rates, including the first intentional departures from controlled flight with external stores.
- The test team completed all weapons safe-separation events of GBU-31, JDAM, and AIM-120 weapons for the Block 2B envelope by the end of August. These tests precede end-to-end weapons delivery accuracy test events performed with mission systems test aircraft.
- The program tested two aircraft modified with new horizontal tail surface coatings and instrumented with temperature sensors to monitor heating from conditions of extended afterburner use. Damage to horizontal tail coatings was previously discovered during flight tests on all three variants involving extended use of the afterburner not expected to be representative of operational use, but which was necessary to achieve certain test points. Non-instrumented test aircraft continue to operate with restrictions to the flight envelope and use of the afterburner.

Flight Sciences Assessment

- Through the end of October, the F-35A flight sciences test team lagged in completing the planned flights for the year, having accomplished 226 sorties against the plan of 241. Productivity in baseline test points also lagged by 6.7 percent, as the team accomplished 1,713 baseline points against a plan of 1,836.
- The amount of added work from new discoveries or from regression of new versions of air vehicle software (i.e., control laws governing performance and handling qualities) has been less than expected through the end of October. The team allocated 311 points for growth, but accumulated only 193 growth test points by the end of October.
- The test team accomplished test points for clearing the flight envelopes for Blocks 2B and 3F.
  - Progress through the Block 2B test points was accomplished according to the plan, with 1,089 Block 2B points accomplished compared to 1,083 planned.
  - The team also accomplished test points needed to clear the Block 3F flight envelope, but did so at a rate behind the plan. Through the end of October, the team accomplished 624 Block 3F envelope test points against the plan of 753 points, or 83 percent of the plan. The work accomplished for the Block 3F envelope included points with weapons bay doors open and with external air-to-air weapon load-outs.
- Weight management of the F-35A variant is important for meeting air vehicle performance requirements. Monthly aircraft weight status reports produced by the program compute a sum of measured weights of components or subassemblies, calculated weights from approved design drawings released for build, and engineering weight estimates of remaining components.
  - According to these reports, the weight estimates for the F-35A decreased by 72 pounds from January to October 2013. The latest October 2013 F-35A weight status report showed the estimated weight of 29,030 pounds to be within 341 pounds of the projected maximum weight needed to meet the technical performance required per contract specifications in January 2015.
  - Although the weight management of the F-35A has demonstrated a positive trend over the past year, this small margin allows for only 1.16 percent weight growth over the next year to meet contract specification requirements in January 2015. The program will need to continue rigorous weight management beyond the contract specification timeline endpoint in January 2015 and through the end of SDD to avoid performance degradation and operational impacts.
- F-35A discoveries included:
  - During early high angle-of-attack testing, problems with the air data computer algorithms were discovered, requiring an adjustment to the control laws in the air vehicle software and delaying a portion of the testing until the updated software was delivered to flight test in September. High angle-of-attack testing resumed, and is required to support the full flight envelope and weapons employment capabilities planned for Block 2B.
  - Buffet and transonic roll-off (TRO) continue to be a concern to achieving operational capability for all variants. The program changed the flight control laws to reduce buffet and TRO in the F-35A. No further changes to the control laws are being considered, as further changes will potentially adversely affect combat maneuverability or unacceptably increase accelerative loading on the aircraft's structure. The program plans to assess the operational effect of the remaining TRO and the effect of buffet on helmet-mounted display utility by conducting test missions with operational scenarios in late CY13 and early CY14.

F-35B Flight Sciences

Flight Test Activity with BF-1, BF-2, BF-3, BF-4, and BF-5 Test Aircraft

- F-35B flight sciences focused on:
  - Continued expansion of the Block 2B flight envelope
  - Expansion of the envelope for vertical-lift and short take-off operations, including operations with external stores and the gun pod (mounted on the centerline station)
  - Flight clearance requirements for the second set of ship trials on the USS *Wasp*
  - Block 2B weapons separation testing (for GBU-12, GBU-32, and the AIM-120 missile)
  - Fuel dump operations with a redesigned dump valve and flap seals
  - Initiating high angle-of-attack testing
  - Completing tanker air refueling with strategic tankers, i.e., KC-135 and KC-10 aircraft
  - Regression testing of new vehicle systems software
- The F-35B fleet was grounded after the first British production aircraft, BK-1, experienced a fueldraulic line failure in the STOVL-unique swivel nozzle at Eglin AFB, Florida, on January 16, 2013. The cause was determined to be a poor manufacturing process used for the hoses, leading to crimping dimensions being out of specification; the stop order was lifted nearly four weeks later on February 11, 2013, allowing all F-35B flights to resume.
- The program modified one F-35B test aircraft with new coatings on the horizontal tail to address deficiencies seen in bonding of the skin under high-temperature and high- airspeed conditions. These conditions involve extended use of the afterburner not expected to be representative of operational use but which was necessary to achieve certain test points. The new bonded coating failed during flight test and experienced dis-bonding and peeling. The program continues to investigate the effects of afterburner use on the horizontal tails and plans to modify two F-35B test aircraft with new coatings and temperature sensing instrumentation to collect more data. Non-instrumented test aircraft continue to operate with restrictions to the flight envelope and use of the afterburner.

Flight Sciences Assessment

- Through the end of October, the F-35B flight sciences test team accomplished 284 of 287 planned flights, a shortfall of 1 percent. Completion of baseline test points was short by nearly 17 percent, as the team accomplished 1,418 of 1,701 planned baseline points. Similar to the F-35A flight science testing, the amount of added points due to growth was lower than expected, as the team flew only 178 growth points through the end of October, below the 287 points planned.
- Completed workup and second set of ship trials (referred to as DT-2) on time. The primary objective of the test period was to collect data for providing a ship-based flight envelope for vertical landings and short take-offs to support Block 2B fleet release and Marine Corps Initial Operational Capability. Flight activity included night operations and inert internal weapons stores.
- Progress through weapons safe-separation testing was behind the planned schedule, as only 12 of the planned 22 separations had been accomplished.
- Progress through the work needed to release the Block 2B flight envelope also lagged the plan, with completion of 1,247 of the 1,530 baseline points. Some weapons-related points were blocked earlier in the year when a problem with the GBU-12 lanyard was discovered, requiring a new lanyard and procedures to be developed. The test team was able to accomplish additional points in the Block 3F envelope – similar to the work being done in the F-35A flight sciences – completing 491 points against the plan of 171, pulling forward 320 points from future Block 3F test plans.
- The following table, first displayed in the FY11 Annual Report, describes the observed door and propulsion problems by component and identifies the production cut-in, if known.

F-35B DOOR AND PROPULSION PROBLEMS				
Category	**Component**	**Problem**	**Design Fix and Test Status**	**Production Cut-In**
Structure	Auxiliary Air Inlet Door (AAID)	Inadequate life on door locks, excessive wear and fatigue due to the buffet environment, inadequate seal design.	New designed doors are being installed on low-rate initial production (LRIP) aircraft as part of the ongoing modification plan; five completed through the end of September. Fatigue testing started in November 2012 and has completed just over 6 percent of the planned two lifetimes of testing as of end of September.	BF-38 LRIP 6 2014
Propulsion	Drive Shaft	Lift fan drive shaft undergoing a second redesign. Original design was inadequate due to shaft stretch requirements to accommodate thermal growth, tolerances, and maneuver deflections. First redesign failed qualification testing.	New design of the drive shaft will begin qualification testing in December. Full envelope requirements are currently being met on production aircraft with an interim design solution using spacers to lengthen the early production drive shaft.	BF-50 LRIP 8 2016
Propulsion	Clutch	Lift fan clutch has experienced higher than expected drag heating during conventional (up and away) flight during early testing.	New clutch plate design, with more heat-tolerant material, is complete. Clutch plates are being thinned on LRIP 5 and 6 aircraft, at the expense of reduced life (engagements) to the clutch, to prevent drag heating.	BF-44 LRIP 7 2015
Propulsion	Roll Post Nozzle Actuator	Roll post nozzle bay temperatures exceed current actuator capability; insulation is needed to prevent possible actuator failure during vertical lift operations.	Insulation between the roll post nozzle bay and the actuators is being installed in pre-LRIP 7 aircraft to allow unrestricted operations; however, the actuators must be replaced at 1,000-hour intervals. New actuators will be installed in LRIP 7 aircraft and beyond, removing the requirements for the insulation and extending the service life to 4,000 hours.	BF-44 LRIP 7 2015
Propulsion	Bleed Air Leak Detectors	Nuisance overheat warnings to the pilot are generated because of poor temperature sensitivity of the sensors; overheats are designed to be triggered at 460 degrees F, but have been annunciated as low as 340 degrees F.	More stringent acceptance test procedures are in place, requiring the sensors to be more accurate. Maintenance personnel are checking the detectors on pre-LRIP 5 aircraft, and replacing them in accordance with directives, if necessary.	BF-35 LRIP 5 2014
Propulsion	Aux Air Inlet Door Aft down-lock seal doors (aka "saloon doors")	Doors are spring-loaded to the closed position and designed as overlapping doors with a 0.5- inch gap. The gap induces air flow disturbance and make the doors prone to damage and out-of-sequence closing. Damage observed on flight test aircraft.	Springs are being limited to 4,000 hours or half the planned lifetime. Program continues to investigate whether a new design to the doors is required.	TBD

- Weight management of the F-35B aircraft is critical to meeting the Key Performance Parameters (KPPs) in the Operational Requirements Document (ORD), including the vertical lift bring-back requirement. This KPP requires the F-35B to be able to fly an operationally representative profile and recover to the ship with the necessary fuel and balance of unexpended weapons (two 1,000-pound bombs and two AIM-120 missiles) to safely conduct a vertical landing.
  - Weight reports for the F-35B have varied little in 2013, increasing 36 pounds from either changes in the

manufacturing processes or more fidelity in the weight estimates from January through October 2013. Current estimates are within 202 pounds of the not-to-exceed weight of 32,577 pounds – the target weight of the aircraft in January 2015 to meet specification requirements and ORD mission performance requirements for vertical lift bring back. The small difference between the current weight estimate and the not-to-exceed weight allows for weight growth of 0.62 percent over the next year to meet technical specifications in January 2015.
  - Managing weight growth with such small margins will continue to be a significant program challenge. Since the program will conduct the technical performance measurement of the aircraft in January 2015, well before the completion of SDD, continued weight growth through the balance of SDD will affect the ability of the F-35B to meet the STOVL mission performance KPP during IOT&E.
- Other F-35B discoveries included:
  - Wet runway testing, required to assess braking performance with a new brake control unit in both conventional and slow landing operations, has been delayed due to the inability to create the properly degraded friction conditions on the runways at the Patuxent River Naval Air Station, Maryland. The program plans to complete this testing in early CY14. Fielded F-35B aircraft at Eglin and at Yuma are operating under restricted landing conditions until the wet runway testing is complete.
  - Buffet and TRO continue to be a concern to achieving operational capability for all variants. The program made changes to the flight control laws to reduce buffet and TRO in the F-35B in CY13. No further changes to the control laws are being considered, as further changes will potentially adversely affect combat maneuverability or unacceptably increase accelerative loading on the aircraft's structure. The program plans to assess the operational effect of the remaining TRO and the effect of buffet on helmet-mounted display utility by conducting test missions with operational scenarios in late CY13 and early CY14.

F-35C Flight Sciences

Flight Test Activity with CF-1, CF-2, and CF-3 Test Aircraft

- F-35C flight sciences focused on:
  - Block 2B envelope expansion for weapons bay doors open and closed
  - Completing electromagnetic environmental effects testing to support shipboard operations
  - Surveying handling qualities in the transonic flight regimes
  - Regression testing of new air vehicle systems software
  - High angle-of-attack testing, which began in August
  - Carrier suitability testing in preparation for the first set of ship trials scheduled for mid-CY14. The program configured aircraft CF-3 with a modified and instrumented nose landing gear system to begin initial catapult testing in August 2013. The test team modified CF-3 with the new arresting hook system and began on-aircraft testing with rolling engagements in late CY13.
- The test team completed three weapon safe-separation events by the end of October.
- The program modified one F-35C with new coatings on the horizontal tail, and similar to what was experienced in the F-35B and the F-35A, the coatings bubbled and peeled after experiencing high-temperature and high-airspeed conditions. These conditions involve extended use of the afterburner not expected to be representative of operational use, but which was necessary to achieve certain test points. The program plans to modify all three F-35C flight sciences aircraft with new tail coatings and temperature-sensing instrumentation to collect data to characterize conditions and determine what, if any, material solutions will be required. Non-instrumented test aircraft continue to operate with restrictions to the flight envelope and use of the afterburner.

Flight Sciences Assessment

- F-35C flight sciences test flights accomplished were ahead of the plan through the end of October, with 181 sorties completed compared to 171 planned.
- The test team lagged by 11 percent in completing the planned baseline test points through the end of October, accomplishing 1,032 points against the plan of 1,165 points. Progress through the Block 2B flight envelope lagged by 12 percent, as 947 of 1,080 points were accomplished. The test team was able to accomplish more test points in the Block 3F envelope than planned – completing 485 points, compared to 85 planned, pulling 400 points projected for completion in 2014 back into 2013.
- Weight management is important for meeting air vehicle performance requirements. The aircraft weight is computed monthly, and adjusted for known corrections from engineering estimates and production modifications.
  - The program added 139 pounds to the F-35C weight status in May 2013 to account for the redesigned arresting hook system. The latest weight status report from October 2013 showed the estimated weight of 34,593 pounds to be within 275 pounds (0.79 percent) of the projected maximum weight needed to meet technical performance requirements in January 2016.
  - This margin allows for 0.35 percent weight growth per year. The program will need to continue rigorous weight management through the end of SDD to avoid performance degradation and operational impacts.
- F-35C discoveries included:
  - Buffet and TRO continue to be a concern to achieving operational combat capability for all variants. Control laws have been changed to reduce buffet and TRO in the F-35A and F-35B with some success; however, both problems persist in regions of the flight envelope, and are most severe in the F-35C.
  - Characterization testing of buffet and TRO in the F-35C with the current control laws and without the use of

leading edge spoilers is ongoing. Unlike the other two variants, the program has the option to conduct flight testing with leading edge spoilers to reduce buffet and the onset of TRO with two of the F-35C flight test aircraft if trade-offs made in control laws are not sufficient to manage the negative impact of these effects.

Mission Systems

Flight Test Activity with AF-3, AF-6, AF-7, BF-17, BF-18, and CF-8 Test Aircraft and Software Development Progress

- Mission systems are developed and fielded in incremental blocks of capability.
  - Block 1. The program designated Block 1 for initial training capability and allocated two increments: Block 1A for Lot 2 (12 aircraft) and Block 1B for Lot 3 aircraft (17 aircraft). No combat capability is available in either Block 1 increment.
  - Block 2A. The program designated Block 2A for advanced training capability and designated this block for delivery of aircraft in production Lots 4 and 5. No combat capability is available in Block 2A.
  - Block 2B. The program designated Block 2B for initial, limited combat capability with internal weapons (AIM-120C, GBU-32/31, and GBU-12). This block is not associated with the delivery of any production aircraft. Block 2B software, once complete with development and certification, will be retrofitted onto earlier production aircraft.
  - Block 3i. The program designated Block 3i for delivery of aircraft in production Lots 6 through 8, as these aircraft will be built with an improved integrated core processor and other upgrades collectively known as “Technology Refresh 2”, or TR2. No new capability beyond Block 2B is introduced in Block 3i.
  - Block 3F. The program designated Block 3F as the full SDD capability for production Lot 9 and later.
- The Edwards test site accepted the fifth F-35C test aircraft, designated as CF-8, in September 2013; it is a mission systems flight test aircraft.
- The six mission systems flight test aircraft assigned to the Edwards AFB test center flew 302 test sorties against a plan of 286 though October, exceeding the plan by 5.6 percent.
- However, the test team accomplished only 54 percent of the planned 2013 baseline mission systems test points from test plans for Blocks 1, 2A, and 2B by the end of October (955 baseline test points accomplished, 1,755 planned). The team also accomplished an additional 1,194 test points for regression testing of new revisions of Block 2A and 2B software and other testing the program found necessary to add to the test plans. The team also lagged in completing planned radar signature testing, completing 346 of 723 planned test points, or 48 percent, by the end of October.
- The program initiated a Block Review Board process in late 2012 to manage the increments of mission systems software development, monitor maturity of capability, and release to flight test.

Mission Systems Assessment

- Despite flying the mission systems test flights planned for CY13, the program did not make the planned progress in developing and testing mission systems capabilities. Software development, integration in the contractor labs, and delivery of mature capability to flight test continued to be behind schedule. Testing of Block 2A training capability (no planned combat capability) was completed in 2013. The first increment of Block 2B software, version 2BS1, was delivered to flight test in February 2013, four months later than indicated in the integrated master schedule.
- The program completed testing on the Block 2A software needed for delivery of the Lot 4 and Lot 5 production aircraft. This production version of software, designated 2AS3, was designed to provide enhanced training capabilities to the Integrated Training Center at Eglin AFB, Florida, and to the first operational units – the F-35B unit at Yuma Marine Corps Air Station, Arizona, and the F-35A unit at Nellis AFB, Nevada.
  - However, the teams at both test centers (Edwards and Patuxent River) determined the initial version of 2AS3 to be deficient in providing the necessary capabilities for unmonitored flight operations under night and instrument meteorological conditions (IMC). In order to finalize Block 2A capability so that it could eventually be certified in production aircraft for flight at night and in IMC, the program made adjustments to plans for the following increment, Block 2B, to accommodate the need for another, final version of Block 2A software, designated 2AS3.1. The test centers completed testing of Block 2AS3.1 in June; however, the certification to allow F-35A and F-35B production aircraft to fly at night or in IMC had not been released as of the time of this report.
  - Additionally, the test teams also noted Block 2A deficiencies in the aircraft sensor operations, particularly the Electro-Optical Targeting System (EOTS), aircraft communications capabilities, pilot electronic interfaces, and the aircraft Caution, Advisory, and Warning System. Although the software was intended to provide more mission systems capability, poor sensor performance and stability, excessive nuisance warnings, and disproportionate pilot workload required for workarounds and system resets made the software of limited utility for training. In any type of operational mission scenario, the performance of the software would be unacceptable.
  - The program delivered 10 F-35A aircraft to the U.S. Air Force, 12 F-35B aircraft to the U.S. Marine Corps, and 2 F-35C aircraft to the U.S. Navy from production Lot 4 through the end of October. These aircraft were delivered in the Block 2A configuration, but with less capability than defined by the production contract. Specifically, 22 of 47 (47 percent) of the capabilities defined in the production contract were not complete when the aircraft were delivered. The program began checkout and delivery of F-35A, F-35B, and F-35C aircraft from production Lot 5, and these aircraft were similarly delivered with less

than planned capabilities. Fifty percent (27 of 54) of the capabilities required by the contract were not complete when these aircraft were delivered to the Services.

- The initial Block 2B software increment began flight testing in February 2013. Though four months later than the 2012 integrated master schedule, this timing was in accordance with the expectations set by the program's new Block Review Board process, which was initiated in late 2012. As it was the initial Block 2B increment, no new capability was mature enough for verification. In October 2013, a new increment of Block 2B, intended to provide a significant increase in verifiable capability, including many fixes to previously identified deficiencies, began flight testing. Initial results with the new increment of Block 2B software indicate deficiencies still exist in fusion, radar, electronic warfare, navigation, EOTS, Distributed Aperture System (DAS), Helmet-Mounted Display System (HMDS), and datalink. These deficiencies block the ability of the test team to complete baseline Block 2B test points, including weapons integration. The program's plan is to gradually increase maturity of the software and reduce these obstacles to test progress over three more increments of software in CY14. The degree to which the maturity of the capability has improved and the test teams can verify performance against planned criteria will determine how long it will take to complete Block 2B development and flight test.
- The program began implementing plans for testing Block 3i capability, which will be used to deliver production aircraft in Lots 6 through 8, all of which will have an upgraded core processor and other mission systems processor improvements. The program plans Block 3i to include no new capability beyond Block 2B, as it is intended to only encompass rehosting of Block 2B capability on the new TR2 hardware.
  - One F-35A mission systems test aircraft was temporarily modified with the TR2 hardware in November 2013 to conduct risk reduction testing of an early version of 3i software. Testing was attempted on an F-35C test aircraft in October, which was temporarily modified with the TR2 hardware, but the software did not load properly and the ground testing could not be conducted.
  - One mission systems test aircraft of each variant will be modified in early CY14 to begin the start of flight testing of the 3i software.
  - All production aircraft from Lot 6 and beyond will have the TR2 hardware and will only be able to operate mission and vehicle systems software that is compatible with this hardware configuration.
- Shortfalls in the test resources required to test mission systems electronic warfare capabilities under operationally realistic conditions were identified by DOT&E in February 2012. The DoD programmed for an Electronic Warfare Infrastructure Improvement Program starting in FY13 to add both closed-loop and open-loop emitter resources for testing on the open-air ranges, to make at least one government anechoic chamber capable of providing a representative threat environment for electronic warfare testing, and to upgrade the electronic warfare programming laboratory that will produce threat data files. However, progress has been slower than needed to assure these resources are available in time for Block 3 IOT&E in 2018. JSF IOT&E will not be adequate and will be delayed unless this test capability is available.
- Deficiencies in the HMDS added testing at both the Edwards and Patuxent River test sites in late CY12 and in CY13. The program dedicated 42 flights to investigating and addressing deficiencies in the HMDS. Seven aircraft from all three variants flew test missions from October 2012 through May 2013 to investigate jitter in the helmet display, night vision camera acuity, latency in the DAS projection, and light leakage onto the helmet display under low-light conditions. Although some progress has been achieved, results of these tests have been mixed.
  - Filters for reducing the effects of jitter have been helpful, but have introduced instability, or "swimming," of the projected symbology.
  - Night vision acuity was assessed as not acceptable with the current night vision camera, but may be improved with a new camera planned for inclusion in the next version of the helmet (referred to as the Gen III helmet) being considered by the program.
  - Latency with the DAS projection has improved from earlier versions of software, but has not yet been tested in operationally representative scenarios.
  - Light leakage onto the helmet display may be addressed with fine-tuning adjustments of the symbology brightness—a process pilots will have to accomplish as ambient and background levels of light change, adding to their workload.
  - Although not an objective of the dedicated testing, alignment and "double vision" problems have also been identified by pilots and were noted in the DOT&E report on the F-35A Ready for Training Operational Utility Evaluation.
  - Developmental testing has yet to be accomplished in the full operational flight envelope evaluating mission-related tasks, as the full combat flight envelope is not yet available. Use of the HMDS in the full envelope under operational conditions is needed to verify effectiveness of the HMDS. This might not occur until the Block 2B operational utility evaluation, currently planned for late 2015.
- Three factors create a significant challenge for completing developmental testing of Block 2B mission systems as planned before the end of October 2014: completing tests of prior blocks of mission systems capability, managing growth in testing, and constraints on test resources.
  - The test centers continue to accomplish a significant amount of test points originally designated for completion in prior blocks of mission systems capability. As of the

end of October, 34 percent of the baseline mission system test points accomplished in CY13 (326 of 955) were for capabilities in Block 1; 18 percent (168 of 955) were for capabilities in Block 2A, and 48 percent (461 of 955) were for Block 2B capabilities. The program intends to complete or delete the test points planned in these previous blocks by the time Block 2B capability completes development in late CY14. All program plans and schedules for the subsequent blocks of mission systems software (Block 3i and Block 3F) depend on this occurring so that the development laboratories and test venues can be converted and devoted to testing the Block 3 hardware configuration.

- The program continues to have significant growth in mission systems testing. Beyond the testing accomplished in late CY12 and CY13 for the helmet, additional testing has been required for regression testing of seven software loads delivered to flight test in CY13 through October, and for deficiencies in the EOTS, the radar, night flying qualities, and navigation systems. Dedicated testing added for the purpose of identifying problems with the helmet accounted for only 22 percent of the total mission systems growth in CY13 by the end of October; the remaining growth executed by the program exceeded the planning factors for added testing by over 40 percent. The program plans to complete Block 2B flight testing in October 2014; however, there is no margin for additional growth to meet that date. Projections based on the planned growth rate show that Block 2B developmental testing will complete in May 2015, approximately 7 months later than planned. Projections for completing Block 2B flight testing using the historical rate of continued growth (excluding the growth associated with the HMDS) show that Block 2B developmental testing will complete about 13 months later, in November 2015, and delay the associated fleet release to July of 2016.
- Mission systems SDD flight test aircraft available to support Block 2B developmental testing will be reduced in CY14, as the program will need to modify aircraft with the TR2 processors to achieve the Block 3i configuration. Aircraft from production Lot 6, which are scheduled to be delivered in mid-CY14, cannot be operated with Block 2B software; they must have certified Block 3i software. The program plans to modify one mission systems aircraft of each variant to begin flight testing of the first increment of Block 3i software in early CY14. The reduction of mission systems aircraft to support Block 2B developmental testing, created by the need to test software to support the production and delivery of Lot 6 and later aircraft, will add to the challenges of completing Block 2B development on schedule.

• Mission systems discoveries included:
  - Although improving, stability of the mission systems software continues to fall short of objectives. The program tracks mission systems software stability by analyzing the number of anomalies observed as a function of flight time. The program objective for time between resets for the integrated core processor and the Communications/ Navigation/Identification Friend or Foe suite is a minimum of 15 hours between reset events. October reports for the latest Block 2B mission systems software increment in flight test show a rate of 11.4 hours between anomalies, based on 79.5 hours of flight test. Subsystems, such as the radar, EOTS, DAS, and the navigation solution often require component resets as well, but these are not tracked in the stability metric.
  - The EOTS fails to meet target recognition ranges, exhibits track instability in portions of its field-of-view, and has large line-of-sight angle and azimuth errors when computing target locations. These deficiencies are being investigated and addressed by the program with software fixes.
  - The program continues to monitor loading of the aircraft core processors in the laboratories as more functionality is added in software increments. Projections of the loads expected on all processors for the Block 3 capabilities estimate that three processors, which support landing systems, weapons employment, multi-aircraft datalinks, and earth spatial modeling, will be tasked between 160 and 170 percent of capacity. The program intends to shift the distribution of processing loads with each incremental build of mission systems software; however, margin is limited and the efficiencies gained by the changes need to be assessed under actual, sensor-stressing, flight conditions.
  - The DAS has displayed a high false alarm rate for missile detections during ownship and formation flare testing. The inability of the DAS to distinguish between flares and threat missiles makes the warning system ineffective and reduces pilot situational awareness.
  - The onboard navigation solution – referred to as the ownship kinematic model – has shown excessive position and velocity errors when not receiving updates from the GPS satellite constellation. These errors prevent accurate targeting solutions for weapons employment in a GPS-denied environment. The program is addressing these errors in the next iteration of software and further flight testing will be required.
  - The radar mapping function does not provide adequate target location accuracy.

Weapons Integration

• Weapons integration involves flight sciences testing, mission systems testing, and ground crew support. Testing includes measuring the environment around the weapon during carriage (internal and external), handling characteristics of the aircraft, safe-separation of the weapon from the aircraft, communications between the aircraft sensors and the weapons, and weapons delivery accuracy events. The program has identified lethality, the product of weapons integration test and evaluation, as the critical path to completing development of Block 2B and Block 3F. The Block 2B weapons are the GBU-12 laser-guided bomb, the GBU-31/32 JDAM, and the AIM-120 air-to-air missile. The Block 3F weapons add Small Diameter Bomb Increment I (SDB-I), AIM-9X air-to-air missile, Joint Standoff Weapon, gun (internal for F-35A and external gun pod for F-35B and F-35C), and the United Kingdom's Paveway IV bomb.

- As of the end of October, weapons integration was near the planned progress scheduled for the year on the F-35A. The test teams had completed 567 of 589 planned environmental test points and all 19 planned weapons separation events. Progress on the other variants, however, was behind the plan. On the F-35B, the team had completed 285 of the 455 planned environmental test points and 12 of the 24 planned separation events. On the F-35C, the team began environmental testing late in the year and had completed 176 of 181 planned test points but only 2 of 10 planned separation events.
- Progress in testing of mission systems capability to enable end-to-end weapon delivery events was behind schedule for all Block 2B weapons. Weapons integration has been slowed by discoveries of deficiencies requiring software fixes and additional testing.
  - Problems with the lanyard on the laser-guided bomb required a new lanyard and routing procedure
  - Inaccuracies in the data transfer of position and velocity from the aircraft to the JDAM, which spatially align the bomb with the target, required a fix in the mission systems software
  - Problems involving integration of the AIM-120 medium-range missile have been difficult to replicate in lab and ground testing
  - Poor target track quality displayed to the pilot from the radar, or from fusion of the aircraft sensors, prevented targeting solutions for simulated weapons engagements
  - Poor performance of the EOTS in image quality, tracking stability, and targeting accuracy required software fixes to allow weapons integration testing of the air-to-ground munitions to proceed
  - Erroneous target coordinates were derived from the synthetic aperture radar mapping function
- The integrated test team continued to rework weapons integration scheduling in 2013 to account for discoveries of deficiencies and the slower than expected delivery of capability needed to conduct weapons delivery accuracy (WDA) events. The team conducted the first WDA test event with a laser-guided bomb on October 29, followed two days later by the first launch of the AIM-120 air-to-air missile. The second launch of an AIM-120 missile occurred on November 15. Data analyses of the missile launches was ongoing at the time of this report. The team accomplished the first WDA test event with a JDAM bomb (GBU-32) on December 6; data analysis was ongoing at the time of this report. These early WDA events have included non-operationally relevant workarounds to mission systems deficiencies that will not be tolerable in operational testing or combat employment. Completion of all Block 2B weapons testing by the end of October 2014 is dependent on:
  - The ability of the test team to accomplish a successful weapons-related test mission at a consistently high rate
  - The Block 2B version of mission systems software delivered in October 2013 adequately correcting deficiencies and permitting WDA events to proceed in an operationally relevant manner
  - Reliable instrumentation and priority from range support assets
  - Maintaining the test aircraft used for weapons testing in the Block 2B configuration while the program manages the requirement to start testing mission systems aircraft in the Block 3i configuration
- Current program schedules indicate weapons integration testing to be complete by the end of October 2014 and August 2016 for Blocks 2B and 3F, respectively. To meet the schedule for Block 2B, the test team planned to have completed 8 of 15 total Block 2B WDA events by the beginning of December; however, only 4 have been accomplished. WDA events beyond these first four have been blocked from completion due to lack of adequate mission systems performance in radar, fusion, and EOTS. Corrections to the known deficiencies and fix verification are planned to be delivered in the 2BS4.2 and 2BS5 versions of software, the first of which is scheduled to begin weapons flight testing in March 2014. The result of this blocking of subsequent WDA events is a 4- to 6-month delay in the completion of Block 2B weapons integration, which will likely be done between February and April 2015. Detailed planning of the Block 3F weapons integration schedule to complete in August 2016 is under development. However, given historical performance and reasonable planning factors, it is more likely that the final Block 3F weapons events will not be completed within the current SDD schedule.

Static Structural and Durability Testing

- Durability testing and analysis on the ground test articles of all three variants continued in 2013; progress is measured in aircraft lifetimes. An aircraft lifetime is defined as 8,000 Equivalent Flight Hours (EFH), which is a composite of time under different test conditions (i.e., maneuver and buffet for durability testing). In accordance with the SDD contract, all three variants will complete two full lifetimes, or 16,000 EFH of durability testing. The completion dates for the second aircraft lifetimes are late 2014 for the F-35B and early 2015 for the F-35A and F-35C. The program made plans in 2013 to add a third lifetime of durability testing on the test articles of all three variants.
- The F-35A ground test article, AJ-1, completed the first aircraft lifetime in August 2012, as planned. For most of 2013, AJ-1 underwent detailed inspections and repairs on cracks revealed after the first lifetime of testing, including repairs to the wing forward root rib and to a bulkhead stiffener. The

second lifetime of durability testing is planned to begin in December 2013.
- F-35B durability testing on BH-1 completed the first lifetime of 8,000 EFH on February 9, 2013, then underwent detailed inspection and repairs prior to starting the second lifetime of testing on July 22. The program completed the first block of 1,000 EFH (9,000 EFH total) on August 19, approximately 1 month ahead of schedule. Further testing was halted in September when cracks were discovered in two of the bulkheads, requiring repair.
- The F-35C fatigue test article restarted testing on January 9, 2013, after previously completing 4,000 hours of testing and associated inspections. It completed 8,000 EFH of testing, or the first lifetime, on September 28. Testing is behind schedule, as cracks discovered in the floor of the avionics bay in February caused a two-month pause while interim repairs were completed. Cracks discovered in fuselage station 402 and the surrounding structure caused a stop test after 7,620 EFH of testing to complete repairs. These cracks were not predicted by prior analysis. Detailed inspections from the first lifetime were ongoing as of this report.
- Component durability testing for two lifetimes of the vertical tails was completed for the F-35A and F-35B during 2012. Vertical tail testing started in August 2012 for the F-35C and completed 12,901 EFH as of the end of October 2013. Component testing of the horizontal tail for the F-35A and F-35C began third-lifetime testing, completing 23,000 EFH and 21,000 EFH, respectively, as of the end of August.
- The redesigned F-35B auxiliary air inlet doors, required for STOVL operations, are undergoing ground tests on the F-35B static loads test article (BG-1). Static load testing was completed late in CY12 and durability testing had completed just over 3,000 cycles (approximately 8 percent) of the planned testing as of the end of August. Modifications of the auxiliary air inlet doors on production aircraft have already begun.
- Discoveries from durability testing included significant findings in both the F-35A and F-35B ground test articles.
  - Discoveries this year on the F-35A test article include cracks in the engine thrust mount shear webs (designed to carry some of the fore and aft engine load) on both sides of the aircraft, and a crack in the frame of the web stiffener located at fuselage station 402. The program has redesigned the thrust mounts for production cut-in with Lot 6, and retrofits to be completed on earlier aircraft during depot modification periods. Root cause, corrective action, and modification plans for the frame crack are to be determined.
  - In the F-35B, the program halted testing in December 2012 after multiple cracks were found in a bulkhead (FS472) flange on the underside of the fuselage during the 7,000-hour inspection. Root cause analysis, correlation to previous model predictions, and corrective action planning are ongoing.
    - Discoveries during detailed inspections following the first lifetime of testing include cracks on the left and right hand sides of the wing aft spar lower flanges and cracking in the frame of the jack point stiffener, a portion of the support frame outboard of the main fuselage above the main landing gear designed to support load bearing of the aircraft during jacking operations. Redesign, modification, and retrofit plans for these discoveries have not yet been determined by the program. As of August 5, 2013, two redesigns of the part were being evaluated for potential replacement.
    - During its 8,000-hour detailed inspection period between February and July, cracks were found on both the right and left rear spar lower flanges near bulkhead FS556. This particular spar was already on the list of limited life parts, but not for the location of concern.
    - Also during its 8,000-hour inspections, cracks were found in the lower arch of the FS496 bulkhead, but were below limits which would cause a break in planned testing, which restarted at the end of July. At the 9,000-hour inspection in September, the cracks had grown, but were not deemed sufficient to stop testing, but required increased inspection intervals. The cracks continued to grow during subsequent testing, until at 9,056 EFH, at the end of September, the bulkhead severed and transferred loads which caused cracking in the adjacent FS518 bulkhead. Analysis and corrective action were ongoing at the time of this report.
    - All of these discoveries will require mitigation plans and may include redesigning parts and additional weight. Also, the repairs to the jack point stiffeners – accomplished after the first lifetime of testing – were not adequate, requiring the program to design a new repair concept.
  - Discoveries in the F-35C test article include cracks in the floor of the avionics bay and, similar to the F-35B, cracking in the frame of the jack point stiffener. Cracks were also found in the bay floor of the power distribution center; repair, retrofit, and production impacts are to be determined.

Modeling and Simulation

Verification Simulation (VSim)

- VSim is a man-in-the-loop, mission software-in-the-loop simulation developed to meet the operational test agencies' requirements for the Block 2B operational utility evaluation and Block 3F IOT&E.
- The program is now at significant risk of failing to (1) mature the VSim and (2) adequately verify and validate that it will faithfully represent the performance of the F-35 in the mission scenarios for which the simulation is to be used in operational testing. Key concerns are:
  - VSim development, and verification and validation activities may not be completed in time to support the Block 2B operational utility evaluation, beginning in late CY15. In particular, long lead items such as threat mission data files are at risk of being delivered too late for integration into VSim in time to support the planned Block 2B operational utility evaluation timeline.

Additionally, the current VSim schedule has validation and accreditation documentation production activities scheduled until September 2015, months late to support the initial accreditation report required by the Operational Test Readiness Review for the Block 2B operational utility evaluation, scheduled for May 2015.
- The current VSim validation plan does not provide the detail or rigor needed to be able to anticipate accreditation of VSim for use in mission-level evaluation in operational testing. Shortfalls identified include: lack of detail in validation plans for VSim component models; lack of a clear path from component model validation to F-35 system validation to mission-level validation; absence of planned validation for government-furnished threat and weapons models that require significant additional validation after the modifications made to them during integration into VSim; and lack of a plan for structured regression testing after model modifications have been made. As of November 2013, the JSF Operational Test Team, the JSF Program Office, and Lockheed Martin are in the midst of a series of intensive VSim validation meetings aimed at overcoming these shortfalls.
- VSim may not adequately replicate the installed system performance (i.e., the performance of all F-35 systems and subsystems as installed in the aircraft) in the mission scenarios for which the simulation is planned to be used in the Block 2B operational utility evaluation. There may not be adequate validation data to support accreditation of the simulation for operational testing.
- No dedicated testing is planned by the program to validate F-35 installed performance in the VSim. The program currently expects validation data to come from planned developmental mission systems and weapons integration testing. However, developmental testing seeks only to acquire verification of contract specification criteria, and does not span the set of conditions over which mission effectiveness will be assessed using VSim in both developmental and operational testing. This creates a significant gap for the program in being able to validate VSim for both developmental and operational testing.

- In addition to the risks cited above, DOT&E has highlighted shortfalls in the test resources needed to gather key elements of data required for validation of the VSim for IOT&E, in particular for electronic warfare performance in the presence of advanced threats. These shortfalls are a function of limitations in the test assets currently available to represent threat systems. DOT&E has made formal recommendations to address the shortfalls and is pursuing solutions to make the assets available in time to prepare for IOT&E in a realistic threat environment.
- The JSF Program Office and Lockheed Martin have begun to try to address these concerns. Important recent activities have included technical interchange meetings with threat model developers in the intelligence community to address the modeling of electronic attack capabilities, a series of intensive validation planning meetings currently underway to provide detailed validation data requirements, and a summer 2013 VSim risk reduction event using the simulation in an F-35 Block 2A configuration.

Other Models and Corporate Labs Activity

- At the beginning of 2013, the Program Office had accredited 7 of the 25 models and simulations currently planned to support verification of the F-35. No additional models and simulations planned to support verification of F-35 requirements were accredited in 2013; so, the total number accredited remains at seven.
- As of the end of 2012, the program had planned to accredit six models and simulations intended for use in the requirements verification plan in 2013. Of the 18 remaining models and simulations listed in Program Office documentation as requiring accreditation for use in verification, the program characterizes 12 as on-track for accreditation. The progress of the remaining six is characterized as either off-track with mitigation efforts in place or as on-track but with significant execution risk.

Training System

- In late 2012, the program completed a Ready For Training Operational Utility Evaluation (OUE) to support the Air Force's Air Education and Training Command's decision to begin student training at Eglin AFB, Florida. The OUE evaluated the capability of both the F-35A air vehicle and the training system to train an experienced initial cadre of pilots in the equivalent of the familiarization phase of a fighter aircraft transition syllabus. It also evaluated the ability of the F-35A maintenance and Autonomic Logistics Information System (ALIS) to sustain a sortie generation rate for the Block 1A syllabus.
- Restrictions on the aircraft operating limits prevented instruction in most high performance maneuvering and flight through instrument meteorological conditions (i.e., clouds). However, pilots were adequately trained in the basic operation of the aircraft. Mission systems were still immature, but generally unnecessary for this phase of training since no combat training could be performed. Even at this reduced level of activity, the radar, the HMDS, and the cockpit interfaces caused increased workload or had deficiencies. Aircraft availability was low during the OUE, but was adequate to meet the training sortie requirements with extensive workarounds.
- Pilot training classes continued throughout 2013. Although aircraft availability and reliability at the training center remains below expectations, the shortened syllabus allowed pilot production to remain at planned levels. Eglin originally planned to produce 68 pilots during the 2013 period of performance, but the Services reduced their need to 66 pilots. All students completed planned training (of the reduced syllabus) on schedule.

- There are currently two configurations of aircraft at the training center, Block 1B and 2A. Six Lot 4 (Block 2A) aircraft were delivered in 2013 and several Lot 5 aircraft are in various stages of delivery. The first two F-35C aircraft were delivered to Eglin AFB in June. Pilot training using the syllabus for the Block 2A configuration starts in early 2014 after a small group rehearsal.
- The training center continued to conduct maintenance training for experienced maintenance personnel for both the F-35A and F-35B during 2013. As of the end of September, 978 personnel had completed training in one or more of the maintenance courses to support fielded maintenance operations.

Live Fire Test and Evaluation

F135 Engine

F135 engine vulnerability testing consisted of two test series: (1) fuel ingestion tests to examine the vulnerability of the F135 engine caused by fuel leakage from ballistically damaged fuel tanks adjacent to the engine inlets, and (2) ballistic tests to determine the damage tolerance of engine components, including fluid-filled components, sensors, actuators, and rotating components.

- The fuel ingestion tests demonstrated the engine can tolerate a range of inlet fuel flows. These fuel flow rates simulated quantities representative of missile fragment-induced damage to fuel tanks adjacent to the engine. System-level ballistic test events planned for FY15, using a structural F-35C test article with an operating engine, will quantify the exact relationship of the simulated leak rates to those expected in an actual threat encounter. Further analysis will assess the vulnerability to multiple fragment impacts, which are probable in missile encounters.
- The fuel ingestion tests did not simulate engagements by ground-based or aircraft gun systems that are possible during low-altitude close-air support missions and within-visual-range air-to-air combat. A Concept Demonstrator Aircraft engine test in 2005 showed the engine could not tolerate fuel ingestion events representative of such conditions (i.e., low-altitude, high-speed, high-engine thrust, and higher leak rates). The program made no design changes in response to those earlier test results and this vulnerability remains in the final production engine design. A ballistic liner in the fuel tank could mitigate this vulnerability, but the program removed this feature during its weight-reduction efforts, saving 48 pounds.
- Tests using single missile fragments showed that the F135 rotating components were tolerant to these threats, with little or no effect on engine performance or component survival. However, three of four tests against fuel-filled external components resulted in massive fuel leaks, and one produced a sustained fire. The F-35C system-level tests in FY15 will evaluate whether installation effects, resulting in leaked fuel interacting with the engine exhaust, would increase the risk of fire. Engine vulnerability to high-explosive incendiary (HEI) and armor-piercing incendiary (API) threats was not confirmed in this test series since historical data on similar engines already demonstrated that these threats can penetrate the engine core and create cascading damage resulting in engine failure and fires.

F-35B Lift System

- Ballistic tests on an F-35B STOVL propulsion system showed that single fragment damage to the lift fan did not degrade propulsion system performance. Analyses showed that fragment-induced damage could result in the release of more than 25 percent of a single lift fan blade, resulting in a catastrophic STOVL system failure. In order to preserve the test article for the remainder of the series, these engagement conditions were not tested. More severe threats, encountered at low-altitude or in air-to-air gun engagements, will likely cause catastrophic damage.
- Ballistic tests of the lift fan shaft demonstrated that the design changes from the earlier Concept Demonstration Aircraft article improved its survivability against all threats, including the more severe API threat.
- The F-35 has no sensors to warn the pilot of lift fan damage prior to conversion to STOVL flight upon return for landing. Conversion to STOVL flight puts high loads on the quickly accelerating system components that can result in catastrophic failure before the pilot can react and return the aircraft to wing-borne flight, or can create uncontained damage that cascades into other critical system failures. Prognostics and Health Management sensors that monitor component health and system degradation for maintenance purposes, could provide some warning, but the relevant software and hardware would have to be improved to provide reliable information to the pilot to support critical survivability decisions.

On-Board Inert Gas Generation System (OBIGGS)

- An OBIGGS/lightning protection Critical Design Review in February 2013 reviewed a system design capable of providing fuel tank inerting that would prevent fuel tank ullage explosion due to ballistic threat encounters or lightning strikes. The program is currently planning the F-35B fuel system simulator testing and ground tests on all three variants. Tests will include a spectrum of mission profiles, including high descent-rate dives to evaluate the improved OBIGGS ability to provide fuel tank inerting without compromising fuel tank and wing structure integrity.
- In-flight inerting does not protect the aircraft against damage to the airframe resulting from lightning-induced currents. Most line-replaceable units (e.g., actuators and components of the electrical power system) have passed lightning tolerance qualification testing, but the existing F-35 airframe fasteners, selected to satisfy weight reduction criteria, are not lightning tolerant. The program still needs to complete lightning tolerance qualification testing for remaining components and current injection tests, before lifting current restrictions preventing aircraft operations within 25 miles of known lightning.

Polyalphaolefin (PAO) Shut-Off Valve

- A live fire test in 2012 demonstrated crew and aircraft vulnerabilities to avionics coolant (PAO) system fires. The threat ruptured the PAO pressure line in the area just below the cockpit, causing a sustained PAO based fire with a leak rate of 2.2 gallons per minute (gpm). These results showed that a PAO shut-off valve that could detect and react to a 2 gpm, low leak rate could mitigate this vulnerability. Designing a system with this criterion poses some technical challenges, given a potential for excessive false alarms at these detection rates.
- DOT&E repeatedly recommended redesigning and reinstalling a PAO shut-off valve after the program decided on removal for weight reduction. The program has been reconsidering the reinstatement of the PAO shut-off valve and has tasked Lockheed Martin to develop a technical solution to meet the criteria demonstrated in live fire tests. The program has not provided any updates on the operational feasibility and effectiveness of the design, or an official decision to reinstate this vulnerability reduction feature.

Fueldraulic Fuses

- The fueldraulic system is a fuel-based hydraulic system used to control the F-35B engine exhaust nozzle. It introduces a significant amount of fuel plumbing to the aft end of the engine and, consequently, an increased potential for fire. A live fire test in 2012 demonstrated the fueldraulics system is vulnerable to missile fragments, resulting in potential fire and loss of aircraft. Engine ballistic tests in FY13 also showed that the fueldraulics system is vulnerable and that a shut-off for a damaged system could mitigate much of the vulnerability.
- A fueldraulic shut-off feature could also provide safety-related protection. In 2013, prior to a routine flight test, testers discovered an F-35B fueldraulics line failure due to an improperly manufactured hose that could have led to an engine nacelle fire. An effective fueldraulic shut-off would prevent such an outcome.

Electrical System

- The F-35 includes several technologies used for the first time in a fighter aircraft that represent advancement of the more electric aircraft topology. The advances also provide a potential source of unique F-35 vulnerabilities.
- All flight control electronic units and the electrical power system electrical distribution units have two voltage levels (270 and 28 volts DC) in internal circuits. An in-flight incident in 2007, electrical arcing tests in 2009, and the flight-critical system-level test events in 2012 showed that the vulnerability of the F-35 electrical power system requires further analyses to address the likelihood and significance of ballistically induced arcing between the 270-volt and 28-volt electrical systems.
- Lockheed Martin also confirmed that all three F-35 variants include up to 28 wire harnesses that contain both 28- and 270-volt wires, but the contractor is still working on providing the comprehensive extent and locations of these harness runs. Lockheed Martin should conduct a vulnerability analysis as soon as possible to determine the likelihood of ballistically- or lightning-induced arcing from the 270-volt on a 28-volt system and to determine whether the resulting damage effects would be catastrophic to the airplane. DOT&E will review these analyses to provide a comprehensive assessment of the F-35 vulnerability to ballistic damage to the electrical power system.

Chemical/Biological Vulnerability

The program continues to make progress in the development of the decontamination system in preparation for the full-up system-level test planned for FY17.

- The F-35 Chemical Biological Warfare Survivability Integrated Product Team oversaw design and construction of a full-scale shelter liner and associated portable process containment shelter for chemical and biological decontamination operations. The contractor will set up the initial demonstration of shelter and liner for a form, fit, and function demonstration in 1QFY14 in conjunction with the Tactical, Cargo, and Rotary-Wing Aircraft Decontamination device. A full-scale setup at Edwards AFB in FY14 will demonstrate performance of the integrated liner, shelter, and decontamination system in preparation for the FY17 full-up system-level test of the apparatus with F-35 test article BF-4.
- The Integrated Product Team is coordinating closely with the Joint Program Executive Office for Chemical and Biological Defense in developing the F-35 Joint Strike Fighter variant of the Joint Service Aircrew Mask. The mask, scheduled to undergo a Critical Design Review in 1QFY14, has high-schedule risk because its development is contingent on mask integration with the F-35 HMDS. The Mask Program Manager expects an LRIP version of the mask to be available in 3QFY14 in preparation for Mask/HMDS flight qualification in 1QFY15.

Gun Ammunition Lethality and Vulnerability

- The F-35 program, the Air Force, Navy, Marines, and their international partners are conducting lethality live fire testing and evaluation of three different 25 mm gun ammunition types.
  - PGU-48 frangible tungsten armor piercing design for the F-35A
  - PGU-32 semi-armor piercing HEI ammunition for the F-35B and F-35C
  - PGU-47 armor-piercing explosive ammunition for the partner F-35A variant and, depending on the overall cost and final lethality and reliability assessment results, possibly for the U.S. F-35B and F-35C variants
- Each ammunition is specialized against different target sets particular to each Service, including personnel, small boats, ground structures, trucks, light armor, and fixed-/rotary-wing aircraft.

- Fracture characterization tests of the PGU-48 showed the tungsten to be much more frangible than other tungsten materials tested previously, which should increase predicted damage against targets employing widely-spaced materials. Characterization of all three ammunitions will continue in FY14 with terminal ballistics tests against multi-plate structures (representing vehicle materials) as well as building wall materials. FY15 tests will include ground-based and flight testing against representative targets.
- The program assessed the vulnerability of the F-35 aircraft to ballistic threats while carrying these ammunitions in FY13. Ballistic tests against a single F-35 ammunition type (PGU-32) showed that propellant explosive reaction was highly unlikely, while a propellant fire was probable. No propellant fire generated by ballistic impact triggered a propellant explosion. There was no evidence of sympathetic reactions in multiple round tests.

Issues Affecting Operational Suitability

Overall suitability performance continues to be immature, and relies heavily on contractor support and workarounds unacceptable for combat operations. Aircraft availability and measures of reliability and maintainability are all below program target values for the current stage of development.

F-35 Fleet Availability

- Average F-35 availability rates for operational units are below established threshold values. (Availability is not a meaningful metric for aircraft dedicated to test, and thus SDD aircraft are not included in this section.)
  - The program established an availability threshold rate of 50 percent and an objective rate of 75 percent to track fleet performance for Performance Based Logistics agreements.
  - Aircraft availability rates by operating location from November 2012 through October 2013 are summarized in the following table. The first column indicates the average availability achieved for the whole period, while the maximum and minimum columns represent the range of monthly availabilities reported over the period.

F-35 AVAILABILITY FROM NOVEMBER 2012 THROUGH OCTOBER 2013*

Operational Site	Average	Maximum	Minimum
Whole Fleet	37%	46%	26%
Eglin F-35A	38%	51%	24%
Eglin F-35B	39%	54%	22%
Eglin F-35C **	32%	61%	13%
Yuma F-35B	29%	45%	6%
Edwards F-35A	29%	41%	14%
Nellis F-35A	37%	63%	14%

* Data do not include SDD aircraft
** Eglin F-35C data began in August 2013

- Overall fleet availability has averaged 37 percent and showed a gradual decline in the latter half of the period reported in the table, with the last five months of the period all below the average for the year. Late in the reporting period, the program began increasing the number of aircraft undergoing modifications and depot-level repairs, which contributed to the decline in fleet availability. While some operating sites did achieve threshold availability for a month or more, overall fleet availability never reached the threshold of 50 percent and was as low as 26 percent in February.
- Unavailable aircraft are considered Not Mission Capable (NMC) because they are undergoing maintenance (NMC-M) for systems necessary for safe flight or are awaiting parts from supply (NMC-S).
  - From November 2012 through August 2013, the NMC-M rate averaged 35 percent and was generally stable, but rose afterward and peaked at 47 percent in October. This observed NMC-M rate is well above the target rate of 6 percent established by the program for Performance Based Logistics evaluation.
    - A significant portion of the aircraft down time has been the result of field maintenance organizations waiting for technical dispositions or guidance from the contractor on how to address a maintenance issue that has grounded an aircraft. These Action Requests (ARs) are a result of incomplete or inadequate technical data in the field, and waiting for their resolution accounts for 25 to 30 percent of the aircraft downtime. Recent trends have shown an increasing number of ARs per aircraft each month. Reducing the rate of ARs, or decreasing the response time to the ARs, should improve NMC-M rates.
    - The requirement for modifications will continue to increase on the fleet and will likely adversely affect NMC-M rates for the next two years. Analysis of current modification plans show that up to 13 percent of the fielded fleet would be unavailable due to depot work alone in the late 2014 timeframe.
  - Over the same period, the NMC-S rate averaged 27 percent, peaking at just over 30 percent in July 2013 and then gradually declining. The target value established by the Program Office is an NMC-S rate of 20 percent or less. According to the Program Office, lower than expected performance in NMC-S rates has been due to late contracting of the necessary spares for recent production lots. They expect that improved contracting performance and increasing maturity of the supply system will result in improved parts support by late 2014.

F-35 Fleet Reliability

- The F-35 program uses reliability growth curves that project expected reliability for each variant throughout the development period based on accumulated flight hours.
  - These growth curves are established to compare observed reliability with a target to meet the Mean Flight Hours Between Critical Failure (MFHBCF) threshold requirement by 75,000 flight hours for the F-35A and F-35B, and by 50,000 flight hours for the F-35C.

- Currently, none of the variants are achieving their predicted reliability based on flight hours accumulated as of the end of August 2013, as shown in the following table.

F-35 RELIABILITY AS OF AUGUST 31, 2013 – MFHBCF, HOURS							
Variant	Requirement		Current Values				Observed MFHBCF as of May 2012
	Threshold MFHBCF	Threshold Flight Hour Target	Observed MFHBCF	Current Total Flight Hours	Objective MFHBCF from Growth Curve	Observed as % of Objective Value	
F-35A	20	75,000	4.5	4,204	13.5	33%	5.9
F-35B	12	75,000	3.0	3,286	7.7	39%	4.2
F-35C	14	50,000	2.7	903	9.0	30%	6.7

- Though month-to-month reliability rates vary significantly, in part due to the small fleet size, the F-35B showed slight improvement over the reporting period, while F-35A reliability appears to be relatively flat. The program has fielded too few F-35C aircraft to assess reliability trends.
- Statistical analysis of the 90-day rolling averages for Mean Flight Hours Between Critical Failure – Design Controllable ($MFHBCF_{DC}$) through the end of July 2013 show flat trend lines for the F-35A and F-35B with most data points below the threshold growth curve, meaning the observed reliability is not within the desired envelope for design controllable failures. Design controllable failures are those that can be attributed to deficiencies in component design, but considered by the Program Office to be fixable by design modification.
  - While some design improvements will be incorporated in production of the Lot 5 aircraft, most of the remaining planned improvements are being incorporated in Lots 6 and 7. The next opportunity to expect improvement in the fleet reliability performance is likely to be in 2015. However, some design improvements planned to be cut-in with these production lots are for structural fatigue life and increased mission capability which will not necessarily improve reliability.
  - Through November 2013, all F-35 test and production aircraft combined had achieved 11,500 total flight hours, 6 percent of the flight hour total (200,000 hours) at which the ORD reliability goal is to be achieved. However, the design is becoming more stable and opportunities for reliability growth are decreasing. While the relatively low number of flight hours shows there is still time for program reliability to improve, this is not likely to occur without a focused, aggressive, and well-resourced effort.
- A number of components have demonstrated reliability much lower than predicted by engineering analysis, which has driven down the overall system reliability. High driver components affecting low availability and reliability include the following, grouped by components common to all variants as well as by components failing more frequently on a particular variant or completely unique to it, as shown in the following table.

HIGH DRIVER COMPONENTS AFFECTING LOW AVAILABILITY & RELIABILITY		
Specific to Variant		Common to All Variants
F-35A	• Data transfer cartridge • Position/strobe light lens assembly	• 270 Volt Direct Current battery • Fiber channel switch • Avionics processor • Power and thermal management system • Landing gear and tire assembly • Display management computer/helmet • On-Board Oxygen Generating System • Crew escape and safety system • 80kW Inverter/Converter/Controller
F-35B	• Upper lift fan door actuator • Main landing gear wheel/tire assembly	
F-35C	• Ejection seat portion assembly • Data security module	

Maintainability

- The amount of time required to repair failures for all variants exceeds that required for mature aircraft, and has increased over the past year. The table below compares the Mean Corrective Maintenance Time for Critical Failure (MCMTCF) and Mean Time To Repair (MTTR) for all unscheduled maintenance for each variant as of August 31, 2013, to the threshold requirement from the ORD and the same value reported in the FY12 Annual Report.

F-35 MAINTAINABILITY AS OF AUGUST 31, 2013 - MCMTCF (HOURS)				
Variant	Threshold	Observed	% of Threshold	FY12 Annual Report
F-35A	4.0	12.1	303%	9.3
F-35B	4.5	15.5	344%	8.0
F-35C	4.0	9.6	241%	6.6

F-35 MAINTAINABILITY AS OF AUGUST 31, 2013 - MTTR (UNSCHEDULED)				
Variant	Threshold	Observed	% of Threshold	FY12 Annual Report
F-35A	2.5	9.2	366%	4.2
F-35B	3.0	8.9	294%	5.3
F-35C	2.5	7.7	307%	4.0

- Maintenance times reported by the Program Office have increased (worsened) compared to those reported a year ago.
  - The causes of this increase are not clear from the available data, which are derived from a fleet that has only early mission systems functionality, but has grown to include three new operating locations this year. It is too early to determine if the increase in maintenance times is from immaturity of sustainment operations in the field (i.e., incomplete technical data and low experience of newly-trained maintenance personnel) or from underlying maintainability and aircraft design issues, such as poor component reliability and maintenance actions requiring excessive time to complete.
  - Cure time to restore low-observable (LO) characteristics following maintenance behind panels not designed for frequent access might be a factor in the increased maintenance time, but the Program Office has not tracked

LO maintenance times separately. The Program Office should include LO and non-LO repair times in their monthly performance metrics to help understand the root cause of these increases and take corrective actions. Further, LO repair should be broken down into repair times for inherent LO failures, and LO repairs required to facilitate other maintenance. The proportion of all LO repairs that are required to facilitate other maintenance should be reported.

Autonomic Logistics Information System (ALIS)

- The Program Office continues to develop and field ALIS in incremental capabilities similar to the mission systems capability in the air vehicle. Overall, the ALIS is immature and behind schedule, which adversely affects maintainability and sortie generation. Shortfalls in functionality and data quality integrity require workarounds and manual intervention.
- ALIS version 1.0.3, required for the Services to accept production Lot 4 aircraft at Eglin AFB, Florida, Nellis AFB, Nevada, and Yuma Marine Corps Air Station, Arizona, underwent initial testing at the Edwards test center in late 2012 and began fielding in early 2013.
  - During initial testing in 2012, the Edwards test team found shortcomings in the systems integration of ALIS applications and a lack of maturity in handling data elements. The team identified four critical (Category I) deficiencies, which required correction before fielding, and 54 severe (Category II) deficiencies, which required significant workarounds.
  - The contractor developed an updated version of the ALIS 1.0.3 software to address some of the deficiencies identified during initial testing and the Edwards test team retested the software in December 2012. The program subsequently started fielding this version of ALIS 1.0.3 in early 2013.
  - The Patuxent River test team reported on the performance of the updated version of ALIS 1.0.3 in May 2013, and indicated that at least three of the four Category I deficiencies identified during initial testing remained open.
- Prior to the start of the Block 2B operational utility evaluation, the program must correct deficiencies in ALIS 1.0.3, finish development of ALIS 2.0, and integrate the propulsion module in ALIS 2.0.1, which is required for Marine Corps Initial Operational Capability (IOC). The Edwards test center plans to begin testing of ALIS 2.0 in April 2014 and ALIS 2.0.1 in September 2014. Delays in the release of ALIS 2.0 or 2.0.1 will add schedule risk to the Block 2B fleet release planned for mid-2015.
- The current Squadron Operating Unit (SOU) used by ALIS failed to meet the deployability requirement in the ORD due to the size, bulk, and weight of the current SOU design. To address the requirement, the program is developing a deployable version of the SOU, deemed SOU V2. It will support aircraft in the Block 2B, 3i, and 3F configuration, and is a critical delivery item for meeting Service IOC dates. The Program Office has divided the SOU V2 development into multiple increments.
  - The first increment includes the capability to deploy and support the requirements for Marine Corps IOC. This increment will align hardware (SOU V2) and software (ALIS 2.0.1) releases to allow testing to begin at the Edwards flight test center in January 2015.
  - The second increment, currently unfunded, will address U.S. Air Force requirements for sub-squadron reporting capabilities and inter-squadron unit connectivity.
  - A third increment, also unfunded, plans to add decentralized maintenance capability, which will allow personnel to manage tasks with or without connectivity to the main SOU.
- To date, diagnostic system performance has failed to meet basic functional requirements, including fault detection, fault isolation, and false alarm rates. Due to the failure to meet these requirements, the program has discontinued the development of enhanced diagnostics (model-based reasoning) for the remainder of SDD. The program has initiated manual workarounds in the field, such as maintainer-initiated built-in tests and reliance on contractor support personnel, for more accurate diagnostics of system faults.

Joint Technical Data

- Development of Joint Technical Data (JTD) modules for the F-35A and F-35B is largely complete. Verification naturally lags behind development, but is progressing toward completion. Verification of modules requiring extensive intrusion into the aircraft is planned to be completed during depot-level modifications or opportunistic maintenance. The F-35C lags behind the other variants, but is proceeding quickly because of variant similarities. The chart below shows the status of JTD development and verification for each variant, propulsion, support equipment, and sustainable low observable (SLO) maintenance. Results exclude JTD for pilot flight equipment and JTD unique to LRIP aircraft (such as structural field repairs) that will not be needed for full-rate production aircraft. From October 2012 to October 2013, the Program Office verified 2,581 aircraft and 822 propulsion modules. Early in 2014, the primary focus in JTD verification will be weapons and stores.

	Data Modules Identified (as of Oct 2013)	Data Modules Completed	% Data Modules Completed	% Data Modules Verified
F-35A[1]	4,404	4,045	91.9%	81%
F-35B[1]	5,314	4,766	89.7%	76%
F-35C[1]	4,514	3,357	74.4%	55%
Propulsion	2,892	2,861	98.9%	94%
SE	2,241	489	21.8%	13%
SLO	1,362	291	21.3%	3%
Total	**20,727**	**15,809**	**76.3%**	**64%**

Note: 1. Includes field and depot-level JTD for Operations and Maintenance (O&M) for air vehicle only

- As stated earlier in the F-35 fleet availability section, aircraft maintenance personnel submit ARs to Lockheed Martin when the needed JTD is not available to troubleshoot or resolve a problem with an aircraft. The time maintenance personnel wait for resolution of these ARs contribute to aircraft non-availability (25-30 percent of the reported NMC time has been due to AR wait time).
  - Lockheed Martin prioritizes and responds to ARs through the Lightning Support Team, which is composed of Service and contractor personnel. The support has been fairly successful in responding to the most critical ARs with at least an interim solution in a timely manner, but because of manpower limitations, has been unable to handle the backlog of less severe ARs.
  - As of August 2013, 231 critical ARs remained open, while over 200 severe ARs were open. A critical AR addresses a deficiency which may cause major loss or damage to a system, or severe injury or possible death to personnel if not corrected. A severe AR addresses a deficiency which adversely affects operational safety, suitability, or effectiveness; however, a workaround is permitted.

F-35B Air-Ship Integration and Ship Suitability Testing

- The Navy deployed two F-35Bs to LHD-1 (USS *Wasp*) for two weeks in August 2013 to continue assessing shipboard suitability and integration. The Navy is continuing to analyze data from this deployment. Permanent modifications to the *Wasp* to prepare for JSF integration included:
  - Addition of transverse stiffeners to the underside of the flight deck for the two landing spots used by the F-35B and application of thermal non-skid material to the topside of the flight deck for one landing location. The Marine Corps applied the non-skid material to the other landing location before an earlier detachment to the *Wasp*.
  - Deck edge modifications, including the removal, replacement, relocation, and shielding of communications systems.
  - Added fire detection and alarming systems for the lithium-ion battery charging and storage area.
- Temporary alterations for the *Wasp* for this detachment include:
  - Lithium-ion battery charging and storage areas. The Marine Corps has not determined the final design of these areas.
  - Short take-off rotation line lights. Analysis of results will determine the precise location of these lights.
  - Addition of test equipment.
- The deployment met the primary objective of collecting data to support the development of a Block 2B operational flight envelope for take-offs and landings. The test team expanded the range of aircraft weight and center of gravity compared to that developed from the first deployment in 2011 and conducted operations in both day and night conditions. The test team completed 95 short take-offs and vertical landings, including forward and aft facing landings, and 17 night take-offs and landings during the deployment.
- The Marine Corps is developing solutions to a number of challenges in integrating the F-35B onto L-class ships:
  - Large-scale application of a thermal non-skid material to the flight deck in F-35B landing locations.
  - Modification of the flight deck structure to eliminate excess stress, which includes transverse panel breakers installed on the underside of the existing flight deck structure.
  - Design of separate charging and storage lockers for the lithium-ion batteries required for the JSF and new storage locker for pilot flight equipment, as the JSF helmet is larger and more fragile than legacy helmets.
  - New firefighting procedures in the event of a fire on the flight deck near aircraft carrying internal ordnance.
  - Understanding requirements for gun pod storage.
  - Conducting feasibility studies on the resupply of F-35B engines while underway, which could include a greater space allocation for engine storage aboard ship or through underway replenishment using a Navy system currently installed on one supply ship and scheduled for installation on CVN-78.
  - The Marine Corps has determined that new active noise reduction personal hearing protection is necessary for on-deck personnel because of the high level of engine noise. Noise damping materials and/or personal hearing protection may also be needed for below-deck personnel.

F-35C Air-Ship Integration and Ship Suitability Testing

- Although a number of air-ship integration issues are common to both CVN and L-class ships, such as lithium-ion battery storage, pilot flight equipment storage, need for new shipboard firefighting procedures, and high noise levels, some issues and their solutions are particular to aircraft carriers. The Navy has made progress in addressing some of these integration issues, but several challenges remain.
  - The program began testing its redesigned arresting hook system on a flight test aircraft in late CY13. The redesign was necessary after the original system failed to engage the cable and demonstrate sufficient load-carrying capacity. The arresting hook system remains an integration risk as the JSF development schedule leaves no time for new discoveries. Other risks include the potential for gouging of the flight deck after a missed cable engagement (due to an increase in weight of 139 pounds) and the potential for sparking from the tail hook across the flight deck because of the increased weight and sharper geometry of the redesigned hook.
  - The Navy is redesigning the cooling system in the Jet Blast Deflectors, which deflect engine exhaust during catapult launches, to handle JSF engine exhaust. The redesign will include improvements in side-cooling panels.
  - CVN-78 will receive the new Heavy underway replenishment (UNREP) system along with one resupply ship, but the Navy has delayed this system for eight years on other ships. This new UNREP system is the

only system capable of transporting the JSF engine and container while the carrier is underway.
- The JSF engine container was unable to sustain the required sudden drop of 18 inches (4.5 g's) without damage to the power module during shock testing. The Navy is redesigning the container to better protect this engine, but this is likely to result in an increase in container size and weight. The Navy estimates new container availability in late 2016.
- Engine noise is a potential risk to personnel on the flight deck and one level below the flight deck. The Navy has decided to procure active noise reduction personal hearing protection for on-deck personnel. Projected noise levels one level below the flight deck (03 level) will require at least single hearing protection. On most carriers this is a berthing area, but on CVN-78 this is a mission planning space; personnel wearing hearing protection in mission-planning areas will find it difficult to perform their duties. The Navy previously tested acoustic damping material in 2012 and is developing a model to optimize material placement.
- Storage of the JSF engine is limited to the hangar bay, which will affect hangar bay maintenance operations. The impact on the JSF logistics footprint is not yet known.
- Lightning protection of JSF aircraft while on the flight deck will require the Navy to modify nitrogen carts to increase capacity. Nitrogen is used to fill fuel tank cavities and inert aircraft at specified intervals while on deck.

Progress in Plans for Modification of LRIP Aircraft

- The Program Office and Services continued planning for modification of early LRIP aircraft to attain planned service life and the final SDD Block 3 capability.
  - Planning has focused on modifying aircraft in preparation for the Block 2B operational utility evaluation and Marine Corps IOC, both planned to occur in 2015.
  - Because operational test aircraft are to be production-representative, the Program Office must coordinate verification and approval of all modifications, the availability of docks at the aircraft depots as they open for operation, and the availability of long-lead aircraft parts needed for modifications with inputs from the Services on modification priority.
- The Program Office developed a modification and retrofit database that contains information for each entry on Service prioritization, when the modification will become part of the production line, which aircraft will require modification, whether unmodified aircraft are limited in performance envelope and service life or will require additional inspections, and operational test requirements and concerns.
- Modifications that do not require depot induction will be performed by depot field teams (who will travel to aircraft operating locations or to depots to work alongside depot teams) or by unit-level maintainers. The Program Office and Services adjudicate the location of all Block 2B modifications.
- Modifications to support the operational utility evaluation of Block 2B capability include:
  - Missions systems modifications, including those for Block 2B capability
  - Structural life limited parts, referred to as Group 1 modifications
  - STOVL Mode 4 operations modifications, which include a modification to the Three Bearing Swivel Module, which is required to allow STOVL aircraft to conduct unrestricted Mode 4 operations
  - Lightning certification, which includes OBIGGS modification (the lightning qualification of line-replaceable components and development of a system-level test still need to be completed before the aircraft modifications can proceed)
  - Support/training systems, which include the ALIS and pilot training device to support operational test aircraft
  - Other modifications, including those to vehicle systems, airframes, aircraft operating limitations, and weapons.
- The concurrency of production with development created the need for an extensive modification plan to ensure aircraft are available and production-representative for operational testing. The current modification schedule contains no margin and puts at risk the likelihood that operationally representative aircraft will be available for the Block 2B operational utility evaluation when it is currently planned by the Program Office to occur in 2015.

Recommendations

- Status of Previous Recommendations. The program and Services are satisfactorily addressing three of ten previous recommendations. The remaining recommendations concerning correction of the schedule in the TEMP, end-to-end ALIS testing, VSim validation, alignment of weapons test schedules with the Integrated Master Schedule, test of the redesigned OBIGGS system, reinstatement of the PAO shut-off valve, reinstatement of the dry-bay fire extinguisher system, and provision of a higher resolution estimate of time remaining for controlled flight after a ballistic damage event are outstanding.
- FY13 Recommendations. The program should:
  1. Ensure flight test timeline estimates for remaining SDD flight testing faithfully account for the historical growth in JSF testing, in particular for mission systems and weapons integration.
  2. Plan realistic rates of accomplishment for remaining weapons integration events; assure the events are adequately resourced from the planning phase through data analysis.
  3. Resource and plan SDD flight test to acquire the needed validation data for VSim.
  4. Track and publish metrics on overall software stability in flight test. The stability metrics should be "mission focused" and account for any instability event in core

or sensor processors, navigation, communication, radar, EOTS, DAS, or fusion display to the pilot.

5. Design and reinstate an effective fueldraulic shut-off system to protect the aircraft from fuel-induced fires. Recent testing has shown that this feature could protect the aircraft from threat-induced fire; this is also a critical flight safety feature.
6. Determine the vulnerability potential of putting 270-volt power on a 28-volt signal bus. Due to the unique electrical nature of the F-35 flight control system, the Program Office should thoroughly examine and understand this vulnerability before this aircraft becomes operational. The Program Office should successfully incorporate the wire harness design and the associated vulnerabilities in the F-35 vulnerability analysis tools.
7. Develop a plan to improve the Integrated Caution and Warning system to provide the pilot with necessary vulnerability information. The vehicle system should have the capability of detecting and reporting to the pilot any component ballistic damage (e.g., lift fan shaft) that could lead to catastrophic failure (e.g., upon attempt to convert to STOVL flight).
8. Track LO and non-LO repair times across the fleet and report them separately in monthly performance metrics. Separately track LO repairs due to inherent LO failures and due to facilitating other maintenance actions, and note the proportion of all LO repairs that are caused by facilitating other maintenance actions.
9. Plan to conduct the operational utility evaluation of Block 2B using comparative testing of the capabilities Block 2B provides relative to the capabilities provided by legacy aircraft. This approach was used to test the F-22, and is particularly critical for Block 2B operational testing because no detailed formal requirements for Block 2B performance exist.

F-35 Joint Strike Fighter (JSF)

Executive Summary

Test Planning, Activity, and Assessment

- The program focused on completing F-35 Joint Strike Fighter (JSF) Block 2B development and flight testing in an effort to provide limited combat capability to the fielded early production aircraft and to support the Marine Corps plans for declaring Initial Operational Capability (IOC) in 2015.
  - The test centers sustained flight operations at nearly the planned pace through the end of November, despite stoppages and restrictions placed on the test fleet of aircraft.
  - Flights sciences testing for the F-35A lagged behind its test flight and test point goals for CY14 as the test centers prioritized resources to focus on Block 2B mission systems testing. Flight sciences testing for the F-35B and F-35C maintained overall test point productivity by accomplishing additional test points for Block 3F, while lagging behind planned progress for completing Block 2B.
  - Test flights using the mission systems aircraft were ahead of the plan for the year, but test point productivity for Block 2B and Block 3i lagged behind the annual plan.
- In spite of the focused effort, the program was not able to accomplish its goal of completing Block 2B flight testing by the end of October.
  - Slower than planned progress in mission systems, weapons integration, and F-35B flight sciences testing delayed the completion of the testing required for Block 2B fleet release. The program now projects this to occur by the end of January 2015, instead of the end of October 2014 as was previously planned.
  - Restrictions imposed on the test fleet as a result of the engine failure in June reduced test point availability and slowed progress in mission systems and flight sciences testing from July through November. For example, the effect on mission systems testing was approximately 17 percent loss of productivity in accomplishing test points, from 210 points accomplished per month prior to the engine restrictions to approximately 175 points per month.
  - Discoveries of deficiencies continued to occur in later versions of Block 2B software, further slowing progress. For example, completion of weapons delivery accuracy events lagged the plans for CY14 and was put on hold in August when the program discovered a deficiency in the F-35 navigation system.
  - Through the end of November, 10 of 15 weapon delivery events had been completed; all events were planned to be completed by the end of October. However, the program must transition development and flight test resources to Block 3 in order to preserve an opportunity to complete the System Design and Development phase as planned in 2018. Block 2B will finish later than planned, with deficiencies remaining that will affect operational units; fixes for these deficiencies will be deferred to Blocks 3i and 3F.

- In the FY13 Annual Report, DOT&E estimated that the program would complete Block 2B testing between May and November 2015 (7 to 13 months late), depending on the level of growth experienced, while assuming the program would continue test point productivity equal to that of the preceding 12 months. Since the end of October 2013, the program has made several adjustments to reduce the delay estimated in the FY13 report:
  - In February 2014, while finalizing the 2014 annual plan, the program consolidated test points from plans of earlier blocks of mission systems (Blocks 1A, 1B, and 2A) with those from the Block 2B test plan and decided to account for only those test points needed for Block 2B fleet release, eliminating approximately 840 points. All of these points were planned to be accomplished as of the DOT&E report. This reduction amounts to approximately four months of testing.

- Further adjustments to the baseline number of test points needed for Block 2B fleet release were made in June 2014, resulting in additional reduction of points planned for the year. Although the program added points for new testing requirements (i.e., Manual Ground Collision Avoidance System), they also eliminated points that were assessed as no longer required. These adjustments resulted in the net reduction of 135 points.
- The program continued to experience an average test point growth rate throughout CY14 higher than planned (91 percent growth experienced through the end of November, 45 percent planned), but lower than experienced in CY13 (124 percent).
- The program realized a higher test point productivity rate per aircraft in CY14 than in CY13 (averaging 40 points per aircraft per month through the end of November, compared to 35).
- The program delayed plans to transition aircraft out of the Block 2B configuration to the Block 3i configuration, allowing more mission systems test aircraft to be available to contribute to Block 2B testing. At the time of this report, only AF-3 had been modified to the Block 3i configuration, among the six mission systems test aircraft assigned to the Edwards AFB test center, California, where the majority of the mission systems testing is accomplished. BF-5, a mission systems test aircraft assigned to the Patuxent River test center, Maryland, was modified into the Block 3i configuration in September and completed limited Block 3i testing prior to entering climatic testing later in the month.

- Based on test point accomplishment rates experienced since October 2013, the program will complete Block 2B development in February 2015.
  - This estimate assumes no further growth in Block 2B testing (this is possible only if the current version entering test is the final Block 2B version) and productivity at the current rate. It further assumes all current Block 2B mission systems aircraft staying in the Block 2B configuration through the end of January 2015 (the program's estimated completion date for Block 2B development), then one F-35B and one F-35C mission systems test aircraft converting to Block 3i while the other three stay in the Block 2B configuration until developmental testing is complete. Also, the operating restrictions stemming from the engine failure must be relieved for the test aircraft such that all blocked test points are made available.
  - Completion of Block 2B development by the end of January will, therefore, require a significant increase in test point productivity and/or elimination of additional test points.
- In April, the program accepted a DOT&E recommendation that the Block 2B Operational Utility Evaluation (OUE), which was being planned for CY15, should not be conducted and that instead, resources should be focused on conducting limited assessments of Block 2B capability and re-allocated to assist in the completion of development and testing of Block 3i and Block 3F capabilities.
  - This recommendation was based on DOT&E's review of Block 2B progress and assessment of the program's ability to start the Block 2B OUE as planned without creating a significant impact to Block 3F development.
  - The Program Office, JSF Operational Test Team, and Service representatives then began working to "re-scope" use of operational test aircraft and operational test activities in lieu of the OUE—detailed planning is still under development. The scope of the operational test activities will be limited until the flight restrictions induced by the engine failure are removed from the operational test aircraft. Availability of the operational test aircraft will continue to be affected in CY15 and CY16 by the depot time required for modifications.

F-35A Engine Failure

- As a result of the engine failure that occurred in an F-35A in late June, the program imposed aircraft operating limitations (AOL) on all variants of F-35 aircraft at the flight test centers and operational/training bases. These AOLs were:
  - Maximum speed of 1.6 Mach (0.9 Mach for production aircraft at operational/training bases),
  - Maximum g-load of 3.2 g for test aircraft and 3.0 for production aircraft,
  - Maneuvers limited to half-stick roll rate and 18 degrees angle of attack
  - No rudder input, unless required for safe flight (production aircraft restriction only)
  - Note: In some circumstances during flight test (but not in operational/training aircraft), exceedances were permitted and testing continued, controlled by the flight test team monitoring the aircraft, on an aircraft-by-aircraft basis (i.e., individual aircraft are cleared for specific test points).
- Due to the AOL, numerous test points needed for the Block 2B fleet release and Marine Corps IOC were blocked and cannot be attempted until the restrictions are lifted.
  - These test points include:
    - Loads and buffet, Short Take-off and Vertical Landing (STOVL) envelope expansion, and propulsion testing for F-35B flight sciences
    - Loads and buffet for F-35A flight sciences testing
    - Manual ground collision avoidance system testing (for both aircraft). The manual ground collision avoidance system is a warning system that alerts the pilot that the state of aircraft attitude and altitude may be entering an unsafe condition (Service IOC requirement).
  - There was also a requirement to inspect the engine with borescope equipment after no more than three flight hours; this creates additional down time and places stringent scheduling requirements, which negatively affects aircraft availability.
    - Restrictions for test aircraft were gradually reduced between June and November, allowing access to more test points. The program developed a procedure to

"rub-in" the seal in the stators of the engines in the test aircraft. Once this procedure was accomplished, restrictions were eased to allow greater g and angle of attack, but not to the full limits of the planned Block 2B envelope.
- ▪ The program began installing "pre-trenched" stators (where clearance between the stator and rotor has already been cut into the seal and no rub-in procedure is necessary) in the engines of the test aircraft in October, as they became available, to remove the restrictions associated with the engine failure. By the end of November, 6 of the 18 test aircraft had the pre-trenched stators installed. The program plans to have the engines in all developmental test aircraft modified by the end of February 2015. Also, the borescope inspection requirements were removed in November, with the latest revision of the list of restrictions. However, fielded production aircraft remained restricted at the time of this report.

Mission Data Load Development and Testing

- The F-35 relies on mission data loads – which are a compilation of the mission data files needed for operation of the sensors and other mission systems components – working in conjunction with the system software data load to drive sensor search parameters and to identify and correlate sensor detections of threat radar signals. The loads will be produced by a U.S. government lab, the U.S. Reprogramming Lab.
  - The first two mission data loads support the Marine Corps IOC, planned for July 2015. Because the lab received its equipment late from the major contractor who produces the equipment, and with limited capability, the first two mission data loads will not be available until November 2015.
  - Mission data loads undergo a three-phased lab development and test regimen, followed by flight test. The current plans are to certify the first two mission data loads in November 2015 after flight testing occurs between March and October 2015. Although this is later than desired by the program and the Marine Corps, truncating the mission data load development and conducting flight testing early on a limited open-air range for the purpose of releasing a mission data load in mid-2015 would create significant operational risk to fielded units, since the load will not have completed the planned lab test regimen and because the test infrastructure on the open-air range is capable of verifying only a small portion of the mission data.

Weapons Integration

- Progress in weapons integration, in particular the completion of planned Block 2B weapon delivery accuracy (WDA) events, has been less in 2014 compared to that planned by the program. The program planned to complete all 15 Block 2B WDA events by the end of October, but completed only 7. Through the end of November, the program completed 10 Block 2B WDA events and deferred 2 to Block 3F testing due to deficiencies and limitations in Block 2B capabilities. The remaining 3 Block 2B WDA events are scheduled to be completed by the end of January 2015.
  - Multiple deficiencies in mission systems, aircraft grounding, and subsequent flight restrictions caused by the June engine failure all contributed to the limited progress.
  - In addition, all WDA events were put on hold in August, when a deficiency in the aircraft's navigation solution was discovered. Corrections to the deficiency were tested and confirmed in October, permitting Block 2B WDA events to restart in November.

Suitability

- Overall suitability continues to be less than desired by the Services, and relies heavily on contractor support and unacceptable workarounds, but has shown some improvement in CY14.
  - Aircraft availability was flat over most of the past year, maintaining an average for the fleet of 37 percent for the 12-month rolling period ending in September – consistent with the availability reported in the FY13 DOT&E report of 37 percent for the 12-month period ending in October 2013. However, the program reported an improved availability in October 2014, reaching an average rate of 51 percent for the fleet of 90 aircraft and breaking 50 percent for the first time, but still short of the program objective of 60 percent set for the end of CY14. The bump in availability in October brought the fleet 12-month average to 39 percent.
  - Measures of reliability and maintainability that have Operational Requirements Document (ORD) requirements have improved since last year, but all nine reliability measures (three for each variant) are still below program target values for the current stage of development.
  - The reliability metric that has seen the most improvement since May 2013 is not an ORD requirement but a contract specification metric, mean flight hour between failures scored as "design controllable" (which are equipment failures due to design flaws). For this metric, the F-35B and F-35C are currently above (better than) program target values, and F-35A is slightly below (worse than) the target value but has been above the target value for several months over the last year.

Live Fire Test and Evaluation (LFT&E)

- The F-35 LFT&E program completed two major live fire test series using an F-35B variant full-scale structural test article. Preliminary evaluations are that the tests:
  - Demonstrated the capabilities of multiple structural wing load paths and aft boom structure to mitigate threat-induced large scale structural failure.
  - Confirmed the expected vulnerabilities of the fuel tank structure.

- Demonstrated the expected cascading damage vulnerability to fuel ingestion, fuel and hydraulic fire, and hydrodynamic ram events.

- Engine live fire tests in FY13 and prior live fire test data and analyses demonstrated vulnerability to engine fire, either caused by cascading effects or direct damage to engine fuel lines and fueldraulic components. Additional details and analyses of the uncontained F135 fan blade release and subsequent fuel fire in an F-35A at Eglin AFB in June are needed to support and update the existing engine vulnerability assessment.
- The program demonstrated performance improvements of the redesigned fuel tank ullage inerting system in the F-35B ground-based fuel system simulator. However, aircraft ground and flight tests, designed to validate the fuel system simulator tests and aircraft system integration, revealed redesign deficiencies that require further hardware and software modifications.
- Lockheed Martin provided test and analysis results to resolve the concern expressed in FY13 for the potential aircraft loss due to ballistically-induced shorting of the 270 Volt and 28 Volt flight control electrical systems. Protection on the 28 Volt electrical system (designed for lightning protection) provides tolerance to such a single ballistic shorting event and is unlikely to result in a loss of aircraft.
- The F-35 program continues to make progress in assessing the survivability of the F-35 to unconventional threats. Development of the chemical and biological agent protection and decontamination systems will be evaluated in the full-up system-level decontamination test planned for FY16. The Navy has been testing the vulnerability of the F-35B electrical and mission systems to electromagnetic pulse (EMP), and plans to complete this testing by 2QFY15.
- The program is making advances in assessing the lethality of the 25 mm x 137 mm PGU-48 Frangible Armor Piercing (FAP) round, a designated round for the F-35A variant, and the PGU-32/U Semi-Armor Piercing High Explosive Incendiary-Tracer (SAPHEI-T) ammunition currently designated for the F-35B and F-35C variants.

Actual versus Planned Test Metrics through November 2014

TEST FLIGHTS					
	All Testing	Flight Sciences			Mission Systems
	All Variants	F-35B Only	F-35A Only	F-35C Only	
2014 Actual	1,268	313	197	286	472
2014 Planned	1,209	296	262	261	390
Difference from Planned	4.9%	5.7%	-24.8%	9.6%	21.0%
Cumulative Actual	5,046	1,648	1,194	944	1,260
Cumulative Planned	4,674	1,471	1,205	894	1,104
Difference from Planned	8.0%	12.0%	-0.9%	5.6%	14.1%

TEST POINTS											
	All Testing	Flight Sciences[1]						Mission Systems			
	All Variants	F-35B Only		F-35A Only		F-35C Only		Block 2B[2]	Block 3i	Block 3F	Other
		2B	3F	2B	3F	2B	3F				
2014 Baseline Accomplished	7,055	1,070	846	546	708	768	1,453	1,126	177	0	361
2014 Baseline Planned	7,471	1,127	619	583	1,356	922	648	1,490	276	74	376
Difference from Planned	-5.6%	-5.1%	36.7%	-6.3%	-47.8%	-16.7%	124.2%	-24.4%	-35.9%	-100.0%	-4.0%
Added Points	1,756	119		236		329		1,021	51	0	0
Test Point Growth Rate	24.9%	6.2%		18.8%		14.8%		90.7%	28.8%	0%	0%
Total Points Accomplished in 2014[3]	8,811	2,035		1,490		2,550		2,147	228	0	361
Cumulative SDD Actual[4]	34,888	11,689		9,269		8,322		3,872	177	0	1,559
Cumulative SDD Planned	35,683	11,252		10,056		7,399		4,359	276	74	2,267
Difference from Planned	-2.2%	3.9%		-7.8%		12.5%		-11.2%	-35.9%	N/A	-31.2%
Estimated Test Points Remaining	22,956	77	7,013	54	4,049	150	4,880	529	523	3,811	1,870

1. Flight Sciences Test Points are shown separately for Block 2B and Block 3F. Flight envelopes differ in airspeed, maximum allowable g, and weapons carriage, depending on variant.
2. Includes Block 0.5, Block 1, and Block 2A quantities for Cumulative Actual and Cumulative Planned
3. Total Points Accomplished = 2014 Baseline Accomplished + Added Points
4. SDD – System Design and Development

System

- The F-35 Joint Strike Fighter (JSF) program is a tri-Service, 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/Vertical-Landing (STOVL)
  - F-35C Aircraft Carrier Variant (CV)
- It is designed to survive in an advanced threat (year 2015 and beyond) environment using numerous advanced capabilities. It is also designed to have improved lethality in this environment 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 (JDAM) and Joint Standoff Weapon, AIM-120C radar-guided Advanced Medium-Range Air-to-Air Missile, and AIM-9 infrared-guided short-range air-to-air missile.
- The program provides mission capability in three increments:
  - Block 1 (initial training, two increments were fielded: Blocks 1A and 1B)
  - Block 2 (advanced training in Block 2A and limited combat in Block 2B)
  - Block 3 (limited combat in Block 3i and full combat in Block 3F)
- 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, and in highly-defended areas of joint operations.
- F-35 will be used to attack fixed and mobile land targets, enemy surface units at-sea, and air threats, including advanced cruise missiles.

Major Contractor

Lockheed Martin, Aeronautics Division – Fort Worth, Texas

Test Strategy, Planning, and Resourcing

- In March, DOT&E recommended to the USD(AT&L) that the Block 2B Operational Utility Evaluation (OUE), which was being planned to occur in mid-2015 in accordance with the approved Test and Evaluation Master Plan (TEMP), should not be conducted. Instead, resources should be focused on conducting limited assessments of Block 2B capability and re-allocated to assure the completion of development and testing of Block 3i and Block 3F capabilities. This recommendation was based on DOT&E's review of Block 2B progress and assessment of the program's ability to start the Block 2B OUE as planned without creating a significant impact to Block 3F development.
  - The factors that led to the DOT&E recommendation include: poor operational suitability, an inability to prepare pilots with adequate training and approved tactics on the planned schedule, and the deferral to Block 3 of operationally-relevant deficiencies that would affect performance. It was clear in March that aircraft availability for operational testing would be driven by the long timelines required to modify and retrofit the early production operational test aircraft to the Block 2B configuration, which would not be complete until mid-2016. DOT&E assessed that delaying the Block 2B OUE until late 2016, as opposed to cancelling it, would have a negative impact on the program's ability to complete development of the full Block 3F combat capability in a timely manner.
  - In April, in coordination with the Service Acquisition Executives and the JSF Program Executive Officer, the USD(AT&L) agreed with the DOT&E recommendation and approved revising the operational test period that was allocated for the Block 2B OUE in the TEMP into a re-scoped effort of assessing the limited Block 2B set of capabilities. The JSF Operational Test Team, JSF Program Office, and the Services' operational test agencies began re-planning the Block 2B operational test period and activities.
  - By the middle of October, five of the six F-35A operational test aircraft assigned to the Edwards AFB, California, operational test squadron had been converted to the Block 2B configuration and loaded with a version of Block 2B software equivalent to the one being flown on the developmental test aircraft. The sixth F-35A operational test aircraft began an extended modification period at the depot in September and is scheduled to be returned to Edwards AFB in February 2015 in the Block 2B configuration. These operational test aircraft, although not in a full Block 2B operationally-representative configuration as would have been necessary to start the OUE, will be used to accomplish both developmental and operational testing events. They will be loaded with the latest version of Block 2B software as it becomes available and is determined airworthy for operational test purposes.
  - Program schedule pressures that caused DOT&E to recommend not completing the Block 2B OUE as planned increased throughout CY14. For example, Block 2B flight testing, which was scheduled to be complete in October 2014, is now projected by the Program Office to complete in January 2015. Aircraft depot modification plans are another example. The program developed plans to upgrade fielded production aircraft from Lots 3 through 5, which includes operational test aircraft planned

for use in the OUE, to the full Block 2B configuration. These plans show that all of the operational test aircraft which were planned for the Block 2B OUE will not be in the full Block 2B configuration until September 2016, 21 months later than would have been needed to conduct the OUE.

- DOT&E conditionally approved Revision 4 of the TEMP in March 2013, under the provision that the program revise the master schedule so that there was no overlap of spin-up training for IOT&E and the certification period needed for the Services' airworthiness authorities to approve a flight clearance with the software to be used for IOT&E. Specifically, this would require the program to adjust the start of the spin-up training from February to July 2017, coinciding with an Operational Test Readiness Review. This adjustment also moved the start of IOT&E to January 2018, vice August 2017, and hence pushed the completion of IOT&E into FY19. In spite of the conditional approval, the program continues to show schedules that plan for the start of spin-up training in February 2017 and the start of IOT&E in August 2017. In addition to the justifications for adjusting the schedule that DOT&E outlined in the March 2013 TEMP conditional approval memo, the program has encountered more challenges to meeting the planned schedule to start IOT&E in August 2017 and completing System Design and Development (SDD) in 2018. These challenges include:
  - Block 3i flight testing began in late May 2014, five months later than the program's baseline plan.
  - Block 3F flight testing was scheduled to start in November 2014 according to the program's baseline plan; current program estimates show the testing starting no earlier than late February 2015, three months late.
  - Modification plans for the IOT&E aircraft will likely not have aircraft ready to begin the start of spin-up training in February 2017 as planned by the errant schedule submitted in the TEMP. To become Block 3F capable, the operational test aircraft require extensive modifications, including new processors, in addition to those needed for Block 2B capability. Block 3F modification plans are taking into consideration some modifications that already have engineering solutions and approved designs. Other modifications – although known to be required – are still in the formal change approval process leading to parts and modification kits being developed and procured from suppliers. Some of these latter modifications are currently not scheduled to be available until May 2017 for the F-35A and February 2018 for the F-35C, which is later than needed to support spin-up training for IOT&E.
  - There is carryover of incomplete work from Block 2B development into Block 3. In coordination with the Services, the program completed a review in June of 1,151 open deficiency reports identified during Block 2B development and earlier. Of these, 572 were rated as relevant to and affecting Block 2B capability; 579 were carried over for consideration for corrections in Block 3.
  - The program removed test points that were originally planned to be flown to support Block 2B fleet release (approximately 1,000 mission systems test points); some of these points may carry over and need to be flown during Block 3F development.
  - In order to account for these realities and reduce the overlap of spin-up training for IOT&E with final development activities (such as the activities that provide the certifications for use of the final configuration), the program master schedule should be adjusted to reflect these realities and depict the start of spin-up training for IOT&E no earlier than the Operational Test Readiness Review in November 2017, and the start of IOT&E for Block 3F to occur six months later, in May 2018 and completing in May 2019. If it becomes apparent that spin-up training entry criteria (e.g., providing properly configured production-representative aircraft in sufficient numbers) cannot be met on this timeline, then the schedule will have to be adjusted again.
- This report reviews the program by analyzing the progress of testing and the capability delivered as a function of test results. The program plans a specific set of test points (discrete measurements of performance under specific test conditions) for accomplishment in a given calendar year. In this report, test points planned for a given calendar year are referred to as baseline test points. In addition to baseline test points, the program accomplishes test points added for discovery, regression of new software, and verification of fixes to deficiencies identified in flight test; these additional points are referred to as "growth" points in this report. Cumulative SDD test point data refer to the total progress towards completing development at the end of SDD.

F-35A Engine Failure

- An F-35A aircraft assigned to the training center at Eglin AFB, Florida experienced an engine failure on take-off on June 23, 2014. The aircraft was a Lot 4 production aircraft, delivered to Eglin AFB in June 2013, and had flown approximately 160 hours prior to the incident.
- As a result of the engine failure, the Program Office and the Services initiated a series of actions that affected flight operations for both the fielded production aircraft and the test aircraft.
  - The Program Office instituted an operational pause to flight testing at the test centers on June 25, and the contractor suspended acceptance flight operations at the production plant.
  - A fleet-wide stop order was issued by the Program Office on July 4, which officially suspended flight operations and ground engine runs. This order also initiated requirements to visually inspect the affected engine components using special equipment called a borescope.
  - On July 8, the program began lifting restrictions by permitting engine runs up to 30 percent power for engines that had completed the borescope inspections.

- On July 16, the program began permitting limited flight operations for F-35B and F-35C aircraft with stringent flight limitations and continued inspection requirements.
- Aircraft operating limitations have been incrementally revised to permit flight testing to continue. By mid-September, the flight sciences aircraft of each variant had been cleared to continue testing without engine-imposed envelope restrictions. The rest of the test fleet continues to conduct flight testing, but under a restricted flight envelope. The program plans to have all engine-imposed restrictions removed from the developmental test fleet by the end of February 2015, after modifications to the engines of each aircraft are complete.
- On October 10, the program confirmed that excessive rubbing between the hard polyamide seal of the second stage stator and the titanium interface of the integrated blade third stage rotor led to the engine failure. This excessive rubbing occurred on a previous flight while maneuvering within the limited, cleared training envelope. Friction from the rubbing created excessively high temperatures within the titanium rotor, creating small cracks that eventually led to catastrophic failure of the rotor during the take-off on June 23. It is not clear what occurred differently than expected in the air vehicle and/or engine that caused the excessive rubbing.

• Inspections of the engines on all variants led to discoveries on nine production and test aircraft requiring engine replacement.
• As of July 23, restrictions on the flight test aircraft blocked 53 percent (1,357 of 2,575) of the remaining Block 2B test points; however, test points have incrementally become available as the flight restrictions were relaxed on some of the test aircraft beginning in September after the test centers complied with actions found necessary by the root cause analysis.
• Resolution of the way forward with the engines in test and production aircraft was ongoing at the time of this report.
  - The program developed and tested an engine “rub-in” procedure. This procedure is designed to ensure the engines have sufficient clearance between the rotors and seals to prevent excessive rubbing during maneuvering. The rub-in process is accomplished through two flights during which a specific profile is flown to accomplish the procedure, followed by inspections. As flight test jets completed the rub-in procedure, they were cleared to accomplish some of the blocked test points and fly within an expanded, although still limited, flight envelope.
  - The program is developing an interim redesign of the seal, which will have grooves pre-cut in the polyamide material to provide clearance between the seal and the rotor and will prevent excessive rubbing during maneuvering. A prototype of this “pre-trenched” seal was flight tested in October and is being installed in the engines of each developmental test aircraft.
  - The program is working with the engine contractor to develop a new redesigned seal for production engines. Plans on a final design were not complete at the time of this report.

F-35A Flight Sciences

Flight Test Activity with AF-1, AF-2, and AF-4 Test Aircraft

• F-35A flight sciences testing focused on:
  - Completing the full Block 2B flight envelope
  - High angle of attack testing (clean wing for Block 2B and with external stores for Block 3)
  - Ground and flight testing of the redesigned fuel tank ullage inerting system (i.e., inerting of the space not occupied by fuel in a fuel tank), consisting of the On-Board Inert Gas Generation System (OBIGGS) and associated fuel pressurization and ventilation system
  - Start of Block 3F loads and flying qualities testing, predominantly flying with externally-loaded air-to-ground and air-to-air weapons
  - Regression testing of updated versions of vehicle systems software
  - Testing of the aerodynamic loads in the gun bay. (Note: Block 3F F-35A aircraft will have an internal gun; F-35B and F-35C aircraft will use a podded gun mounted on the center fuselage station.)
• Restrictions imposed on the fleet from the June engine failure coupled with the focus on Block 2B mission systems testing hampered progress in F-35A flight sciences testing.
• Excessive free-play in the rudder hinges on AF-2 required extended downtime for repair. These repairs occurred in July during the period of restrictions from the engine fire.

F-35A Flight Sciences Assessment

• Through the end of November, test point accomplishment in CY14 was 6 percent behind the plan for accomplishing Block 2B points and 48 percent behind for Block 3F. The test team flew 25 percent fewer test flights than planned for the year (197 flown; 262 planned). Prioritization of flight test resources to focus on mission systems flight testing for Block 2B at the Edwards AFB test center (where mission systems and F-35A flight sciences testing are conducted) reduced the opportunity for flight science testing to achieve planned progress in Block 3F testing.
• The plan for Block 2B test points was adjusted in CY14, resulting in the net reduction of 343 of 926 (37 percent) of the original points planned for the year. The program designated these points as no longer required for Block 2B fleet release.
• Restrictions imposed from the June engine failure initially blocked access to almost all (254 of 261) remaining Block 2B flight sciences test points. The program was able to relax the restrictions on an aircraft-by-aircraft basis beginning in September, providing access to some of the blocked test points; all points were available as of the end of October. The prioritization of mission systems testing coupled with the restrictions from the engine failure created a debt of flight sciences testing on the F-35A that will need to be overcome in CY15 and early CY16 for the program to maintain Block 3F flight envelope release schedule.

- The program added 236 flight sciences test points through the end of November, equating to a growth rate of 19 percent, which is near the planned growth rate of 17 percent.
- AF-4 underwent a modification from March through May, during which the redesigned fuel tank ullage inerting system was installed. This modification and testing is part of the effort to address deficiencies in lightning protection and vulnerability reduction to ballistic threats. Testing to assess on-the-ground inerting performance of the redesign and to validate modeling results was completed in May. Flight testing to assess the fuel system pressurization and ventilation capability of the redesign was mostly completed in June; dive test points were blocked by restrictions imposed by the engine failure. Further testing to assess corrections to the redesign is scheduled to occur in December 2014.
- Discoveries in F-35A flight sciences testing:
  - Higher than expected wear in the rudder hinges of AF-2 was discovered during routine inspections, following flight testing in regions of the envelope where higher dynamic loads are exerted on the rudder surfaces. Replacement of the clevis of the middle rudder hinges was necessary, and additional inspections to check rudder free play are required.
  - AF-4 encountered a blown tire and damage to the main landing gear while conducting crosswind landing testing in February, requiring a two-week down period for repairs.
  - Ground testing on aircraft AF-4 revealed that pressure from the OBIGGS inadvertently pushes fuel between tanks. Per engineering directive, the test team removed and capped the inert air distribution lines that were causing the fuel transfer as a temporary measure to permit AF-4 to continue developmental testing of other (non-OBIGGS) test requirements. Further modifications to software and the addition of a control valve were made to AF-4 in November for testing planned for December 2014.
  - Inerting the aircraft on the ground with external nitrogen forces fuel to vent from the fuel tanks under certain fuel states. The procedure to purge the fuel system with external nitrogen was introduced with the redesigned ullage inerting system to provide lightning protection on the ground. The program plans to address this fuel venting by testing two additional check valves on AF-4 for incorporation into the final design.
- Weight management of the F-35A is important for meeting air vehicle performance requirements and structural life expectations. These estimates are based on measured weights of components and subassemblies, calculated weights from approved design drawings released for build, and estimated weights of remaining components. These estimates are used to predict the weight of the first Lot 7 F-35A aircraft (AF-72), planned for delivery in August 2015, which will be the basis for evaluating contract specification compliance for aircraft weight.
  - According to these reports, the program has reduced weight by 16 pounds in CY14 (from January to October estimate). The current estimate of 29,016 pounds is 355 pounds (1.2 percent) below the planned not-to-exceed weight of 29,371 pounds.
  - The program has demonstrated positive weight management of the F-35A over the past 38 months, showing a net loss of 123 pounds in the estimates from August 2011 to October 2014. The program will need to ensure the actual aircraft weight meets predictions, as well as continue rigorous management of the actual aircraft weight beyond the technical performance measurements of contract specification in CY15 through the balance of SDD to avoid performance degradation that would affect operational capability.

F-35B Flight Sciences

Flight Test Activity with BF-1, BF-2, BF-3, BF-4, and BF-5 Test Aircraft

- F-35B flight sciences focused on:
  - Continued expansion of the Block 2B flight envelope, including weapons separation testing
  - High angle of attack testing
  - Wet runway testing (completed with BF-4 in May at Edwards AFB)
  - Testing of landing control authority in crosswind conditions
  - Testing with external air-to-air and air-to-ground weapons (Block 3F capability)
  - STOVL mode flight operations
  - Testing of fuel dump capability with a new valve and seals
  - Ground and flight testing of the redesigned ullage inerting system
  - Flight testing in support of expeditionary operations (i.e., landing on matted runways, AM-2 padding)
  - Preparations for and conducting climatic testing on BF-5 in the climatic chamber

F-35B Flight Sciences Assessment

- Through the end of November, test point accomplishment for CY14 was 5 percent behind the plan for accomplishing Block 2B points and 37 percent ahead of the plan for Block 3F points. Test flights were slightly ahead of plan (313 flown; 296 planned). The test force maintained test point productivity by accomplishing test points from the Block 3F test plan for flying qualities, air data, propulsion, and loads in the STOVL mode and with external stores. The program projects the completion of Block 2B flight sciences testing to occur by the end of December 2014, two months later than planned.
- This projection follows adjustments made by the Program Office to the plan for Block 2B test points in CY14, which resulted in the net reduction of 394 out of 1,545 (26 percent)

of the points planned for the year. These points were reviewed by the contractor and the Program Office, and designated as no longer required for Block 2B fleet release and Marine Corps IOC. This reduction brought the total 2014 plan to 1,151 points, 1,127 of which were planned to be completed by the end of November.

- Crosswind landing testing in the conventional landing mode (not vertical landing) was not completed; but sufficient testing was accomplished to clear landings up to 20 knots of crosswind, short of the ORD requirement of 25 knots of crosswind.
- BF-4 was modified with the redesigned fuel tank inerting system late in CY13. Testing to assess ground inerting performance and validate results from the fuel system simulator – a full mock-up surrogate of the F-35B fuel system – was completed in December 2013. Further testing of the tank inerting system did not occur until September 2014, as other test requirements (i.e., wet runway testing) needed to be conducted with BF-4, and known deficiencies needed to be addressed with corrections to software. Flight testing of the tank inerting system is ongoing. Regression testing to verify correction of deficiencies in the redesign discovered from ground testing (on the aircraft and in the simulator) was conducted in early October and will continue in December after updated software is released to the test aircraft for flight testing.
- Discoveries in F-35B flight sciences testing included:
  - Early fuel dump testing in 2011 discovered that fuel does not completely eject overboard, but collects in the area between the flaperons and the aircraft structure and runs inboard toward the Integrated Power Package exhaust outlet, creating a potential fire hazard. Testing of a redesigned dump nozzle, improved seals for the flaperons, and heat-shrinkable tubing added to wiring harnesses for protection in the event of fuel wetting have all contributed to a new fuel dumping procedure.
  - Inerting performance in certain fuel tanks during ground testing of the redesigned ullage inerting system did not meet the performance demonstrated during fuel system simulator testing. To address this discrepancy, an additional OBIGGS distribution line was installed on aircraft BF-4. The discovery affects all variants; retrofit kits have been developed for the F-35A and F-35C variants.
  - The redesigned ullage inerting system has the potential to generate pressure spikes when pressure in the aerial refueling manifold is released into the fuel tanks. A blanking plate was installed on BF-4 to isolate the aerial refueling manifold from the OBIGGS as a temporary measure to allow it to ferry to Edwards AFB to conduct testing on wet runways. A software modification of the valve control logic was tested in late September, allowing removal of the blanking plate.
  - The aircraft does not maintain residual inerting after flight for the required interval of 12 hours, which is a lightning protection requirement. Residual inerting is a result of the inert air produced by the OBIGGS remaining in the ullage area of the fuel tanks after a flight. The program is investigating a correction to this problem. If the residual inerting cannot be improved, aircraft maintainers will be required to purge fuel tanks with external nitrogen more frequently or alternative lightning protection strategies (e.g., lightning-protected shelters, will have to be adopted.
  - In heavy buffet conditions, which occur between 20 and 26 degrees angle of attack, faults occurred in the inertial measurement units (IMUs) in the aircraft that degraded the flight control system (two of three flight control channels become disabled), requiring a flight abort. This condition blocked 28 test points needed for the Block 2B fleet release. The program made adjustments to the flight control software, which were tested in late October and the test points were unblocked, enabling some testing in the heavy buffet conditions to continue. However, nine additional test points needed for the Block 2B fleet release remained blocked at the end of November because of high dynamic loads on the rudder at lower altitudes, in the same angle of attack range, and require additional analyses and mitigation to complete.
- Weight management of the F-35B aircraft is critical to meeting the Key Performance Parameters (KPPs) in the ORD, including the vertical lift bring-back requirement. This KPP requires the F-35B to be able to fly an operationally representative profile and recover to the ship with the necessary fuel and balance of unexpended weapons (two 1,000-pound bombs and two AIM-120 missiles) to safely conduct a vertical landing. These estimates are based on measured weights of components and subassemblies, calculated weights from approved design drawings released for build, and estimated weights of remaining components. These estimates are used to predict the weight of the first Lot 7 F-35B aircraft (BF-44), planned for delivery in August 2015, which will be the basis for evaluating contract specification compliance for aircraft weight.
  - Weight reports for the F-35B as of October show that the program added 18 pounds to the estimated weight in CY14 and a net addition of 82 pounds over the last 38 months (August 2011 to October 2014). The current estimate of 32,412 pounds is 337 pounds (1 percent) below the objective vertical lift bring-back not-to-exceed weight of 32,749 pounds.
  - Managing weight growth for the F-35B will continue to be a challenge in light of the small weight margin available and the possibility for continued discovery through the remaining SDD phase, which extends two years past the delivery of the first Lot 7 aircraft, planned for August 2015. The program will need to ensure actual weights meet predictions. Known modifications and retrofits for production aircraft in Lots 2 through 6 will add weight to those aircraft, varying from 210 pounds for the Lot 3 aircraft to 17 pounds for the Lot 6 aircraft. In

addition, the program is currently redesigning the FS496 bulkhead for Lot 9 production aircraft and later as a result of the failure of that bulkhead in the ground test article during durability testing. The effect of the redesigned bulkhead on the weight of the aircraft is not yet known.

- The following table, first displayed in the FY11 Annual Report and updated each year, describes observed door and propulsion problems by component and identifies the production cut-in of the correction or update, if known.

F-35B DOOR AND PROPULSION PROBLEMS				
Category	Component	Problem	Design Fix and Test Status	Production Cut-In
Structure	Auxiliary Air Inlet Door (AAID)	Inadequate life on door locks, excessive wear and fatigue due to the buffet environment, inadequate seal design.	New designed doors are being installed on Low-Rate Initial Production (LRIP) aircraft as part of the on-going modification plan; 14 completed through the end of September. Fatigue testing of the doors started in November 2012 and completed the planned 2 lifetimes of testing at the end of September 2014. Inspections were ongoing as of the end of November, with no discoveries. Fix appears to resolve problem.	BF-38 LRIP Lot 6 2014
Propulsion	Drive Shaft	Lift fan drive shaft is undergoing a second redesign. Original design was inadequate due to shaft stretch requirements to accommodate thermal growth, tolerances, and maneuver deflections. First redesign failed qualification testing.	New design completed qualification testing and appears to reduce the problem. Full envelope requirements are currently being met on production aircraft with an interim design solution using spacers to lengthen the early production drive shaft. New design is dependent on updated propulsion software load planned to be available by Lot 9.	BF-56 LRIP Lot 9 2016
Propulsion	Clutch	Lift fan clutch has experienced higher than expected drag heating during conventional (up and away) flight during early testing.	New clutch plate design, with more heat-tolerant material, is complete. Clutch plates are being thinned on Lot 5 and 6 aircraft, at the expense of reduced life (engagements) to the clutch, to prevent drag heating. Solutions appear to be effective; very few hot clutches are experienced in fleet wide operations now.	Tail TBD Mid-LRIP Lot 8 2015
Propulsion	Roll Post Nozzle Actuator	Roll post nozzle bay temperatures exceed current actuator capability; insulation is needed to prevent possible actuator failure during vertical lift operations.	Insulation between the roll post nozzle bay and the actuators is being installed in pre-Lot 6 aircraft to allow unrestricted operations, however the actuators must be replaced at 1,000 hour intervals. New actuators will be installed in Lot 6 aircraft and beyond, removing the requirements for the insulation and extending the service life to 4,000 hours.	BF-38 LRIP Lot 6 2015
Propulsion	Lift Fan Inter Stage Vanes (ISV)	Vanes between stages of the lift fan experience excessive vibration/flutter during mode 4 flight when temperature is below 5°F or above 107°F degrees and speed is greater than 130 knots calibrated airspeed.	Aircraft are restricted from mode 4 flight outside the temperature and speed restrictions noted. A unit level Time Compliant Technical Directive is being accomplished for 48 fielded lift fans to replace the ISVs with a new ISV made of more durable material tolerant over a greater temperature range, with production cut in on new Lift Fans.	New vanes retrograded in fielded aircraft, incorporated in new production lift fans

F-35C Flight Sciences

Flight Test Activity with CF-1, CF-2, CF-3, and CF-5 Test Aircraft

- F-35C flight sciences focused on:
  - Structural survey testing of the newly designed arresting hook system (This testing was a pre-requisite for the first developmental testing period aboard an aircraft carrier, referred to as DT-1, which was conducted in November 2014.)
  - Block 2B weapons envelope and loads testing
  - Block 2B high angle of attack testing
  - Testing with external air-to-air and air-to-ground weapons (Block 3F capability)
  - Fuel dump testing
- The program modified CF-3 and CF-5 with the new arresting hook system and modified nose landing gear, which was necessary to prepare for and accomplish the first set of ship trials, completed in November.

F-35C Flight Sciences Assessment

- Through the end of November, test point accomplishment for CY14 was 17 percent behind the plan for Block 2B points and 124 percent ahead for Block 3F points. Test flights were 10 percent ahead of the plan (286 flown; 261 planned). Similar to the F-35B, the test force has been able to maintain test point productivity by completing points from the Block 3F test plan, such as performance assessments with external weapons, which were completed earlier than planned.
- Similar to the other variants, the program adjusted the plan for Block 2B test points, resulting in a net reduction of 81 of 1,003 test points (8 percent) planned for the year. These points were designated as no longer required for Block 2B fleet release.
- Transonic Roll-Off (TRO) and airframe buffet continue to be a program concern. All three variants required

modifications of the control laws to control the effects of transonic flight and buffet producing maneuvering. In anticipation of difficulty in these flight regimes, the ability to incorporate spoilers in F-35C aircraft was provided early in the program. F-35C handling characteristics in transonic and buffet-producing regimes were in need of correction and worse than in other variants. Flight testing with the addition of spoilers is planned, but not yet started.

- CF-8 (a mission systems test aircraft assigned to the Edwards AFB test force) was scheduled to undergo modifications to include the redesigned fuel tank inerting system in June 2014; however, the modification was delayed pending conversion of CF-8 to the Block 3i configuration. The program has scheduled the modifications for February 2015, with ground and flight testing to follow soon after.
- Discoveries included:
  - The test force flew test missions with CF-2 in December 2013 and January 2014 to assess and characterize the effects of buffet and TRO on the helmet-mounted displays and handling qualities while conducting tasks associated with operational maneuvering (basic offensive and defensive fighter maneuvers). Buffet affected display symbology, and would have the greatest impact in scenarios where a pilot was maneuvering to defeat a missile shot.
  - Deficiencies in the nosewheel steering motor and the pitch pivot pin of the arresting hook system slowed testing (see ship integration section for details of the arresting hook system testing).
- Weight management is important for meeting air vehicle performance requirements, including the KPP for recovery approach speed to the aircraft carrier, and structural life expectations. These estimates are based on measured weights of components and subassemblies, calculated weights from approved design drawings released for build, and estimated weights of remaining components. These estimates are used to project the weight of the first Lot 8 F-35C aircraft (CF-28), planned for delivery in April 2016, which will be the basis for evaluating contract specification compliance for aircraft weight.
  - The weight reports show that the program has reduced weight by 62 pounds in CY14 (from January to October estimate). The current estimate of 34,519 pounds is 349 pounds (1 percent) below the planned not-to-exceed weight.
  - The program has demonstrated positive weight management of the F-35C over the past 38 months, showing a net loss of 103 pounds in the estimates from August 2011 to October 2014. The program will need to ensure the actual aircraft weight meets predictions and continue rigorous management of the actual aircraft weight beyond the technical performance measurements of contract specification in CY16 through the balance of SDD to avoid performance degradation that would affect operational capability.

Mission Systems

Flight Test Activity with AF-3, AF-6, AF-7, BF-4, BF-5, BF-17, BF-18, CF-3, and CF-8 Flight Test Aircraft and Software Development Progress

- Mission systems are developed, tested, and fielded in incremental blocks of capability.
  - Block 1. The program designated Block 1 for initial training capability and allocated two increments: Block 1A for Lot 2 (12 aircraft) and Block 1B for Lot 3 aircraft (17 aircraft). No combat capability is available in either Block 1 increment. All Lot 2 aircraft have been converted to Block 1B; the U.S. Services currently have 26 Block 1B aircraft (13 F-35A in the Air Force and 13 F-35B in the Marine Corps). Additionally, two F-35B Block 1B aircraft have been accepted by the United Kingdom and one F-35A Block 1B aircraft by the Netherlands; these aircraft are currently assigned to the training center at Eglin AFB.
  - Block 2A. The program designated Block 2A for advanced training capability and delivered aircraft in production Lots 4 and 5 in this configuration. No combat capability is available in Block 2A. The U.S. Services have 62 aircraft in the Block 2A configuration (32 F-35A in the Air Force, 19 F-35B in the Marine Corps, and 11 F-35C in the Navy). Additionally, one F-35B and one F-35A have been accepted by the United Kingdom and the Netherlands, respectively; both aircraft are assigned to the training center.
  - Block 2B. The program designated Block 2B for initial, limited combat capability for selected internal weapons (AIM-120C, GBU-32/31, and GBU-12). This block is not associated with the delivery of any production aircraft. Block 2B software has been in flight test since February 2013. Once complete with flight test and certification, Block 2B software may be retrofitted onto aircraft from production Lots 2 through 5, provided the necessary hardware modifications have been completed as well. Block 2B is planned to be the Marine Corps IOC configuration.
  - Block 3i. The program designated Block 3i for delivery of aircraft in production Lots 6 through 8, as these aircraft will be built with a set of upgraded integrated core processors (referred to as Technical Refresh 2, or TR2). The capabilities associated with Block 3i software will vary based on the production lot. Lot 6 aircraft are expected to be delivered with capabilities equivalent to Block 2A in Lot 5, aircraft in Lots 7 and 8 are planned to be delivered with capabilities equivalent to Block 2B. Block 3i software began flight testing in May 2014. The program delivered the first Block 3i aircraft, an F-35A, to Luke AFB, Arizona, in late October. Four more F-35A aircraft were delivered to Luke AFB and one F-35B to Marine Corps Air Station (MCAS) Beaufort, South Carolina, by the end of November.
  - Block 3F. The program designated Block 3F as the full SDD capability for production Lot 9 and later. Although under development, flight testing with Block 3F software on the F-35 test aircraft has not started. The program

plans to begin flight testing in early CY15. Aircraft from production Lots 2 through 5 will need to be modified, including the installation of TR2 processors, to have Block 3F capabilities.
- Mission systems testing focused on:
  - Completing flight testing of Block 2B capabilities
  - Start of flight testing of Block 3i software, which began in May
  - Start of Generation III helmet-mounted display system (HMDS) testing
  - Multi-ship data link performance (via the multi-platform advanced data link (MADL) system and Link 16)
  - Radar performance
  - Troubleshooting navigation solution problems, which caused a pause in weapon testing in August
  - Manual Ground Collision Avoidance System testing, which was added by the program in CY14 as a Block 2B capability to be delivered with fleet release
  - Flight testing six increments of Block 2B software and two increments of Block 3i software (note: the program plans to release another version of 3i software to flight test prior to the end of CY14)
  - Block 3F software – first version began testing on the Cooperative Avionics Test Bed (first flight was on July 31)
- The six mission systems flight test aircraft assigned to the Edwards AFB test center flew an average rate of 7.0 flights per aircraft per month in CY14 through November, exceeding the planned rate of 5.4 by 30 percent, and flew 121 percent of the planned flights (472 sorties accomplished compared to 390 planned).
- The program prioritized flight test activity to attempt to complete Block 2B flight testing by the end of October 2014, per the approved baseline schedule. However, as of the end of November, 87 percent of the total Block 2B mission systems baseline test points were accomplished (3,654 of 4,183 total points accomplished, 529 points remaining).
- The test team accomplished 74 percent of the planned 2014 baseline mission systems test points from test plans for Blocks 2B and 3i by the end of November (1,303 baseline test points accomplished, 1,766 planned). The team also accomplished an additional 1,072 growth test points. These points were needed for regression testing of new revisions of Block 2B software, identifying and characterizing deficiencies in mission systems performance, verification of corrections of deficiencies, and other testing the program found necessary to add to the baseline test plans. Although the program plans for some growth points during development, the rate of growth experienced for CY14 through the end of November for Block 2B testing (91 percent) was higher than the planned rate of 45 percent used by the program for CY14. The growth rate for the limited amount of Block 3i testing was 29 percent.
- Five F-35A operational test aircraft (all of which include flight test instrumentation and recording equipment identical to SDD mission systems test aircraft) were modified and loaded with a developmental test version of Block 2B software – one aircraft in July, two in August, one in September, and one in October. As a result of the decision to not conduct the Block 2B OUE, the program is able to use these aircraft to support the effort to complete Block 2B developmental testing. Depending on the availability of these aircraft after the Block 3F modifications plan is finalized, they will be available to support re-scoped Block 2B operational test activity.

Mission Systems Assessment
- Block 2B
  - Although test flight sortie goals were exceeded, and over 75 percent of planned baseline test points were accomplished as of the end of November, delivery of Block 2B capability, and thus the ability to complete development by October, was hampered by several factors:
    - The need to develop, release, and test unplanned versions of Block 2B software to improve stability and fix deficiencies.
    - Discoveries continued to occur in later versions of software.
    - Restrictions to flight test aircraft apart from those imposed due to the June engine failure reduced the accessible test points.
      - For example, flight operations with AF-6 and AF-7 mission systems test aircraft were suspended temporarily on June 20 when the program issued a stop order on F-35A production aircraft until inspections were completed on the nacelle vent inlet tube. A crack in the tube was discovered on a production F-35A aircraft at Eglin AFB following an incident where ground crews observed fuel leaking from the tube during hot pit ground refueling operations on June 11 (AF-6 and AF-7 are Lot 1 production aircraft assigned to the Edwards AFB test center).
      - Following the inspections, the program released an interim aircraft operating limitation restricting F-35A production aircraft to 3 g's and no air refueling. This affects all fielded production aircraft as well, which carry these restrictions concurrent with the restrictions related to engine failure, until they are modified. These restrictions remained in place on AF-6 and AF-7 until the test center replaced the tubes.
  - To date, performance of 2BS5 software, which began flight testing in June, has shown improvement in startup and inflight stability compared to earlier versions. However, fusion of information from own-ship sensors, as well as fusion of information from off-board sensors is still deficient. The Distributed Aperture System continues to exhibit high false-alarm rates and false target tracks, and poor stability performance, even in later versions of software.
  - In June, the Program Office and the Services completed a review of nearly 1,500 deficiency reports accumulated since the beginning of testing to adjudicate the status

of all capability deficiencies associated with Block 2B fleet release/Marine Corps IOC. The review showed that 1,151 reports were not yet fully resolved, 151 of which were assessed as "mission critical" with no acceptable workaround for Block 2B fleet release. The remaining development and flight test of Block 2B will determine the final status of these 151 mission critical deficiencies, whether they are corrected or will add to the incomplete development work deferred to Block 3F with the less critical flaws.

- Growth in mission systems test points (regression for new software versions, testing fixes) for CY14 through the end of November was at 91 percent; that is, for every Block 2B "baseline" test point accomplished in CY14, 0.91 "growth" points have been accomplished. Growth in test points for Block 2B has slowed later in CY14 as the program has deferred fixes of deficiencies to Block 3i or Block 3F, averaging 61 percent for the period August through November. This average rate of growth, although higher than the planning rate for the year, is less than that observed in CY13 (124 percent) at the time of reporting for the FY13 DOT&E Annual Report.
- The program is eliminating test points that are designed to characterize performance (i.e., in a greater envelope than a specific contract specification condition), reducing the number of test points needed to verify the final Block 2B capability for fleet release, and deferring fixes for deficiencies to Block 3. The program has also added points for the capability required by the Services to be included in Block 2B capabilities. Formal adjustments to the 2014 test plans through the end of October resulted in a net reduction of 135 Block 2B baseline test points. In November, the program considered making further adjustments to the plan in order to complete testing necessary to support Block 2B fleet release by the end of January 2015. After reviewing the remaining 529 baseline test points, the program deemed 139 as potentially no longer required and another 147 as optional, designating only 243 of the 529 remaining points as essential for completing testing to support Block 2B fleet release. Formal adjustments of the test plans were pending as of the completion of this report. These reductions in the 2014 plan are in addition to the removal of approximately 840 test points that occurred when the program consolidated test plans for software increments prior to Block 2B with the plan for 2014, all of which were planned to be flown prior to the 2014 plan.
- The program planned to complete Block 2B mission systems flight test in October, which did not occur. The completion date of Block 2B mission systems testing will depend, in part, on realizing further reductions to baseline test points and elimination of any remaining restrictions imposed on the fleet of test aircraft due to the engine failure. As of the end of November, 529 of 4,183 Block 2B baseline test points remained. Assuming the program would continue test point productivity equal to that realized in the preceding 12 months, the program will be able to complete the remaining 529 Block 2B test points by the end of February 2015. This estimate is based on the following assumptions:
  - Modifications to upgrade any additional mission systems test aircraft from the Block 2B to Block 3i or Block 3F configuration (besides AF-3) occurs after January 2015, which is the program's current estimate for completing Block 2B development. Starting in February, two of the seven remaining mission systems test aircraft upgrade to the Block 3i configuration, while the remaining mission systems test aircraft stay in the 2B configuration to complete testing. This schedule allows other mission systems test aircraft to be modified to support testing of the Block 3i and Block 3F mission systems software, the Generation III HMDS, and OBIGGS on the F-35C variant.
  - The operating restrictions stemming from the engine failure do not restrict access to the remaining test points. These restrictions are lifted on each test aircraft after a "pre-trenched" stator is installed in the engine. Through the end of November, the engines in 6 of the 18 test aircraft had been modified with these stators and the program plans to have the entire test fleet modified by the end of February 2015.
  - No additional growth is experienced in the remainder of Block 2B flight testing, and deficiencies not currently addressed by fixes included in the final test release of Block 2B software (version 2BS5.2) will be deferred to Block 3 or not addressed.

- Block 3i
  - Block 3i was not planned to incorporate any new capability or fixes from the Block 2B development/fleet release. The first increment of Block 3i capability, designated 3iR1, is the initial release to Lot 6 aircraft and will include only Block 2A capability (inherently less capable than the final Block 2B fleet release). Subsequent increments of Block 3i software will have additional capability. However, the prospects for Block 3i progress are dependent on completion of Block 2B development and flight test, which determines:
    - When test aircraft are converted to Block 3i; two of seven mission systems aircraft – one at the Edwards test center and one at the Patuxent River, Maryland, test center – have been modified so far (flight testing can only occur on test aircraft upgraded with TR2 hardware).
    - How much incomplete development work will be inherited by Block 3i due to deficiencies deferred from Block 2B.
  - Though it eventually began in 2014, Block 3i flight test progress began late, and has progressed much slower than expected. As of the end of November 2014, the program had completed only 25 percent of the baseline Block 3i

test points, accomplishing 177 of 700 test points, which represented 64 percent of the plan for the year.

- The program temporarily modified two mission systems aircraft – CF-8 in October 2013 and AF-3 in November 2013 – with a portion of the TR2 hardware to attempt loading the first build of Block 3i software. The attempt on CF-8 failed, but the software was successfully loaded on AF-3, allowing the test center to complete ground software regression testing. AF-3 was returned to the Block 2B configuration to support testing until May 2014, when it underwent the full TR2 modification in preparation for Block 3i flight testing.
- In May, the first increment of flight test software (3iR1) was delivered to flight test approximately five months later than planned (December 2013 to May 2014). This version of the software is needed for delivery of Lot 6, TR2 equipped aircraft. The Edwards test center conducted flight testing of the Block 3i software on AF-3. The Patuxent River test center conducted one test flight of Block 3i software on BF-5, which is currently deployed to the climatic chamber for testing. No testing of Block 3i software has yet been accomplished on an F-35C test aircraft. As of the end of November, all remaining Block 3i test points were blocked, as the test centers were awaiting the next iteration of Block 3i software to proceed with flight testing.
- The test centers identified deficiencies in the 3iR1 software, five of which needed to be corrected before the software could be used in the Lot 6 production aircraft. These deficiencies were corrected and tested in the lab with an updated version of software. This final version of 3iR1 software was not flight tested at test centers, but tested by the contractor at the production facility, and is used to deliver Lot 6 aircraft.
- The second iteration of Block 3i software, 3iR4, included capability to test the new Generation III HMDS. The Edwards test center flew four test missions with 3iR4 on AF-3 in September, accomplishing regression test points and some initial test points from the Generation III HMDS test plan. This was the first testing of the new HMDS on F-35 test aircraft. The test team discovered deficiencies, particularly in the stability of the new display management computer for the helmet, and suspended further testing until software that fixes the deficiencies in the helmet system can be provided to the major contractor and included in an updated load of mission systems software.
- The third increment of Block 3i software, version 3iR5, will be used to provide production software for Lot 7 aircraft, the first lot to be delivered with the Generation III HMDS. The program plans for the production software to have the equivalent capabilities as Block 2B and plans to deliver 3iR5 software to flight test in January 2015. However, even if this occurs, since Block 2B development and flight testing were not completed as planned in October, the completion of Block 3i testing will be delayed if the equivalent capabilities from Block 2B development are to be realized in Block 3i. The program plans to convert four of the five Block 2B mission systems test aircraft at the Edwards test center to the Block 3i configuration in February 2015. Assuming this transition takes place, Block 3i flight testing could conclude by July 2015, two months later than the planned completion of May 2015. This assumes nominal growth of 66 percent is experienced during the rest of Block 3i development and flight testing, the program completes testing of the remaining baseline test points without reductions, and the program uses four of the six mission systems test aircraft at the Edwards test center for dedicated Block 3i testing. Of the two remaining mission systems test aircraft, one other test aircraft could be available for further Block 2B testing and one could be used to start Block 3F testing. Additional time will be needed to address corrections if additional deficiencies are identified in the Generation III HMDS and will add risk to the schedule.

- Block 3F
  - In order to manage and complete Block 3F development and flight testing as planned in late 2017, the program needs to complete Block 2B development and flight test as soon as possible and transition to Block 3. The program currently acknowledges four to six months "pressure" on the end of Block 3F development and test. The program needs to complete Block 2B development soon to focus resources (staffing, labs, flight test aircraft) on the development and testing of Block 3F, designated as "full warfighting capability."
  - The test centers and contractor began detailed test planning for Block 3F flight test. The draft test plan has nearly 6,000 test points. Plans completed after the 2012 re-baselining of the program showed the start of Block 3F flight testing in May 2014; however, current program plans are to start Block 3F flight test in March 2015, 10 months later than the 2012 baseline.

Mission Data Load Development and Testing

- The F-35 relies on mission data loads – which are a compilation of the mission data files needed for operation of the sensors and other mission systems components – working in conjunction with the system software data load to drive sensor search parameters and to identify and correlate sensor detections of threat radar signals. An initial set of files was produced by the contractor for developmental testing during SDD, but the operational mission data loads – one for each potential major area of operation – will be produced by a U.S. government lab, the U.S. Reprogramming Lab (USRL). These mission data loads will be used for operational testing and fielded aircraft, including the Marine Corps IOC aircraft.
- In accordance with the approved mission data optimization operational test plan, mission data loads undergo a three-phased lab development and test regimen, followed by

flight test. The current plans are to certify the first two mission data loads, which are needed to support Marine Corps IOC, in November 2015 after flight testing occurs on operational test aircraft between March and October 2015. These plans provide the mission data load later than needed for the Marine Corps' objective IOC date of July 2015. However, truncating the mission data load development and conducting open-air flight testing early on a limited open-air range for the purpose of releasing a mission data load in mid-2015 would create significant operational risk to fielded units, since the load will not have completed the planned lab testing and because the open-air range test infrastructure is capable of verifying only a small portion of the mission data. The program should complete lab testing of the mission data loads, as is planned in the mission data optimization operational test plan, prior to accomplishing the necessary flight testing to ensure the loads released to the fleet are optimized for performance. If mission data loads are released to operational units prior to the completion of the lab and flight testing required in the operational test plan, the risk to operational units must be clearly documented.

- Several items are currently creating risk to the program's ability to deliver certified mission data loads. Mission data lab equipment was held by the major contractor at their Fort Worth facility for three years past the planned delivery to the USRL to support mission systems software development for production aircraft, reducing productivity at the USRL. The USRL did not receive sufficient documentation of the equipment and software tools that were delivered by the program; this has hampered their training and slowed development. Contract issues had prevented USRL from direct communications with the subcontractor that designed both the electronic warfare system on the aircraft and the mission data programming tools. These communications were needed to understand undocumented lab and mission data file generation tool functions. The Program Office has taken steps to improve these communications. Other challenges that may affect on-time delivery of mission data include instability in the contractor-delivered mission data file generation tool, which creates the final mission data load, and slower than expected development of software analysis tools that optimize sensor performance.
- Mission data load development and testing is a critical path to combat capability for Block 2B and Block 3F. Accuracy of threat identification and location depend on how well the mission data loads are optimized to perform in ambiguous operational environments. This is difficult work given a stable software capability in the platform, adequate lab equipment, and stable/well-understood mission data file generation tools – none of which are yet available in the program.
- The current lab is essentially a copy of the mission systems integration lab used by the major contractor to integrate and test software. It is not adequate for development of mission data loads for use in operationally realistic conditions. As identified by DOT&E in early 2012, the program must plan and execute a significant upgrade to the lab in order for it to generate an operationally realistic signal environment for mission data load optimization. Though funding has been made available, plans for this upgrade, and integration with the Block 2B, Block 3i, and Block 3F mission data loads have not been finalized.

Weapons Integration

- Progress in weapons integration, in particular the completion of planned weapon delivery accuracy (WDA) events, has been very limited in 2014 compared to that planned by the program. Multiple deficiencies in mission systems, aircraft grounding, and subsequent flight restrictions caused by the June engine failure all contributed to the limited progress.
- Each WDA event requires scenario dry-runs in preparation for the final end-to-end event to ensure the intended mission system functionality, as well as engineering and data analysis requirements (to support the test centers and weapon vendors) are available to complete the missile shot or bomb drop. Per the approved TEMP, these preparatory events, as well as the end-to-end events, are to be accomplished with full mission systems functionality, including operationally realistic fire control and sensor performance.
- Mission systems developmental testing of system components required neither operation nor full functionality of subsystems that were not a part of the component under test. The individual mission system component tests were designed by the developmental teams to verify compliance with contract specification requirements rather than to test the full mission systems performance of the aircraft and complete the find-fix-ID-track-target-engage-assess kill chain for air-to-air and air-to-ground mission success. WDA events, however, were specifically designed to gather both the necessary weapons integration and fire-control characterization and performance using all the mission systems required to engage and kill targets.
- Planning and scheduling of the WDA events assumed that all associated mission systems functionality would be mature by the WDA preparatory event dates. However, due to the limitations in progress in Block 2B mission systems, this has not occurred.
  - Deficiencies in the Block 2B mission systems software affecting the WDA events were identified in fusion, radar, passive sensors, identification friend-or-foe, electro-optical targeting system, and the aircraft navigation model. Deficiencies in the datalink systems also delayed completion of some events. Overall, these deficiencies have both delayed the WDA event schedule and compromised the requirement to execute the missions with fully functional and integrated mission systems.
  - The program had planned to complete all Block 2B WDA events by October 2014. This did not occur. Through the end of November, 10 of 15 live fire events had been completed, while the program planned to have all 15 completed by the end of October. In November, the

program deferred two of the planned Block 2B WDA events to Block 3, due to deficiencies and limitations of capability in Block 2B mission systems. The adjacent table shows the planned date, completion or scheduled date, and weeks delayed as of the end of November for each of the WDA preparatory and end-to-end events. Events completed are shown with dates in bold font; events scheduled are shown with dates in italicized font. The program should complete the remaining three Block 2B WDA flight test events, using the currently planned scenarios, and ensuring full mission systems functionality is enabled in an operationally realistic manner.

WEAPONS DELIVERY ACCURACY (WDA) PROGRESS

Weapon	WDA Number	Preparatory Events			End-to-End Event		
		Planned	Completed/ *Scheduled*[1]	Weeks Delayed	Planned	Completed/ *Scheduled*	Weeks Delayed
AIM-120	102	Sep 13	**Sep 13**	2	Oct 13	**Oct 13**	2
	112	Sep 13	**Sep 13**	3	Oct 13	**Nov 13**	3
GBU-12	113	Sep 13	**Oct 13**	3	Oct 13	**Oct 13**	0
GBU-32	115	Sep 13	**Nov 13**	6	Nov 13	**Dec 13**	3
AIM-120	108	Oct 13	**Dec 13**	7	Dec 13	**Feb 14**	12
	110	Oct 13	**Aug 13**	43	Dec 13	**Nov 14**	50
	111	Dec 13	*Deferred to Block 3F*	--	Jan 14	*Deferred to Block 3F*	--
	106	Dec 13	**Sep 14**	40	Jan 14	**Nov 14**	43
GBU-31	114	Dec 13	**May 14** **Jun 14** **Oct 14**	45	Feb 14	**Nov 14**	41
AIM-120	104	Feb 14	**Aug 14** **Sep 14**	30	Mar 14	*Jan 15*	44
	107	Mar 14	**Jun 14**	12	May 14	*Dec 14*	30
	101	May 14	**May 14** **Sep 14**	17	Jun 14	*Dec 14*	26
	103	Jun 14	**Mar 14** **Apr 14**	-8	Aug 14	**May 14**	-10
	109	Jul 14	**Jan 14**	-29	Sep 14	**Mar 14**	-27
	105	Sep 14	*Deferred to Block 3F*	--	Oct 14	*Deferred to Block 3F*	--

1. Some WDA events require more than one preparatory event.

Static Structural and Durability Testing

- Structural durability testing of all variants using full scale test articles is ongoing, each having completed at least one full lifetime (8,000 equivalent flight hours, or EFH). All variants are scheduled to complete three full lifetimes of testing before the end of SDD; however, complete teardown, analyses, and Damage Assessment and Damage Tolerance reporting is not scheduled to be completed until August 2019. The testing on all variants has led to discoveries requiring repairs and modification to production designs and retrofits to fielded aircraft.
- F-35A durability test article (AJ-1) completed 11,000 EFH on September 13, which is 3,000 hours into the second lifetime. Testing restarted on October 29, after completing non-invasive inspections, which are required at 1,000 EFH intervals.
  - Cracking of the right hand side (RHS) Fuselage Station (FS) 402, discovered after the first lifetime of testing (8,000 EFH) at the end of CY12, required repairs to the test article, production redesign for production Lot 8 and later aircraft, and retrofitting a modification for production Lot 4 through 7 aircraft.
  - Discoveries from the second lifetime of testing, which started on December 13, 2013, include:
    - Cracking of the left hand side (LHS) integrated power package shear web lug at FS503, found at 10,082 EFH
    - Cracking of the LHS FS503 frame support, found at 10,162 EFH
    - Cracking in the LHS F2 fuel floor flange, found at 11,000 EFH
  - Disposition of these discoveries and repair plans were under consideration as of the time of this report.
- F-35B durability test article (BH-1) has been halted since September 2013, when the FS496 bulkhead severed at 9,056 EFH, transferred loads to an adjacent FS518 bulkhead, and caused cracking. Root cause analysis and corrective action – for repairing the bulkheads on the test article, modification for the fielded aircraft, and redesign for production Lot 8 (and subsequent lots) – have been ongoing throughout CY14. The program planned to restart testing in late September 2014, but repairs took longer than expected. Testing had not restarted as of the end of November. According to the Program Office, the effect on fielded aircraft will be limited life for FS496 (approximately 10 years of service life) until replaced or repaired.
  - Modifications to the test article include the addition of seven splice plates to repair cracks in the FS496 and FS518 bulkheads.
  - For retrofitting/modifying FS496 in production aircraft in Lots 1 through 8, the program is considering a number of fatigue mitigation steps, including relocating system attachment points, hardening the fastener holes through a

cold working process, and the use of laser shock peening (LSP) to enhance fatigue life in sections of the bulkhead where tensile stresses are known to be concentrated. The objective of treating areas with LSP is to create compressive pre-stress states near surfaces where tensile stresses are expected to be high and hence reduce crack initiation. However, LSP has not been used on the type of aluminum alloy (AL-7085) used in manufacturing the FS496 bulkheads in the F-35B, and the ability to affect the structural life is not well understood. The program should require the contractor to conduct rigorous finite-element analyses to assess the benefit of LSP application. The main objectives are to assess the LSP effect in reducing tensile stress concentrations in critical areas and to assure limited increase of tensile stresses in the other areas. To date, the effect on AL-7085 fatigue properties due to LSP application are yet to be characterized, therefore a finite-element analysis using the existing AL-7085 fatigue property data is likely to over-estimate the effect of LSP in improving fatigue resistance, which should also be taken into account.

- For aircraft in Lot 9 and beyond, the program is redesigning the five carry-through bulkheads in the F-35B (FS450, FS472, FS496, FS518, and FS556). The redesign will include LSP on two bulkheads, cold working of fastener holes on four, and increasing thickness in portions of all five bulkheads. The overall effect on aircraft weight increase is not yet known.
- Because of the extensive repair required to the FS496 bulkhead, the certification path to full life will likely require additional follow-on testing.

- F-35C durability test article (CJ-1) began second lifetime testing on April 2, and completed 2,312 EFH into the second lifetime in August (10,312 EFH total), followed by inspections. Testing resumed October 28, 2014.
  - Discoveries after the first lifetime of testing caused redesigns in the FS518 fairing support frame and FS402 upper inboard frame. Repairs and redesigns were completed at 8,869 EFH and 8,722 EFH, respectively.
  - Discoveries from the second lifetime of testing include cracking of outboard wing spar #5 and cracking on both the left and right hand sides of the FS575 center arch frame. Repairs to both were completed at 10,000 EFH prior to restart of testing.

Modeling and Simulation

Verification Simulation (VSim)

- The Verification Simulation (VSim) is a man-in-the-loop, mission software-in-the-loop simulation developed to meet the OTAs' requirements for Block 3F IOT&E, as well as to provide a venue for contract compliance verification for the Program Office.
- At the beginning of CY14, the program planned to accredit the VSim for use in Block 2B contract compliance verification by the end of the year. However, lack of progress on the Verification and Validation (V&V) process, and to a lesser extent the VSim development process, caused the program to charter an independent review of VSim. This review eventually led to cancellation of the contract verification portion of Block 2B VSim planned usage. For similar reasons, after the Block 2B OUE re-scoping effort began, the JSF Operational Test Team determined that VSim would likely not support planned Block 2B operational testing in 2015 and reduced the requirements for the simulation's intended uses to support only tactics development and other activities that directly contribute to the fielding of Block 2B capabilities.
- About one-third of the validation evidence for Block 2B VSim was reviewed by the developmental and operational test stakeholders before the contractual use of VSim for Block 2B was cancelled. This review confirmed that additional time was needed before VSim V&V could potentially meet expectations. Collaborative replanning of Block 2B activities is not complete, but V&V reviews to support operational testing needs are now planned for early 2015, with accreditation of VSim for tactics development and other uses expected in October 2015.
- Exercising the V&V process for Block 2B VSim is critical to reducing risk for its use in Block 3F IOT&E. Rigorous validation will identify gaps in VSim performance, including threat modeling, in time to create the appropriate fixes for Block 3F. Creation of test and V&V procedures as well as V&V reports and accreditation documentation will provide a significantly better understanding of VSim status by the end of 2015.
- Rigorous validation depends on good source data, and the contractor and Program Office improved efforts to ensure VSim needs are met in the Block 3F flight test plan. Those plans are not finalized, but will certainly result in deficits as the enterprise-wide need for flight tests exceeds available resources. Success in validating Block 3F VSim will depend on bridging this gap with acceptable data sources.
- The contractor has increased resources on VSim V&V teams, and the quality of the V&V products is increasing. However, the rate of completing validation points (a comparison of VSim model performance to aircraft hardware performance under similar test conditions using data from flight test, avionics test bed, or labs), has been much slower than planned. This makes completing the validation reports, which analyze the points with respect to intended use, at risk to support even the reduced accreditation requirements for Block 2B. Additional resources may be required to complete the significant task of validating the complex federation of models in VSim in time for Block 3F IOT&E.
- Although the VSim validation process has improved, DOT&E has continued to highlight shortfalls in the test resources needed to gather key elements of data required for validation of the VSim for IOT&E, in particular for electronic warfare performance in the presence of advanced threats. These shortfalls are a function of limitations in the

test assets currently available to represent threat systems. DOT&E has made formal recommendations to address the shortfalls and is pursuing solutions to make the assets available in time to prepare for IOT&E in a realistic threat environment.
- Limiting VSim Block 2B validation, and use, to tactics development and evaluation will help the program progress towards V&V of Block 3F. Block 3F use of VSim for IOT&E is not optional; it is required for an adequate IOT&E.

Training System
- Pilot training continues at Eglin AFB, Florida, and expanded in September 2014 when additional F-35B training began at MCAS Beaufort, South Carolina. Additional F-35A pilot training is planned to start in May 2015 at Luke AFB, Arizona. Sixty-six student pilot training slots were available in FY14, but nine were not used due to reduced Service requirements.
- The training center began transitioning from the Block 1B to the Block 2A training syllabus for all three variants in December 2013, and completed the transition in February 2014. The ability to train in and for adverse weather conditions was added to the Block 2A syllabus during CY14. The Block 2B syllabus is planned for delivery in mid-2015, and is planned to include limited combat capability.
- Lot 5 deliveries to pilot training bases continued throughout 2014, including the first nine F-35A to Luke AFB, and an additional eight F-35A, one F-35B, and six F-35C aircraft to Eglin AFB. Lot 6 deliveries, which began in late October, included the first F-35B aircraft delivered directly to MCAS Beaufort where it joined other F-35B aircraft transferred from Eglin AFB.
- All training to date has been in Block 2A-configured aircraft, which have envelope and other restrictions that preclude high performance training events. Because of this, all pilots attending Block 2A training complete only a portion of the planned syllabus before moving to their units.
- The Training Management System (TMS) is a database that includes course material, syllabus flow, student records, and schedules for aircrew and maintainers. The academic center is using the TMS for instruction and tracking student progress. TMS functionality is relatively unchanged from that which existed during the 2012 training system OUE. For example, the TMS cannot yet be effectively used for scheduling, pilot qualification tracking, and the other typical unit functions. This year, the Program Office added funding to correct these deficiencies and improve the functionality for tracking operational unit “continuation training,” which includes monthly training requirements and pilot qualifications. Planned delivery is in the 2017 timeframe, and will also require Automatic Logistics Information System (ALIS) system-level architecture modifications to achieve full capability. Until then, flying units at both training and operational bases will most likely continue to use legacy scheduling and training databases, which causes double entry into databases and impedes program-level data analysis such as annual flying hour progress.
- The training center continued to conduct maintenance training for experienced maintenance personnel for all F-35 variants during 2014. As of the end of October, more than 1,800 U.S. personnel and foreign partner students had completed training in one or more of the maintenance courses, including ALIS, to support fielded maintenance operations. For the 12-month period ending in October 2014, the contractor provided 1,018 training slots for maintenance courses, of which 701 were filled by U.S. or foreign partner students, equating to 69 percent training seat utilization rate. In addition, active duty personnel at the field units conducted training that is not included in these metrics. The Integrated Training Center at Eglin AFB currently offers 13 maintenance classes ranging from 3 to 13 weeks in length.

Live Fire Test and Evaluation

F-35B Full-Scale Structural System Vulnerability Assessment
- The F-35 LFT&E Program completed the F-35B full-scale structural test series. The Navy’s Weapons Survivability Laboratory (WSL) in China Lake, California, completed 15 tests events using the BG:0001 test article. Preliminary review of the results indicates that:
  - Anti-aircraft artillery (AAA) threat-induced damage stressed the critical wing structure members, but multiple structural load paths successfully limited the damage to expected areas around the impact points while preserving the static flight load carrying capabilities. Consistent with predictions, the tests demonstrated other cascading damage effects, including threat-induced fire and damage to adjacent fuselage fuel tanks.
  - AAA and missile fragment-induced damage stressed the structural limitations of the forward fuselage fuel tanks (F-1 and F-2). Cascading effects from the F-1 tank damage included a large fuel release into the cockpit and damage to the pilot seat mounting structure. To mitigate the vulnerability to the pilot, the Program Office has recently altered the F-35B fuel burn strategy so that the F-1 tank behind the pilot empties sooner. Threat-induced damage in these fuel tank tests also caused large fuel discharge into the engine inlet, which would have likely caused engine failures due to fuel ingestion. The engine was not installed for these tests.
  - The extent of AAA-induced structural damage to the wing leading edge flap and the horizontal tail is not flight critical from a structural tolerance perspective. The leading edge tests demonstrated the potential for sustained fire, which could have flight-critical cascading effects on the wing structure.
  - The ballistic damage tolerance testing of propulsion system related structural components (variable area vane box nozzle, and hinges on the roll duct nozzle, lift fan, and auxiliary air inlet doors) revealed these components were nearly insensitive to expected threats. However, sustained fires were created in the shot into the variable area vane box nozzle due to leakage in the actuating hydraulics, and

the shot into the roll duct nozzle door due to damage to the adjacent fuel tank. These fires would ultimately have led to cascading structural damage.
  - Data support the evaluation of residual loading capabilities of the aft boom structure, including vertical tail and horizontal tail attachments, following a man-portable air defense system impact and detonation. While having fuel in the aft-most F-5 fuel tank increased structural damage due to resultant hydrodynamic ram effects and fire, flight control surfaces remained attached. Further structural analysis of the damage effects is being completed to verify the structural integrity of the aft boom structure.

F135 Engine

- F135 live fire engine testing in FY13, engine vulnerability analysis in FY13, and uncontained engine debris damage analysis in FY03 demonstrated two primary threat-induced engine damage mechanisms:
  - Penetration of the engine case and core that could cause blade removal, resulting in damage to turbomachinery leading to propulsion loss or fire
  - Damage to external engine components (e.g., fuel lines, pumps, gearbox, etc.) leading to critical component failure and fire
- Engine fuel ingestion testing in FY07 further demonstrated the potential of an engine stall providing a fire ignition source in the presence of additional fuel system damage.
- The uncontained F135 fan blade release and subsequent fuel fire in an F-35A at Eglin AFB in June provides an additional data point that needs to be reviewed and analyzed to support the F-35 vulnerability assessment.

Polyalphaolefin (PAO) Shut-Off Valve

- The Program Office tasked Lockheed Martin to develop a technical solution for a PAO shut-off valve to meet criteria developed from live fire test results. This aggregate, 2-pound vulnerability reduction feature, if installed, would reduce the probability of pilot incapacitation, decrease overall F-35 vulnerability, and prevent the program from failing one of its vulnerability requirements.
- The program has not provided any updates on the feasibility and effectiveness of the design, nor an official decision to reinstate this vulnerability reduction feature.

Fuel Tank Ullage Inerting System

- The program verified the ullage inerting design changes and demonstrated improved, inerting performance in the F-35B fuel system simulator (FSS) tests. A preliminary data review demonstrated that the system pressurized the fuel tank with nitrogen enriched air (NEA) while maintaining pressure differentials within design specifications during all mission profiles in the simulator, including rapid dives, but revealed the potential for pressure spikes from the aerial refueling manifold, as noted in the flight sciences section of this report. The Program Office will complete and document detailed data review and analyses to evaluate NEA distribution and inerting uniformity between different fuel tanks and within partitioned fuel tanks.
- The program developed a computational model to predict inerting performance in the aircraft based on the F-35B simulator test results. Patuxent River Naval Air Station completed the ground inerting test on an actual F-35B aircraft to verify the model, but a detailed comparison to F-35B FSS has not yet been completed. The program will use this model, in conjunction with the completed F-35A ground tests and F-35C ground tests planned to start in February 2015, to assess the ullage inerting effectiveness for all three variants. The confidence in the final design and effectiveness will have to be reassessed after the deficiencies uncovered in the aircraft ground and flight tests have been fully resolved.
- When effective, ullage inerting only protects the fuel tanks from lightning-induced damage. The program has made progress in completing lightning tolerance qualification testing for line-replaceable units needed to protect the remaining aircraft systems from lightning-induced currents. Lightning tolerance tests using electrical current injection tests are ongoing, and the program is expected to complete the tests by 2QFY15.

Electrical System

- DOT&E expressed a concern in FY13 for the potential loss of aircraft due to ballistically-induced shorting of power and control circuits in the F-35 flight control electrical systems. The F-35 is the first tactical fighter aircraft to incorporate an all-electric flight control system, using a 270 Volt power bus to power flight control actuator systems and a 28 Volt bus to control those actuators. The F-35 aircraft carries these voltages in wire bundles where they are in close proximity. Live fire tests of similar wire bundle configurations demonstrated the potential for arcing and direct shorts due to ballistic damage.
- Lockheed Martin completed an electrical power systems report, which included a summary of development tests to demonstrate that transient-voltage suppression diodes installed throughout the 28 Volt systems shunt high voltage (including 270 Volt) to ground, preventing the high voltage from propagating to other flight-critical components. Some components might be damaged as a result of a short, but their redundant counterparts would be protected. Testing used direct injection of the high voltage, rather than shorting from ballistic damage, but the electrical effects would be the same.

Vulnerability to Unconventional Threats

- The full-up, system-level chemical-biological decontamination test on the BF-4 test article planned for 4QFY16 at Edwards AFB is supported by two risk-reduction events:
  - The Limited Demonstration event conducted in 4QFY14 showed that the proposed decontamination shelter and liner design can sustain conditions of 160°F and 80 percent relative humidity. The high temperature alone is sufficient

to decontaminate chemical agents. The combination of high heat and humidity has been shown effective in decontaminating biological agents. Both chemical and biological decontamination techniques take 10 to 12 days to complete.
  - A System Integration Demonstration of the decontamination equipment and shelter was conducted on an F-16 test article during 1QFY15 at Edwards AFB to simulate both hot air chemical and hot/humid air biological decontamination operations. This testing will not demonstrate the decontamination system effectiveness in a range of operationally realistic environments.
- The F-35 variant of the Joint Service Aircrew Mask (JSAM-JSF) successfully passed its Preliminary Design Review in 3QFY14. The Joint Program Executive Office for Chemical and Biological Defense and the F-35 Program Office will have to integrate the JSAM-JSF with the Helmet-Mounted Display, which is undergoing a challenging design process and consequently further aggravating this integration effort.
- Planned EMP testing will evaluate the aircraft to the threat level defined in MIL-STD-2169B. Both horizontal and vertical polarization testing, as well as active, passive, and direct drive testing are planned to assess effects and/or damage of the EMP induced currents and coupling to vehicle and mission systems electronics. EMP testing on the F-35B article was completed in 1QFY15; data analysis is ongoing. Follow-on tests on other variants, including a test series to evaluate any Block 3F hardware/software changes, are planned for FY16.

Gun Ammunition Lethality and Vulnerability

- The program completed the ballistic impact response characterization of the PGU-47/U Armor Piercing Explosive (APEX) round for the partner F-35A variant using the AAA and fragment threats. Preliminary data analysis demonstrated no significant reactions or evidence of high pressures that could potentially induce sympathetic reactions from adjacent rounds loaded on the aircraft.
- The program completed the terminal ballistic testing of the PGU-48 FAP round and the PGU-32 round against a range of target-representative material plates and plate arrays. Preliminary FAP test observations indicate lower than expected levels of fragmentation when passing through multiple layer targets. PGU-32 test observations indicate that the round detonates much closer to the impact point of the first target plate than originally called out in ammunition specification. The program will determine the impact of these data on the ammunition lethality assessment.
- Ground-based lethality test planning is ongoing. All three rounds will be tested against a similar range of targets, including armored and technical vehicles, aircraft, and personnel in the open. FY15 funds are in place for all tests except those against boat targets.
- Air-to-ground lethality tests will likely begin no earlier than 1QFY16. Given the development test schedule of the APEX round, the existing flight test plan does not include this round.

Operational Suitability

- Overall suitability continues to be less than desired by the Services, and relies heavily on contractor support and unacceptable workarounds, but has shown some improvement in CY14.
  - Aircraft availability was flat over most of the past year, maintaining an average for the fleet of 37 percent for the 12-month rolling period ending in September – consistent with the availability reported in the FY13 DOT&E report of 37 percent for the 12-month period ending in October 2013. However, the program reported an improved availability in October 2014, reaching an average rate of 51 percent for the fleet of 90 aircraft and breaking 50 percent for the first time, but still short of the program objective of 60 percent set for the end of CY14. The bump in availability in October brought the fleet 12-month average to 39 percent.
  - Measures of reliability and maintainability that have ORD requirements have improved since last year, but all nine reliability measures (three for each variant) are still below program target values for the current stage of development. The reliability metric that has seen the most improvement since May 2013 is not an ORD requirement, but a contract specification metric, mean flight hour between failure scored as “design controllable” (which are equipment failures due to design flaws). For this metric, the F-35B and F-35C are currently above program target values, and F-35A is slightly below the target value, but has been above the target value for several months over the last year.

F-35 Fleet Availability

- Aircraft availability is determined by measuring the percent of time individual aircraft are in an “available” status, aggregated over a reporting period (e.g., monthly). Aircraft that are not available are assigned to one of three categories of status: Not Mission Capable for Maintenance (NMC-M); Not Mission Capable for Supply (NMC-S); and in depot.
  - The program added this third category for tracking fleet status in January 2014 as the number of aircraft entering the depot for modifications or receiving modifications or repair by a depot field team at the home station began to increase. Prior to January 2014, these aircraft were assigned as Non-Possessed (NP) or Out Of Reporting (OOR) for depot-level actions under an NMC-M status.
  - The program established new goals for all three of these unavailable statuses for 2014. The NMC-M goal is 15 percent, NMC-S is 10 percent, and depot status is 15 percent. These three non-available statuses sum to 40 percent, supporting the program’s availability goal of 60 percent for the fleet by the end of CY14. The goal of 60 percent is an interim program goal and does not represent the availability needed for combat operations, nor the 80 percent needed to accomplish IOT&E in an operationally realistic manner.
- Aircraft monthly availability averaged 39 percent for the 12-month period ending October 2014 in the training and

operational fleet, with no statistical trend of improvement for the first 11 months. In October 2014, availability jumped to a reported 51 percent (fleet size of 90 aircraft), a 12 percent increase from the previous month, and the largest month-to-month change since March 2013 (fleet size of 27 aircraft). Month-to-month variance in average availability should decrease as the fleet size increases. The improved availability was seen at most operating locations, and resulted from roughly equal improvements in the NMC-M and NMC-S rates. Historically NMC-M and NMC-S have tended to move in opposite directions; the improvement in one being negated by the increase in the other.

- Aircraft availability rates by operating location for the 12-month period ending October 2014 are summarized in the table below. The first column indicates the average availability achieved for the whole period, while the maximum and minimum columns represent the range of monthly availabilities reported over the period. The number of aircraft assigned at the end of the reporting period is shown as an indicator of potential variance in the rates. Sites are arranged in order of when each site began operation of any variant of the F-35, and then arranged by variant for sites operating more than one variant.

F-35 AVAILABILITY FOR 12-MONTH PERIOD ENDING OCTOBER 2014[1]

Operational Site	Average	Maximum	Minimum	Aircraft Assigned
Total Fleet	39%	51%	35%	90[2]
Eglin F-35A	39%	55%	32%	28
Eglin F-35B	41%	54%	25%	11
Eglin F-35C	50%	64%	24%	10
Yuma F-35B	33%	49%	24%	15
Edwards F-35A	43%	57%	19%	7
Nellis F-35A	28%	51%	2%	4
Luke F-35A[3]	50%	58%	23%	10
Beaufort F-35B[4]	37%	49%	4%	4

1. Data do not include SDD aircraft.
2. Total includes 1 OT F-35B at Edwards that is not broken out in table
3. Luke F-35A data began in April 2014
4. Beaufort F-35 B data began in July 2014.

- Sites that show extreme maximum or minimum availability values tend to have small fleet sizes; for example, Nellis AFB, Nevada, had only four F-35A aircraft for the majority of the reporting period. F-35B operations began at Edwards AFB, California, in October, when a single aircraft was transferred from Yuma MCAS. Availability of that aircraft is not broken out separately, but is included in the whole fleet calculation.
- The NMC-M rate was relatively steady at an average of 26 percent for the 12-month period ending October 2014, nearly twice the goal for 2014, excluding the depot for this entire period. A substantial amount of NMC-M down time continues to be the result of field maintenance organizations waiting for technical dispositions or guidance from the contractor on how to address a maintenance issue that has grounded an aircraft. These Action Requests (ARs) are a result of incomplete or inadequate technical information in the field, in the form of Joint Technical Data (JTD). While JTD validation has progressed (see separate section below), the complexity of AR's is increasing, leading to longer times to receive final resolution. Reducing the rate of ARs or decreasing the response time to the ARs will improve (lower) NMC-M rates. High Mean Times To Repair (MTTR), the average maintenance time to fix a single discrepancy, are experienced in all variants. This also contributes to the persistently high NMC-M rate.
- Over the same 12-month period, the NMC-S rate displayed an improving trend, peaking at 27 percent in November 2013, decreasing to rates in the high 10s to low 20s by mid-2014, and reaching a minimum of 15 percent in October. In 2013, the Program Office predicted that better contracting performance and the maturing supply system would result in improved supply support, which would in turn result in lower NMC-S rates by late 2014. Although the trend is favorable, the rate of improvement is not yet fast enough to allow the program to achieve their goal of 10 percent NMC-S by the end of 2014. If the current trend continues, the program could reach this target in early- to mid-2015.
- A large portion of the fleet began cycling through the depot for Block 2B modifications made necessary by concurrent development, exerting downward pressure on overall fleet availability. The program began reporting the percentage of the fleet in depot status starting in January 2014 at 13 percent. Since then, it has risen to as high as 18 percent in July 2014, and was at 11 percent by the end of October. Current plans show over 10 percent of the operational aircraft inventory will be in depot status for Block 2B modifications through at least mid-2015 (either at a dedicated facility or being worked on by a depot field team at the home station). If the Services elect to upgrade all early production aircraft to Block 3F capability, these aircraft will again be scheduled for depot-level modifications (operational test aircraft must be modified.) All necessary depot-level modifications are not yet identified for Block 3F, as testing and development are not complete. Therefore, the impact on availability due to Block 3F modifications in the 2016 through 2018 timeframe is unknown.
- Although depot modifications reduce overall fleet availability, they potentially improve availability once the aircraft is out of depot by replacing low reliability components with improved versions, such as the 270 Volt Battery Charger and Control Unit. Any increased availability from reliability improvements will take time to manifest in the fleet wide metrics, not showing more strongly until the majority of aircraft have been modified.
- Low availability rates, in part due to poor reliability, are preventing the fleet of fielded operational F-35 aircraft (all

variants) from achieving planned, Service-funded flying hour goals. Original Service bed-down plans were based on F-35 squadrons ramping up to a steady state, fixed number of flight hours per tail per month, allowing for the projection of total fleet flight hours.

- In November 2013, a new "modelled achievable" flight hour projection was created since low availability was preventing the full use of bed-down plan flight hours. The revised model accounted for some actual fleet maintenance and supply data, and made assumptions about many factors affecting availability in the coming years to predict the number of flight hours the fleet could generate in future months.
- Through October 30, 2014, the fleet had flown approximately 72 percent of the modelled achievable hours because availability had not increased in accordance with assumptions. Planned versus achieved flight hours, for both the original plans and the modelled achievable, through October 30, 2014, by variant, for the fielded production aircraft are shown in the table below.

F-35 FLEET PLANNED VS. ACHIEVED FLIGHT HOURS AS OF OCTOBER 30, 2014

Variant	Original Bed-Down Plan Cumulative Flight Hours			"Modelled Achievable" Cumulative Flight Hours		
	Estimated Planned	Achieved	Percent Planned	Estimated Planned	Achieved	Percent Planned
F-35A	11,500	6,347	55%	9,000	6,347	71%
F-35B	8,500	6,085	72%	7,500	6,085	81%
F-35C	1,800	910	51%	1,600	910	57%
Total	21,800	13,342	61%	18,600	13,342	72%

F-35 Fleet Reliability

- Aircraft reliability is assessed using a variety of metrics, each characterizing a unique aspect of overall weapon system reliability.
  - Mean Flight Hours Between Critical Failure (MFHBCF) includes all failures that render the aircraft not safe to fly, and any equipment failures that would prevent the completion of a defined F-35 mission. It includes failures discovered in the air and on the ground.
  - Mean Flight Hours Between Removal (MFHBR) gives an indication of the degree of necessary logistical support and is frequently used in determining associated costs. It includes any removal of an item from the aircraft for replacement with a new item from the supply chain. Not all removals are failures, and some failures can be fixed on the aircraft without a removal. For example, some removed items are later determined to have not failed when tested at the repair site. Other components can be removed due to excessive signs of wear before a failure, such as worn tires.
  - Mean Flight Hours Between Maintenance Event, unscheduled (MFHBME) is useful primarily for evaluating maintenance workload. It includes all failures, whether inherent or induced by maintenance actions, that led to maintenance and all unscheduled inspections and servicing actions.
  - Mean Flight Hours Between Failure, Design Controllable (MFHBF_DC) includes failures of components due to design flaws under the purview of the contractor, such as the inability to withstand loads encountered in normal operation. Failures of Government Furnished Equipment (GFE) and failures induced by improper maintenance practices are not included.
- The F-35 program developed reliability growth projections for each variant throughout the development period as a function of accumulated flight hours. These projections are shown as growth curves, and were established to compare observed reliability with target numbers to meet the threshold requirement at maturity, defined by 75,000 flight hours for the F-35A and F-35B, and by 50,000 flight hours for the F-35C, and 200,000 cumulative fleet flight hours. In November 2013, the program discontinued reporting against these curves for all ORD reliability metrics, and retained only the curve for MFHBF_DC, which is the only reliability metric included in the JSF Contract Specification (JCS). The growth curves for the other metrics have been re-constructed analytically and are used in the tables below for comparison to achieved values, but are not provided by the Program Office.
- As of October 2014, the F-35, including operational and flight test aircraft, had accumulated approximately 22,000 flight hours, or slightly more than 11 percent of the total 200,000-hour maturity mark defined in the ORD.
- Since May 2013, the program has reported Reliability and Maintainability (R&M) metrics on a three-month rolling window basis meaning, for example, the MFHBCF rate published for a month accounts only for the critical failures and flight hours of that month and the two previous months. Before May 2013, R&M metrics were reported on a cumulative basis. The switch to a three-month rolling window is intended to give a more accurate account of current, more production-representative aircraft performance, and eliminate the effect of early history when the SDD aircraft were very immature; however, this process can create significant month-to-month variability in reported numbers.
- A comparison of current observed and projected interim goal MFHBCF rates, with associated flight hours, is shown in the first table on the following page. Threshold at maturity and the values in the FY13 DOT&E report are shown for reference as well.
- Similar tables comparing current observed and projected interim goals for MFHBR, MFHBME, and MFHBF_DC rates for all three variants are also provided. MFHBF_DC is a contract specification, and its JCS requirement value is shown in lieu of an ORD threshold.
- The large number of flight hours and events in each three-month rolling window supporting the observed reliability metrics in the tables above provide statistical evidence that the program experienced reliability growth in

all metrics and all variants between August 2013 and August 2014.
- The critical failure rates for all three variants were below threshold values and below projected interim goals. Due to the large variability in month-to-month reported values, however, the high apparent growth for both the F-35B and F-35C from the data point values above may not be characteristic of the actual growth, with August 2013 being notably below average for those variants, and August 2014 being substantially above average.
- All variants are below their threshold values and projected interim goals for MFHBR and MFHBME.
- Design controllable failure rate is the only metric where any variants exceed the interim goal; as shown in the table with the F-35B and F-35C. For all variants, the degree of improvement in MFHBF_DC by August 2014, relative to the May 2013 value, is greater than the degree of improvement for all other reliability metrics. This indicates the improvement in the contract specification metric of MFHBF_DC is not translating into equally large improvement in the other reliability metrics, which are operational requirements.
- DOT&E conducted an in-depth study of reliability growth in MFHBR and in MFHBME for the period from July 2012 through October 2013. Reliability growth was modeled using the Duane Postulate, which characterizes growth by a single parametric growth rate. Mathematically, the Duane Postulate assesses growth rate as the slope of the best fit line when the natural logarithm of the cumulative failure rate is plotted against the natural logarithm of cumulative flight hours. A growth rate of zero would indicate no growth, and a growth rate of 1.0 is the theoretical upper limit, indicating instantaneous growth from a system that exhibits some failures to a system that never fails. The closer the growth rate is to 1.0 the faster the growth, but the relationship between assessed growth rates is not linear, due to the logarithmic nature of the plot. For example a growth rate of 0.4 would indicate reliability growth much higher than twice as fast as a growth rate of 0.2.
  - Only the F-35A and F-35B variants were investigated due to a low number of flight hours on the F-35C. The study evaluated the current growth rate, then, using that rate, projected the reliability metric to the value expected at maturity.

F-35 RELIABILITY: MFHBCF (HOURS)

Variant	ORD Threshold		Values as of August 31, 2014				Values as of August 2013	
	Flight Hours	MFHBCF	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBCF	Observed MFHBCF (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBCF (3 Mos. Rolling Window)
F-35A	75,000	20	8,834	14.9	8.2	55%	4,204	4.5
F-35B	75,000	12	7,039	8.6	7.5	87%	3,286	3.0
F-35C	50,000	14	2,046	9.2	8.3	90%	903	2.7

F-35 RELIABILITY: MFHBR (HOURS)

Variant	ORD Threshold		Values as of August 31, 2014				Values as of August 2013	
	Flight Hours	MFHBR	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBR	Observed MFHBR (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBR (3 Mos. Rolling Window)
F-35A	75,000	6.5	8,834	4.8	3.1	65%	4,204	2.5
F-35B	75,000	6.0	7,039	4.3	2.5	58%	3,286	1.4
F-35C	50,000	6.0	2,046	3.9	2.3	59%	903	1.6

F-35 RELIABILITY: MFHBME (HOURS)

Variant	ORD Threshold		Values as of August 31, 2014				Values as of August 2013	
	Flight Hours	MFHBME	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBME	Observed MFHBME (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBME (3 Mos. Rolling Window)
F-35A	75,000	2.0	8,834	1.5	0.85	57%	4,204	0.78
F-35B	75,000	1.5	7,039	1.1	0.96	87%	3,286	0.46
F-35C	50,000	1.5	2,046	0.9	0.84	93%	903	0.35

F-35 RELIABILITY: MFHBF_DC (HOURS)

Variant	JCS Requirement		Values as of August 31, 2014				Values as of August 2013	
	Flight Hours	MFHBF_DC	Cumulative Flight Hours	Interim Goal to Meet JCS Requirement MFHBF_DC	Observed MFHBF_DC (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBF_DC (3 Mos. Rolling Window)
F-35A	75,000	6.0	8,834	4.2	4.0	95%	4,204	2.8
F-35B	75,000	4.0	7,039	2.7	3.5	130%	3,286	1.9
F-35C	50,000	4.0	2,046	2.4	3.6	150%	903	1.5

- The study also evaluated the growth rate needed to meet the ORD threshold value at maturity (75,000 hours each for the F-35A and F-35B) from the current observed value of the reliability metric. The results of the study are summarized in the following table.

Metric	Variant	October 2013 Value	Current Growth Rate from Duane Postulate	Projected Value at 75,000 FH	ORD Threshold	Projected Value as % ORD Threshold	Growth Rate Needed to Meet ORD
MFHBR	F-35A	3.30	0.129	4.19	6.5	65%	0.232
	F-35B	1.87	0.210	4.05	6.0	68%	0.305
MFHBME	F-35A	0.82	0.162	1.45	2.0	73%	0.241
	F-35B	0.64	0.347	1.74	1.5	116%	0.312

- For most of the measures, the F-35 must achieve a much faster growth rate than currently exhibited in order to meet ORD requirements by maturity. Reliability growth rates are very sensitive when calculated early in a program, with only relatively low numbers of flight hours (i.e., less than 10,000), and can differ significantly either on the up or down side from growth rates calculated once a program is more mature.
- The above growth rates were calculated with around 4,700 flight hours for the F-35A, and 3,800 for the F-35B. For comparison, observed MFHBME growth rates for several historical aircraft are shown in the table to the right.

Aircraft	MFHBME Growth Rate
F-15	0.14
F-16	0.14
F-22 (at 35,000 flight hours)	0.22
B-1	0.13
"Early" B-2 (at 5,000 flight hours)	0.24
"Late" B-2	0.13
C-17 (at 15,000 flight hours)	0.35

- The growth rates for the F-35 to comply with ORD performance by maturity have been demonstrated in the past, but only on different type aircraft and not on fighters.

• The most recent 90-day rolling averages for MFHBF_DC show more growth in this metric than for any other reliability metric for the period from May 2013 through August 2014. The following contributed to the reported growth in MFHBF_DC.
  - In June 2013, the program re-categorized nut plate failures, one of the most common failures in the aircraft, as induced failures rather than inherent failures, removing them from the calculation of MFHBF_DC. Nut plates are bonded to an aircraft structure and receive bolt-type fasteners to hold removable surface panels in place. One way nut plates can fail, for example, is when torquing a bolt down while replacing a removed panel, the nut plate dis-bonds from the aircraft structure, preventing securing the surface panel.
  - Distinguishing between inherent design failures and induced failures can be subjective in certain cases. For example, if a maintainer working on the aircraft bumps a good component with a tool and breaks it while working on a different part nearby, it is a judgment call whether that is an inherent design failure because the component could not withstand "normal" wear and tear in operational service, or if it's an induced failure because the maintainer was "too rough."
    ▪ Analysis on F-35A data including SDD and LRIP aircraft from September 2012 to April 2014 shows a generally increasing number of failures categorized as induced each month over the entire period, but a generally decreasing number of failures categorized as inherent for each month since April 2013. The decreasing inherent failure count per month is notable, as during this period, the F-35A fleet size and total hours flown per month were increasing steadily.
    ▪ Some of this is due to re-categorizing nut-plate failures. Actual reliability growth can also explain some of this, as could poor training leading to bad troubleshooting and maintenance practices. Some of this could also be due to re-categorizing failures previously scored as inherent failures as induced failures. For example, Program Office maintenance data records showed that there were twice as many inherent failures as induced failures in September 2012, and there were many more inherent failures than induced for every subsequent month through May 2013. Then in June 2013, records showed that there were more than twice as many induced failures than inherent failures, and induced failures have always been much greater than inherent failures for each month afterward. This sudden and abrupt reversal of the relationship between induced and inherent failures across the entire F-35A fleet suggests that scoring failures differently (induced vice inherent) may result in an increase in the design-controllable metric that is not manifested in other reliability metrics.
  - Due to poorer than expected initial reliability of many components, the program has started to re-design and introduce new, improved versions of these parts. Once a new version of a component is designed, it is considered the production-representative version. However, failed components may still be replaced by the old version of the component in order to keep aircraft flying until the new version is produced in enough quantity to proliferate to 100 percent of the fleet and supply stock. During this transition period, only failures of the new version of the component are counted as relevant to the reliability metrics, because the old version is no longer considered production-representative.
    ▪ This creates a situation where not all failures are counted in the calculation of mean flight hours between reliability events, but all flight hours are counted, and hence component and aircraft reliability are reported higher than if all of the failures were counted. The result is an increased estimation of reliability

compared to an estimate using all failures, and is highest at the beginning of the transition period, especially if the initial batch of re-designed components is small.

- For example, as of September 2014, an improved horizontal tail actuator component had been introduced and installed on roughly 30 aircraft out of a fleet of nearly 100. Failures of the older component were not being counted in the metrics at all anymore, but flight hours from all 100 aircraft were counted. This calculation could result in the reported reliability of that component being increased by up to a factor of three compared to reliability if all of the horizontal tail actuator failures were counted. There are hundreds of components on the aircraft, so a single component's increased estimate of reliability may have little influence on overall observed aircraft reliability. However, since multiple components are being upgraded simultaneously due to the unprecedented and highly concurrent nature of the F-35 program, the cumulative effect on the overall observed aircraft reliability of the increased estimate of reliability from all of these components may be significant.

- Tire assemblies on all F-35 variants do not last as long as expected and require very frequent replacement. However, only when a tire failure is experienced on landing is it counted as a design controllable failure. The vast majority of tires are replaced when worn beyond limits, and in these cases they are scored as a "no-defect." Thus, most tire replacements show up in the MFHBR and MFHBME metrics, but not in MFHBF_DC or MFHBCF, even though the aircraft is down for unsafe tires. The program is seeking redesigned tires for all variants to reduce maintenance down time for tire replacements.

- A number of components have demonstrated reliability much lower than predicted by engineering analysis, which has driven down the overall system reliability and/or led to long wait times for re-supply. High driver components affecting low availability and reliability include the following, grouped by components common to all variants followed by components failing more frequently on a particular variant or completely unique to it, as shown below:

HIGH DRIVER COMPONENTS AFFECTING LOW AVAILABILITY AND RELIABILITY		
	Common to All Variants	Additional High Drivers by Variant
F-35A	• Avionics Processors • Main Landing Gear Tires • Thermal Management System • Ejection Seat Assembly • Panoramic Cockpit Display Electronics Unit • Low Observable Cure Parameters • Helmet Display Unit • Seat Survival Kit • Igniter-Spark, Turbine Engine • On-Board Oxygen Generating System	• Exhaust Nozzle Assembly • Exhaust Nozzle Converging-Diverging Link
F-35B		• Upper Lift Fan Door Actuator[1] • 270 Volt DC Battery
F-35C		• Data Transfer Cartridge • Solenoid Operated Fuel Valve
1. Unique to the F-35B		

Maintainability

- The amount of time spent on maintenance for all variants exceeds that required for mature aircraft. Two measures used to gauge this time are Mean Corrective Maintenance Time for Critical Failures (MCMTCF) and Mean Time To Repair (MTTR) for all unscheduled maintenance. MCMTCF measures active maintenance time to correct only the subset of failures that prevent the JSF from being able to perform a defined mission, and indicates how long it takes, on average, to return an aircraft to mission capable status. MTTR measures the average active maintenance time for all unscheduled maintenance actions, and is a general indicator of ease and timeliness of repair. Both measures include active touch labor time and cure times for coatings, sealants, paints, etc., but do not include logistics delay times such as how long it takes to receive shipment of a replacement part.
- The tables below compare measured MCMTCF and MTTR values for the three-month period ending August 2014 to the ORD threshold and the percentage of the value to the threshold for all three variants. The tables also show the value reported in the FY13 DOT&E Annual Report for reference. For the F-35A and F-35C, MCMTCF increased (worsened) over the last year while MCMTCF for the F-35B showed slight improvement. For all variants, MTTR showed improvement over the last year. Both maintainability measures for all variants are well above (worse than) the ORD threshold value required at maturity.

F-35 MAINTAINABILITY: MCMTCF (HOURS)				
Variant	ORD Threshold	Values as of August 31, 2014 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of August 2013 (3 Mos. Rolling Window)
F-35A	4.0	15.6	390%	12.1
F-35B	4.5	15.2	338%	15.5
F-35C	4.0	11.2	280%	9.6

F-35 MAINTAINABILITY: MTTR (HOURS)				
Variant	ORD Threshold	Values as of August 31, 2014 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of August 2013 (3 Mos. Rolling Window)
F-35A	2.5	8.6	344%	9.2
F-35B	3.0	7.5	250%	8.9
F-35C	2.5	6.6	264%	7.7

- More in depth trend analysis between May 2013 and August 2014 shows that the MTTR for the F-35A and F-35C variants have been decreasing slowly, while the MTTR for the F-35B has been growing slightly, with all exhibiting high month-to-month variability. Over the same period, the MCMTCF values for the F-35B and F-35C were increasing slightly and flat for the F-35A, but again with very high monthly variability.
- Several factors likely contribute to extensive maintenance time, especially long cure times for Low Observable repair materials. The Program Office is addressing this issue with

new materials that can cure in 12 hours vice 48 for example, but some of these materials may require freezer storage, making re-supply and shelf life verification in the field or at an austere operating location more difficult.
  - The immaturity of the system overall, including training system immaturity, lack of maintainer experience on such a new aircraft, and incompletely written and verified, or poorly written, JTD may all also contribute to protracted maintenance times.
  - Additionally, design factors of the aircraft itself make affecting certain repairs difficult and time-consuming. Field maintainers have reported poor cable routing behind panels that interferes with required maintenance, and awkward placement of some components, which makes removing and replacing them slow, and increases the chances they will induce a failure in a nearby component working with tools in confined spaces.
  - Scoring also affects higher than expected MTTR values. Discrepancies for which maintainers have to attempt multiple solutions before finding a true fix are being re-scored as a single event, while in the past they were documented as multiple repair attempts, each with its own MTTR. The individual MTTRs for these attempted repairs are now rolled up into the single, re-scored event. Improved diagnostics and training can reduce MTTR by pointing maintainers to the true root cause of discrepancies more quickly.

Autonomic Logistics Information System (ALIS)

- The program develops and fields ALIS in increments similar to the mission systems capability in the air vehicle. Overall, ALIS is behind schedule, has several capabilities delayed or deferred to later builds, and has been fielded with deficiencies. The program does not have a dedicated end-to-end developmental testing venue for ALIS and has relied on feedback from the field locations for identifying deficiencies. Though some of the early deficiencies have been addressed, ALIS continues to be cumbersome to use and inefficient, and requires the use of workarounds for deficiencies awaiting correction. The program has tested ALIS software versions at the Edwards flight test center, including a formal Logistics Test and Evaluation (LT&E) of ALIS software versions 1.0.3 and 2.0.0. These formal test periods had limitations, however, as the ALIS that supports the developmental test aircraft is different than the production ALIS hardware at fielded units. As a result, the program has begun limited testing of software updates at fielded operational sites and will expand this testing in CY15. The program should ensure adequate testing of ALIS software upgrades on operationally-representative hardware is complete prior to fielding to operational units.
  - In the last year, the Program Office adjusted the schedule and incremental development plans for ALIS hardware and software capability releases three times. These adjustments were necessary to align ALIS capabilities with Service requirements to support planned IOC declaration dates.
    - In December 2013, the program re-planned the schedule and capability release of ALIS 2.0.0, the next version to be fielded, moving the initial release from November 2014 to January 2015.
    - In February 2014, the program adjusted the schedule and release plans for the follow-on version of ALIS, version 2.0.1. The schedule for fielding was adjusted by three months (from March 2015 to June 2015) and the life limited parts management (LLPM) module was deferred to later increments of ALIS. Because of delays in development, the LLPM capability was split into two increments (initial and final); the initial increment will be fielded with ALIS 2.0.2 and aligned to support Air Force IOC plans, and the final increment of LLPM will be fielded in ALIS 2.0.3.
    - In November 2014, the program adjusted the schedule and release plans again, moving the final increment of the LLPM to ALIS 3.0.0 and accelerating the integration of an upgraded processor from ALIS 3.0.0 to ALIS 2.0.2, eliminating the need for ALIS release 2.0.3. The content previously planned for ALIS 3.0.0 will be renamed 3.0.1. The program's planned release dates are July 2017 for ALIS 3.0.0 and July 2018 for ALIS 3.0.1.
    - A Windows server update has moved forward to an earlier ALIS release, from ALIS 3.0.0 to 2.0.1, which the program plans to field in June 2015.
- During CY14, the program accomplished the following with ALIS software development and fielding:
  - The program completed the migration of operational units from older versions to ALIS 1.0.3 (the current fielded version) in January 2014 as planned, followed by an updated version in February 2014 (version 1.0.3A3.3.1), which included limited fixes for deficiencies identified during testing in late CY12 and early CY13. ALIS 1.0.3A.3.3.1 has reduced screen refresh and load times compared to 1.0.3, and reduced the number of nuisance/false health reporting codes; however, time-consuming workarounds are required to determine and update the readiness of aircraft to fly missions. The following are examples of workarounds.
    - Additional steps required to process aircraft health information to be compatible with the Exceedance Management System, which is not integrated into ALIS.
    - Manual entry of information into ALIS to track consumables such as oil usage.
    - Frequent submission of formal ARs to Lockheed Martin for assistance, because troubleshooting functionality is incomplete.
    - Manual correlation of health reporting codes between ALIS domains.

- In future versions of ALIS, the program plans to address the above workarounds and include three key requirements identified by the Services as needed for IOC:
  - Integration with a new deployable ALIS standard operating unit (SOU) hardware (SOU V2, described below)
  - Support of detached, sub-squadron operations at deployment locations away from the main operating base
  - Distributed maintenance operations allowing supervisors to verify completion of maintenance operations from various locations at the main or deployed operating base (i.e., dynamic routing).
- The next major increment of ALIS software, version 2.0.0, began testing with the mission systems developmental test aircraft at Edwards AFB in September 2014. The program plans to field version 2.0.0 starting in January 2015. The ALIS 2.0.0 upgrade includes integrated exceedance management, Windows 7, recording of structural health data for use in the future development of prognostic health capabilities, and continued optimization efforts with improvements to data structures and database tuning.
  - Testing of the screen refresh times for ALIS 2.0.0 in a laboratory environment has shown improvement compared to those observed with ALIS 1.0.3A3.3.1. For example, in a simulated environment supporting 28 aircraft, squadron health management debrief time decreased from 101 seconds to less than 5 seconds after implementation of several cycles of improvements. Actual fielded performance is unknown.
  - Preliminary results from the LT&E of ALIS 2.0.0 show that multiple deficiencies from past evaluations remain unresolved, and the system demonstrated deficiencies in new capabilities. Although results have not been finalized with a deficiency review board, the initial LT&E report indicates:
    - » A critical deficiency noted in the LT&E of ALIS 1.0.3 for the failure of the manual control override to work correctly, which results in the incorrect reporting of the air vehicle status as not mission capable in the squadron health management function of ALIS, has not been corrected in ALIS 2.0.0.
    - » ALIS 2.0.0 demonstrated 4 additional critical deficiencies and 53 serious deficiencies.
    - » Exceedance management has been integrated into ALIS 2.0.0 but exhibited processing delays.
    - » The test site was unable to complete testing of all ALIS 2.0.0 functionality because the site lacks a squadron operating unit and instead relied on data transfers between Edwards AFB and Fort Worth, Texas. The test team recommended that the remaining tests be conducted at an operating location with representative hardware.
- ALIS 2.0.0 will provide the basis for incremental builds (versions 2.0.1 and 2.0.2), which are intended to be fielded in support of Marine Corps IOC and the Air Force IOC declarations, respectively.
  - The program plans to deliver ALIS 2.0.1 to the flight test center in February 2015, conduct a formal LT&E, in preparation for fielding in July 2015, which is the current objective date for Marine Corps IOC. ALIS 2.0.1 software will align with a new hardware release (SOU version 2) that will improve deployability and will include fault isolation improvements and a Windows server update.
  - To support the Marine Corps preparation for IOC, the program plans to release ALIS 2.0.1 in May 2015 to Yuma MCAS, Arizona, simultaneous with the planned delivery of the deployable ALIS hardware system for limited validation and verification testing of the software prior to release to the rest of the fielded units. Though the current ALIS release schedule leaves no margin for delay to meeting the Marine Corps IOC objective date in July, fielding ALIS 2.0.1 before formal testing and fix verification is complete may result in the continued need for workarounds to support field operations.
- The program has scheduled ALIS 2.0.2 fielding, which is required to meet Air Force IOC requirements, for December 2015. It will provide a sub-squadron reporting capability that allows air vehicle status reporting of deployed assets back to the parent SOU, and adds dynamic routing, which allows delivery of messages and data via alternate network paths. ALIS 2.0.2 will also reduce the need for propulsion contractor support by integrating the first portion of a required LLPM capability.
- ALIS 3.0.0 will complete the majority of the ALIS development effort. The schedule, which is pending approval, shows a fielding date of July 2017. This version of ALIS will include a complete LLPM capability and eliminate the need for propulsion contractor support.

• The following sections describe progress in the development and fielding of ALIS hardware and alignment with ALIS software capabilities described earlier:
  - The program continued to field ALIS hardware components at new locations during CY14 as the global sustainment bed-down and F-35 basing continued to be activated. The table on the following page shows ALIS components, location, and sustainment function for new components fielded in CY14.
  - In order to reduce post-flight data download times, the program added and fielded a new piece of hardware, the Portable Maintenance Device (PMD) reader, to operational units beginning in July 2014. The PMD reader is designed to accelerate the download of unclassified maintenance data from the aircraft without the need for a secure facility. The PMD reader permits maintenance personnel to download maintenance data only, vice waiting for full portable memory device download from the aircraft to be processed in a secure facility via the Ground Data Security

Assembly Receptacle (GDR). Testing of the PMD could not be done at the flight test center because the architecture of the ALIS supporting the developmental testing aircraft is not production-representative. The fielded PMD readers have functioned as intended. Maintenance downloads generally take less than 5 minutes using a PMD reader, while the procedure using the ground data receptacle – which downloads all data recorded on the PMD – usually takes an hour, delaying access to maintenance information.

- SOU Version 1 (SOU V1), the current ALIS unit-level hardware configuration, failed to meet the deployability requirement in the ORD due to its size, bulk, and weight. The program is developing a deployable version of the SOU, deemed SOU Version 2 (SOU V2). It will support Block 2B, Block 3i, and Block 3F aircraft, and is needed for service IOC dates. It will be incrementally developed and fielded with increasing capability over the next several years.
  - The first increment of SOU V2, a modularized and man-portable design for easier deployability, will first be made available to Marine Corps for IOC in 2015. This first increment aligns SOU V2 hardware and ALIS 2.0.1 software release. The program plans to conduct limited validation and verification testing of the ALIS 2.0.1 software on the SOU V2 once delivered to Yuma MCAS (planned for May 2015), and prior to fielding it to other units in July.
  - The second increment of SOU V2 went on contract in August 2014. This increment will address Air Force hardware requirements for sub-squadron reporting capabilities and inter-squadron unit connectivity and will align with release of ALIS software version 2.0.2. It is scheduled to begin testing at the flight test centers in July 2015.
  - The third increment of SOU V2, which also went on contract in August 2014, will address hardware requirements for decentralized maintenance, which will allow maintenance personnel to manage tasks with or without connectivity to the main SOU and allow for a Portable Maintenance Aid-only detachment; it will align with ALIS 3.0.0.

ALIS HARDWARE FIELDED IN FY14		
Component	**Location**	**Function**
Central Point of Entry	Eglin AFB	One per country to provide in-country and software and data distribution, enable interoperability with government systems at national level, and enable ALIS data connectivity between bases.
Standard Operating Unit (SOU)	Beaufort Academic Training Facility Italian FACO Italian Pilot Training Center Australian Pilot Training Center Luke AFB Pilot Training Center Nellis AFB 57th Fighter Wing Netherlands SOU (at Edwards AFB)	Supports squadron-level F-35 operations, including maintenance, supply chain management, flight operations, training, and mission planning.
Base Kit	Nellis AFB Edwards AFB	Centralizes base supply for bases operating with several squadrons.
LHD Ship Kit	USS *Wasp*	Similar to a squadron kit but permanently installed shipboard.
Deployment Kit	Luke AFB Pilot Training Center	Short of a full squadron kit but contains sufficient hardware to support four aircraft. Will become a squadron kit upon delivery of remaining hardware.
Depot Kit	Hill AFB MCAS Cherry Point	Similar to a base kit but geared to support depot operations.

- ALIS was designed to provide the analytical tools and algorithms to assess air vehicle health management using health reporting codes (HRCs) collected during flight. These functions will enable the Prognostic Health and Management (PHM) System as it matures. PHM has three major components: fault and failure management (diagnostic capability), life and usage management (prognostic capability), and data management, all of which will be an integral part of ALIS. Currently PHM has no prognostic capability, while diagnostic and data management functionality remain immature. The program plans to include the first set of prognostic algorithms in ALIS 2.0.2.
  - Diagnostic capability is designed to enable maintenance by detecting true faults within the air vehicle and accurately isolating those faults to a line-replaceable component. To date, the diagnostic functional capability has demonstrated low detection rates, poor accuracy, and high false alarm rates. The table on the following page shows metrics of diagnostic capability, the ORD threshold requirement at maturity (200,000 hours), and demonstrated performance as of May 2014. For comparison, demonstrated performance from May 2013 is also shown. While detection and isolation performance metrics improved between May 2013 and May 2014, mean flight hours between false alarm performance decreased (worsened).
  - As a result, fielded operations have had to rely on manual workarounds, such as maintainer-initiated built-in tests, extra scheduled inspections, and reliance on contractor support personnel, for more accurate diagnostics of system faults. Although these workarounds have aided troubleshooting, they increase the maintenance man-hours per flight hour and reduce sortie generation rates.

METRICS OF DIAGNOSTIC CAPABILITY			
Diagnostic Measure	Threshold Requirement	Demonstrated Performance (May 2013)	Demonstrated Performance (May 2014)
Fault Detection Coverage (percent mission critical failures detectable by PHM)	98	74	81
Fault Detection Rate (percent correct detections for detectable failures)	98	73	81
Fault Isolation Rate (percentage): Electronic Fault to One LRC	90	77	72
Fault Isolation Rate (percentage): Non-Electronic Fault to One LRC	*70*	70	79
Fault Isolation Rate (percentage): Non-Electronic Fault to 3 or Fewer LRC	90	80	85
Mean Flight Hours Between False Alarm	50	0.59	0.23
Mean Flight Hours Between Flight Safety Critical False Alarm	450	69	170

Joint Technical Data (JTD)

- Lack of verified JTD modules continues to challenge fielded operations, requiring workarounds such as ARs to the contractor for engineering dispositions on required maintenance actions. Also, maintenance personnel in the fielded units are finding that verified JTD may not be adequate to complete maintenance actions efficiently, such as an engine removal and replacement and maintenance built-in test troubleshooting.
- JTD modules are first identified as needed in the field, then developed by the contractor, and finally verified before being provided to the operating locations. Entire JTD packages (i.e., all JTD modules bundled together) are periodically distributed to field locations using ALIS, and then downloaded at the units to the Portable Maintenance Aids.
  - The current process is cumbersome, as all modules are distributed together, including modules with no changes or updates, along with new modules and those with updates. ALIS 2.0.0 should allow the program to deliver partial JTD builds (i.e., changes and amendments to existing JTD).
  - The total number of data modules identified continues to grow as the program matures and additional JTD deliveries are added in LRIP contracts. According to Program Office schedules, the development of identified JTD modules for each variant of air vehicle and for propulsion is on track to meet Service milestones. Air vehicle JTD includes time compliance technical data, depot-level technical data, air vehicle diagnostics and troubleshooting procedures, complete structural field repair series data, aircraft battle damage assessment and repair, and maintenance training equipment. Propulsion JTD development is nearly complete and on schedule. Development of Support Equipment (SE) JTD lags the Program Office schedule by 9 percent (approximately 200 modules out of 2,150 identified), primarily due to the lack of delivery of fault isolation engineering source data.
- Verification of air vehicle JTD modules is behind and has been slowed by the program's dependence on production aircraft to conduct opportunistic aircraft verification events. Because priority is given to the flight schedule, verification events are not scheduled and require support from the field to complete JTD verification. The program has identified more air vehicle JTD modules during the last year, hence the percentage of JTD modules verified has not increased substantially compared to what was reported in DOT&E's FY13 Annual Report. To reduce the number of unverified JTD modules at Marine Corps IOC declaration, the program should provide dedicated time on fielded aircraft for F-35B JTD verification teams.
  - SE JTD verification occurs as modules are developed and released in ALIS, so it lags the schedule by a similar amount as module development. SE assets at the training units at Eglin AFB are the primary source for SE verification.
  - The program placed Supportable Low Observable (SLO) JTD verification on contract in March 2014, with most verification performed using desktop analysis. SLO JTD verification for the F-35B is nearly complete. Since many of the SLO modules for the F-35A and F-35C variants are similar to those for the F-35B, the program expects the verification of SLO modules for those variants to proceed on schedule. SLO JTD verification data were not available at the time of this report; progress in identification and development of SLO modules is reported separately in the table below.
- As of the end of October, the program had verified approximately 84 percent of the identified air vehicle JTD modules for the F-35A, 74 percent for the F-35B, and 62 percent for the F-35C. The table on the following page shows the number of JTD modules identified, developed, and verified for the air vehicle (by variant), pilot flight equipment (PFE), and SE. Overall, 67 percent of the air vehicle, PFE, and SE identified modules have been verified. Propulsion JTD and SLO JTD are tracked and addressed separately.
- Propulsion JTD are current as of April 2014. More current information was not available for this report. Propulsion JTD development and verification has proceeded on schedule and the Program Office considers completion by the end of SDD as low risk.

- SLO JTD are current as of the end of October 2014. SLO JTD are tracked under a separate contract with a period of performance of February 2014 through April 2016. The Program Office did not have data showing verification of SLO JTD modules in time for this report.
- When verified JTD are not available or not adequate to troubleshoot or resolve a problem with an aircraft, maintenance personnel submit ARs to the contractor. These ARs are categorized as critical (Category 1) or severe (Category 2) and sub-categorized as high, medium, or low.
  - The contractor prioritizes and responds to ARs through an engineering team (referred to as the Lightning Support Team), which is composed of Service and contractor personnel.
  - As of October 15, 2014, 24 Category 1 ARs remained open while 617 Category 2 ARs were open. The number of open Category 1 ARs has remained relatively flat over the last year, while the number of open Category 2 ARs has decreased by two-thirds since January 2014.

F-35 JOINT TECHNICAL DATA DEVELOPMENT AND VERIFICATION STATUS
Air Vehicle, Pilot Flight Equipment (PFE), and Support Equipment (SE)
(as of October 2014)

	Module Type	Modules Identified	Modules Developed	Percent Identified Modules Developed	Modules Verified	Percent Identified Modules Verified
F-35A[1]	Unit-level	4,658	4,198	90.1%	3,893	83.6%
F-35B[1]	Unit-level	5,783	5,221	90.3%	4,300	74.4%
F-35C[1]	Unit-level	4,799	3,764	78.4%	2,949	61.5%
Common[2] (all variants)	Unit-level	322	201	62.4%	142	44.1%
PFE	Common	337	254	75.4%	250	74.2%
SE	Common	2,150	945	44.0%	604	28.1%
TOTAL		18,049	14,583	80.8%	12,138	67.3%

1. Includes field- and depot-level JTD for Operations and Maintenance, on- and off-equipment JTD, and structured field repairs.
2. Includes aircraft JTD for general repairs, sealants, bonding, structured field repairs, and non-destructive investigation.

F-35 JOINT TECHNICAL DATA DEVELOPMENT AND VERIFICATION STATUS
Propulsion
(as of October 2014)

	Module Type	Modules Identified	Modules Developed	Percent Identified Modules Developed	Modules Verified	Percent Identified Modules Verified
Propulsion	Engine and Lift Fan	3,123	2,988	95.7%	2,840	90.9%

F-35 JOINT TECHNICAL DATA DEVELOPMENT AND VERIFICATION STATUS
Supportable Low Observable (SLO)
(as of October 2014)

	Module Type	Modules Identified	Modules Developed	Percent Identified Modules Developed	Modules Verified	Percent Identified Modules Verified
SLO	F-35A	676	180	26.6%	N/A	N/A
	F-35B	550	52	9.5%		
	F-35C	547	52	9.5%		
	Common	2	0	0.0%		

Air-Ship Integration and Ship Suitability Testing

F-35B

- The program previously completed two test periods on the USS *Wasp* with developmental test aircraft, one in October 2011 and one in August 2013. These periods assessed handling qualities for take-off and landing operations at sea, and were used to develop an initial flight operating envelope for ship operations. ALIS was not deployed to the ship, and very limited maintenance operations were conducted (routine pre- and post-flight inspections, refueling operations, etc.).
- The Marine Corps began making plans to conduct another test period on the USS *Wasp* in May 2015 to assess ship integration and suitability issues, using non-instrumented production aircraft and a non-deployable version of ALIS (SOU V1) installed on the vessel. This deployment was originally a part of the Block 2B OUE; however, it is being re-scoped to support plans for the Marine Corps IOC later in 2015.
  - Up to six production aircraft are planned to be used for the deployment. These aircraft are not instrumented (as test aircraft are) and will allow the USS *Wasp* to operate its radars and communications systems in a representative manner since there is no concern with electromagnetic interference with flight test instrumentation.
  - The flight operations will not be representative of combat operations, unless the flight clearance and associated certifications enabling the deployment include clearances for weapons carriage and employment. These clearances are expected at fleet release, which the program plans to occur in July 2015, after the deployment.
  - Maintenance will be mostly military, but with contractor logistics support in line with expected 2015 shore-based operations, such as contractors for propulsion data downloads after each flight. Maintenance will be limited to that required for basic flight operations, staging necessary support equipment for engine and lift fan removals only to check if space permits, and loading and downloading demonstrations of inert ordnance on the flight deck.
  - These limitations are not representative of combat deployment operations.
- The Marine Corps and Naval Air Systems Command began exploring issues that would arise with employing more than six F-35B aircraft per Air Combat Element (ACE) on L-class

ships. ACE represents the mix of fixed- and rotary-wing aircraft assigned to the ship to conduct flight operations in support of Marine Corps combat objectives. These "heavy" ACEs could include up to 20 F-35Bs, or 12 or 16 F-35Bs plus MV-22Bs, depending on the specific L-class vessel. Through these exercises, they identified issues, many which will apply to standard-sized ACE operations as well. These issues include:

- The currently-planned service maintenance concept, where few components will be repaired underway but must be sent for repair back to a depot facility or to the Original Equipment Manufacturer (OEM) may not be achievable for initial fielding. The program is conducting a Level Of Repair Analysis (LORA) to assess the feasibility of repairing components at the Intermediate level, including onboard CVN and L-class ships.
- More than six F-35Bs in the ACE will require a more robust engine repair and resupply process than for the standard, six F-35B ACE. The Services are still investigating the best method for F135 engine re-supply at sea. Work continues on the heavy underway replenishment station and a re-designed engine storage container that can survive a drop of 18 inches while protecting the engine and weighing low enough to be transferred across the wire between the supply ship and the L-class or CVN ship. Adequate storage is needed for the engines, spare parts, and lift fans, as well as workspace for engine module maintenance within the small engine shops on L-class vessels.
- Moving an engine container, including placing an engine in or taking one out of the container, requires a 20,000 pound-class forklift and cannot be concurrent with flight ops since this item is required to be on the flight deck for crash and salvage purposes while flying. Engines can be moved around on a transportation trailer once removed from the container to enable engine maintenance in the hangar bay during flight operations.
- Adequate Special Access Program Facilities (SAPF) are required for flight planning and debriefing aboard the ship. Current modification plans for L-class vessels are expected to meet the requirements for a six F-35B ACE, but would be inadequate for an operation with more aircraft.
- Unlike many legacy aircraft, the F-35B needs external air conditioning when on battery power or an external power source. Cold fueling operations, when the engine is not turned on, will thus need an air conditioning cart. For many more F-35B's in the ACE, the logistics footprint will have to increase significantly to include more air conditioning units as many aircraft are refueled cold to achieve efficient operations.

F-35C

- The program began testing the redesigned arresting hook system on aircraft CF-3 at Patuxent River Naval Air Station in February 2014. This test aircraft is modified with unique instrumentation to monitor loads on the arresting hook system and the nose landing gear for catapult launches and arrested landings. The structural survey testing was a pre-requisite for initial carrier sea trials.
  - Testing encountered significant delays, as numerous deficiencies were discovered, some requiring new engineering designs. Testing was planned to be completed in July, to support deployment to a CVN for the first set of sea trials. The following problems caused delays:
    - In February, a hydraulic leak in the nose landing gear steering motor, caused by over-pressurization, required a redesigned valve and halted testing for 10 weeks.
    - Excessive galling of the arresting hook pitch pivot pin, which required a redesigned pin made of titanium and additional inspections after each landing.
    - Damage to the nose landing gear shock strut, which required down time for repair
  - The structural testing was partially completed in two phases, all on CF-3.
    - Phase one completed September 10, 2014, and consisted of 24 test points needed to clear a monitored envelope for carrier landings. Completion of phase one was necessary for CF-3 to conduct landings on a CVN in November.
    - Phase two consists of 20 additional test points to clear an unmonitored envelope for carrier landings. Completion of phase two testing would allow non-loads instrumented test aircraft to conduct landings on a CVN. Phase two work was ceased on September 25, with 17 of 20 phase two test points completed, but the program waived the remaining three test points to allow CF-5 to participate in DT-1.
- Carrier-based ship suitability testing is divided into three phases.
  - The first phase, DT-1, consisted of initial sea trials to examine the compatibility of F-35C with a CVN class ship and to assess initial carrier take-off and landing envelopes with steady deck conditions. DT-1 was conducted November 3 – 15, 2014; it was initially scheduled to begin in July.
    - Testers accomplished 100 percent of the threshold test points and 88 percent of the objective points during deployment, completing 33 test flights (39.2 flight hours) and 124 arrested landings, of 124 attempts, including one night flight with two catapult launches and two arrested landings. The results of the test were still in analysis at the time of this report.
    - No other aircraft deployed to the carrier, except transient aircraft needed for logistical support. All landings were flown without the aid of the Joint Precision Approach Landing System, which is planned for integration on the F-35C in Block 3F. No ALIS equipment was installed on the carrier. The test team created a network connection from the ship to the major contractor in Fort Worth to process necessary maintenance actions.

- The second and third phases, DT-2 and DT-3, consist of ship-borne operations with an expanded envelope (e.g., nighttime approaches, higher sea states than observed in DT-1, if available, and asymmetrical external stores loading). DT-2, which is currently planned for August 2015, will expand the carrier operating envelope. The third set of sea trials is planned for CY16.

• The Navy is working on the following air-ship integration issues, primarily for carriers. Each of the following integration issues also applies to F-35B on L-class ships, with the exception of Jet Blast Deflectors (JBDs):
  - Due to the higher temperature of F-35 engine exhaust compared to legacy aircraft, carrier JBDs need at least two modifications. A cooling water orifice modification enables basic operations, but additional side panel cooling must be added for higher afterburner thrust catapult launches. The Navy is accomplishing these full modifications on at least some JBDs on USS *Abraham Lincoln* (CVN-72) in preparation for IOT&E and on USS *George Bush* (CVN-77) for developmental testing, and performed the basic orifice modification on USS *Nimitz* (CVN-68) for the November DT-1.
  - The Lockheed Martin-developed F-35 ejection seat dolly failed Critical Design Review. The F-35 ejection seat has a higher center of gravity than legacy seats due to supports for the helmet-mounted display, and in the shipboard environment needs to be securely tied down in case of rolling motion from high sea states. The Navy is investigating developing less expensive adapters to the current ejection seat dolly, and determining what seat shop modifications (if any) will be required to safely tie down the dolly when a seat is installed.
  - Two separate methods for shipboard aircraft firefighting for the F-35 with ordnance in the weapon bays are being developed, one for doors open and one for doors closed. Each will consist of an adapter that can fit to the nozzle of a standard hose. The open door adapter will also attach to a 24-foot aircraft tow bar so firefighters can slide it underneath the aircraft and spray cooling water up into the bay.
    - Testing of a prototype open bay adapter was conducted in October and included use on an AV-8B hulk, propane fires, and JP-8 pool fires, as well as assessing ordnance cooling effectiveness. Mobility tests of the rig were also performed on CVN and L-class non-skid, asphalt, grass, dirt, and rough terrain. All tests indicate that the adapter provides sufficient access to the bay for water spray, and featured sufficient ease of use to place the adapter where needed quickly in all environments.
    - The closed door adapter will consist of a penetrating device to punch through the fuselage's carbon fiber skin, secure in place, and hold when water pressure is applied so deck personnel can then back away from the fire. The Navy also plans to test closed bay door firefighting testing of on-aircraft lithium ion battery fires.
  - Work on noise abatement during launch and recovery continues. The Navy is installing sound dampening material in the highest noise level areas for flight operations on the USS *Abraham Lincoln* (CVN-72) during its nuclear refueling and overhaul, and the Office of Naval Research (ONR) will analyze effectiveness compared to untreated ships. This effort will not involve treatment of all work areas, however, and may not be sufficient to allow conversational-level speech in every mission planning space during flight operations.
  - The need for improved flight deck hearing protection is not limited to the F-35, as the F-35 and F/A-18E/F Super Hornet produce similar maximum ground noise in afterburner (149 decibels for the F-35 and 150 decibels for the Super Hornet).
    - Based on an assumed F-35 noise environment of 149 decibels when in maximum thrust where personnel are normally located, 53 decibels of attenuation is required to enable 38 minutes of exposure to this worst-case noise per day before long-term hearing loss ensues. This is estimated to be equivalent to 60 launches and 60 recoveries.
    - Current expected performance for triple hearing protection only reaches into the mid 40's decibels of attenuation though, which enables less than 10 minutes exposure to maximum noise before the daily limit is reached. Workarounds may include re-positioning launch crew personnel and tighter administrative controls for exposure times.
  - The unique Integrated Power Package (IPP), and high-speed/low-thrust engine turn capability for maintenance on the F-35, may introduce new concerns for hangar bay maintenance. The Navy plans to investigate the impact of IPP exhaust emissions on hangar bay atmosphere, exhaust temperature, and the noise environment produced, to determine acceptable hangar bay maintenance practices. No IPP or engine turns were conducted during the DT-1 sea trials.

Progress in Plans for Modification of LRIP Aircraft

• Modification of production aircraft is a major endeavor for the program, driven by the large degree of concurrency between development and production, and is a burden independent of the progress made in developmental testing. Modifications are dependent on the production, procurement, and installation of modification kits, completed either at the aircraft depot locations or at the field units. The program will need to provide operationally representative Block 3F operational test aircraft for an adequate IOT&E.

• During CY14, the Program Office and Services continued planning for modification of early production aircraft to attain planned service life and the final SDD Block 3F capability, including the production aircraft that will be used to conduct operational testing. Planning had previously focused on modifying aircraft in preparation for the Block 2B OUE

and Marine Corps IOC, planned by the program to occur in mid-2015. This created challenges in obtaining long-lead items and dock availability at aircraft depots, and maintaining adequate aircraft availability to maintain pilot currency while eventually modifying all operational test aircraft into a production-representative Block 2B configuration. However, the decision to not conduct the Block 2B OUE allowed the program to focus on Marine Corps IOC aircraft requirements, while attempting to create a more efficient modification plan for operational test aircraft to achieve the Block 3F configuration.
  - The Program Office has prioritized Block 2B associated modification for Marine Corps F-35B IOC aircraft over operational test aircraft. Because manufacturers could not meet the schedule demand for modification kits, not all of the operational test aircraft will be in the Block 2B configuration by early 2015 when the planned start of spin-up training for the OUE would have occurred, as was noted in the FY13 DOT&E Annual Report.
  - Modification planning has also included early plans to ensure operational test aircraft scheduled for IOT&E will be representative of the Block 3F configuration. However, these plans show that the program is likely to face the same scheduling and parts shortage problems encountered in planning for Block 2B modifications of the operational test aircraft.
- Upgrading aircraft to a Block 2B capability requires the following major modifications: mission systems modifications; structural life limited parts (SLLP), referred to as Group 1 modifications; F-35B Mode 4 operations modifications, which include a modification to the three Bearing Swivel Module (3BSM) to allow F-35B aircraft to conduct unrestricted Mode 4 operations; OBIGGS; and upgrades to ALIS and the training systems to fully support Block 2B-capable aircraft.
  - The program maintains a modification and retrofit database that tracks modifications required by each aircraft, production break in of modifications, limitations to the aircraft in performance envelope and service life, requirements for additional inspections until modifications are completed, and operational test requirements and concerns.
  - The program uses this database to develop and update a complex flow plan of aircraft and engines through depot-level modifications, modifications completed by deployed depot field teams, and those completed by unit-level maintainers.
  - The current depot flow plan shows that none of the operational test aircraft would become fully Block 2B-capable by January 2015, and only 7 of 14 will complete the necessary modifications by July 2015, which was the planned start date of the Block 2B OUE. Block 2B modifications would finally be complete on all operational test aircraft in September 2016.
- Program Office modification planning for Block 3F IOT&E has begun and shows some of the same scheduling pressures as have been observed for Block 2B; however, these would have been much worse if the OUE were conducted. The depot flow plan includes a seven-month placeholder to complete all modifications to bring each operational test aircraft to a Block 3F configuration, though the span of time required to complete these modifications, including the next increment of structural modifications (SLLP Group 2), is unknown. Additions to modification packages are possible as the potential for discoveries in flight test still exists. Although the program has prioritized for modification the aircraft planned to be used for IOT&E, the Air Force plans for at least 12 F-35A aircraft to be available for IOC declaration in 2016. These Air Force IOC aircraft will be in the Block 3i configuration from production Lot 6 or later, and may require a post-production OBIGGS modification, which could compete for resources with the aircraft scheduled for IOT&E.
- Management of the SLLP Group 2 modifications will need to be handled carefully as the program and Services prepare for IOT&E. If the program does not schedule SLLP Group 2 modifications to operational test aircraft until after IOT&E is completed, 495 flight hours must remain before reaching that life limit so aircraft can fully participate in IOT&E, per the approved TEMP.

Recommendations

- Status of Previous Recommendations. The program and Services have been addressing the redesign and testing of the OBIGGS system, but performance assessment has not yet been completed. The Program Office addressed the vulnerability of the electrical power system to ballistic threats. The remaining recommendations concerning the reinstatement of the PAO shut-off valve, reinstatement of the dry-bay fire extinguisher system, design and reinstatement of fueldraulic shut-off system, improvement of the Integrated Caution and Warning system to provide the pilot with necessary vulnerability information, and a higher resolution estimate of time remaining for controlled flight after a ballistic damage event are all outstanding.
- FY14 Recommendations. The program should:
  1. Update program schedules to reflect the start of spin-up training for IOT&E to occur no earlier than the operational test readiness review planned for November 2017, and the associated start of IOT&E six months later, in May 2018.
  2. The program should complete lab testing of the mission data loads, as is planned in the mission data optimization operational test plan, prior to accomplishing the necessary flight testing to ensure the loads released to the fleet are optimized for performance. If mission data loads are released to operational units prior to the completion of the lab and flight testing required in the operational test plan, the risk to operational units must be clearly documented.
  3. The program should complete the remaining three Block 2B weapon delivery accuracy (WDA) flight test events using the currently planned scenarios and ensuring full mission

systems functionality is enabled in an operationally realistic manner.

4. The program should require the contractor to conduct rigorous finite-element analyses to assess the benefit of LSP application for the F-35B durability test article and for the F-35B FS496 bulkhead redesign.
5. The program should provide adequate resourcing to support the extensive validation and verification requirements for the Block 3 VSim in time for IOT&E, including the data needed from flight test or other test venues.
6. To accelerate verification of JTD modules, the program should provide dedicated time on fielded aircraft for F-35B JTD verification teams.
7. Extend the full-up system-level decontamination test to demonstrate the decontamination system effectiveness in a range of operationally realistic environments.
8. The program should ensure adequate testing of ALIS software upgrades on operationally-representative hardware is complete prior to fielding to operational units.

F-35 Joint Strike Fighter (JSF)

Executive Summary

Test Planning, Activity, and Assessment

- The program focused on culminating Block 2B development and testing in order to provide a fleet release enabling the Marine Corps F-35B Joint Strike Fighter (JSF) declaration of Initial Operational Capability (IOC), while transitioning development and flight test resources to Block 3i and Block 3F.
  - The program terminated Block 2B developmental flight testing in May 2015, delivering Block 2B capability with deficiencies and limited combat capability. The Marine Corps declared IOC at the end of July 2015. However, if used in combat, the Block 2B F-35 will need support from command and control elements to avoid threats, assist in target acquisition, and control weapons employment for the limited weapons carriage available (i.e., two bombs, two air-to-air missiles). Block 2B deficiencies in fusion, electronic warfare, and weapons employment result in ambiguous threat displays, limited ability to respond to threats, and a requirement for off-board sources to provide accurate coordinates for precision attack. Since Block 2B F-35 aircraft are limited to two air-to-air missiles, they will require other support if operations are contested by enemy fighter aircraft. The program deferred deficiencies and weapons delivery accuracy (WDA) test events from Block 2B to Block 3i and Block 3F, a necessary move in order to transition the testing enterprise to support Block 3i flight testing and Block 3F development, both of which began later than planned in the program's Integrated Master Schedule (IMS).
  - Block 3i developmental flight testing restarted for the third time in March 2015, after two earlier starts in May and September 2014. Block 3i developmental flight testing completed in October, eight months later than planned by the program after restructuring in 2012, as reflected in the IMS. Block 3i began with re-hosting immature Block 2B software and capabilities into avionics components with new processors. Though the program originally intended that Block 3i would not introduce new capabilities and not inherit technical problems from earlier blocks, this is what occurred. The Air Force insisted on fixes for five of the most severe deficiencies inherited from Block 2B as a prerequisite to use the final Block 3i capability in the Air Force IOC aircraft; Air Force IOC is currently planned for August 2016 (objective) or December 2016 (threshold). However, Block 3i struggled during developmental testing (DT), due to the inherited deficiencies and new avionics stability problems. Based on these Block 3i performance issues, the Air Force briefed that Block 3i mission capability is at risk of not meeting IOC criteria to the Joint Requirements Oversight Council (JROC) in December 2015. The Air Force recently received its first Block 3i operational aircraft and is assessing the extent to which Block 3i will meet Air Force IOC requirements; this assessment will continue into mid-2016.
  - Block 3F developmental flight testing began in March 2015, 11 months later than the date planned by the program after restructuring in 2012, as reflected in the IMS. Progress has been limited (flight testing has accomplished approximately 12 percent of the Block 3F baseline test points as of the end of November) as the program focused on closing out Block 3i testing and providing a software version suitable to support plans for the Air Force to declare IOC in August 2016.
- The current schedule to complete System Development and Demonstration (SDD) and enter IOT&E by August 2017 is unrealistic.
  - Full Block 3F mission systems development and testing cannot be completed by May 2017, the date reflected in the most recent Program Office schedule, which is seven months later than the date planned after the 2012 restructure of the program. Although the program has recently acknowledged some schedule pressure and began referencing July 31, 2017, as the end of SDD flight test, that date is unrealistic as well. Instead, the program will likely not finish Block 3F development and flight testing prior to January 2018, an estimate based on the following assumptions:
    - Continuing a six test point per flight accomplishment rate, which is equal to the calendar year 2015 (CY15) rate observed through the end of November.

- Continuing a flight rate of 6.8 flights per month, as was achieved through the end of November 2015, exceeding the planned rate of 6 flights per month (note that if the flight rate deteriorates to the planned rate of 6 flights per month, then testing will not complete until May 2018).
- Completing the full Block 3F test plan (i.e., all 7,230 original baseline and budgeted non-baseline test points in the Block 3F joint test plan).
- Continuing the CY15 discovery rate of 5 percent, i.e., 5 additional test points are required to address new discoveries per 100 baseline test points accomplished. This assumption is optimistic. In the likely event significant new discoveries continue during developmental testing in 2016, additional Block 3F software releases would be needed to address them, adding more test points and extending development further.

- The program could, as has been the case in testing previous software increments, determine that test points in the plan are no longer required for the Block 3F fleet release. However, the program will need to ensure that deleting and/or deferring Block 3F testing before the end of SDD and start of IOT&E does not result in increasing the likelihood of discovery of deficiencies in IOT&E or degrading F-35 combat capability. Whatever capability the program determines as ready for IOT&E will undergo testing fully consistent with the Department's threat assessments, war plans, and the Services' concepts of operation.

- The program has proposed a "block buy" that commits to and combines procurement of three lots of aircraft to gain savings. Executing the "block buy" would require commitments to procuring as many as 270 U.S. aircraft, as well as commitments by foreign partners to purchasing substantial numbers of aircraft. Depending upon the timing, it is possible a commitment to the "block buy" would be made before operational testing is complete. In that case, entering a "block buy" would raise the following questions:
  - Is it premature to commit to the "block buy" given that significant discoveries requiring correction before F-35's are used in combat are occurring, and will continue to occur, throughout the remaining developmental and operational testing? The program continues to struggle with Block 3F developmental testing, and in December 2015 the Air Force rated its proposed initial operational capability supported by Block 3i as "red" due to the problems ongoing testing has revealed.
  - Is it prudent to further increase substantially the number of aircraft bought that may need modifications to reach full combat capability and service life? As the program manager has noted, essentially every aircraft bought to date requires modifications prior to use in combat.
  - Would committing to a "block buy" prior to the completion of IOT&E provide the needed incentives to the contractor and the Program Office to correct an already substantial list of deficiencies in performance, a list that will only lengthen as Block 3F testing continues and IOT&E is conducted?
  - Would entering a "block buy" contract prior to the completion of IOT&E be consistent with the "fly before you buy" approach to defense acquisition that many in the Administration have supported? Similarly, would such a "block buy" be consistent with the intent of Title 10 U.S. Code, which stipulates that IOT&E must be completed and a report on its results provided to Congress before committing to Full-Rate Production—a commitment that some could argue would be made by executing the "block buy?"

Helmet Mounted Display System (HMDS)

- The program tested the Generation III (Gen III) helmet-mounted display system (HMDS), which is intended to resolve all of the deficiencies discovered in the Gen II system in prior years. The Gen III system is a requirement for Air Force IOC in 2016; it will be the helmet used to complete SDD and IOT&E. After Gen III developmental testing, developmental test pilots reported less jitter, proper alignment, improved ability to set symbology intensity, less latency in imagery projections, and improved performance of the night vision camera. However, operational testing in realistic conditions and mission task levels, including gun employment, is required to determine if further adjustments are needed.

Mission Data Load Development and Testing

- The F-35 relies on mission data loads—which are a compilation of the mission data files needed for operation of the sensors and other mission systems—to work in conjunction with the system software data load to drive sensor search parameters and to identify and correlate sensor detections, such as threat and friendly radar signals. The U.S. Reprogramming Lab (USRL), a U.S. government lab, produces these loads for U.S. operational and training aircraft. Mission data optimization testing, which includes both lab-testing and flight-testing, is conducted by an Air Force operational test unit augmented by Navy personnel. The unit provides the test plans to the DOT&E for approval and independent oversight.
- Significant deficiencies exist in the USRL that preclude efficient development and adequate testing of effective mission data loads for Block 3F. Despite being provided a $45 Million budget in FY13, the program has still not designed, contracted for, and ordered the required equipment—a process that will take at least two years, not counting installation and check-out. In addition, despite the conclusions of a study by the Program Office indicating that substantial upgrades are needed to the laboratory's hardware, the program is currently only pursuing a significantly lesser upgrade due to budgetary constraints. This approach would leave the USRL with less capability than the F-35 Foreign Military Sales Reprogramming Lab. Unless remedied, these deficiencies in the USRL will translate into significant limitations for the F-35 in combat against existing threats.

The program must take immediate action to complete required modifications and upgrades to the lab before the USRL is required to provide the Block 3F mission data load for tactics development and preparations for IOT&E.

- After the program delayed the build-up of the USRL equipment and software tools, which created schedule pressure on Block 2B mission data load development and testing, the Program Office forced the USRL to truncate the planned testing, forgoing important steps in mission data load development in order to provide a limited mission data load in June 2015 for the Marine Corps IOC declaration in July 2015. Fielded operational units must take into consideration the limited extent of lab and flight testing that occurred—which creates uncertainties in F-35 effectiveness—until the USRL is able to complete development and testing of a Block 2B mission data load. This is planned to occur in early 2016.

Weapons Integration

- The program terminated Block 2B developmental testing for weapons integration in December 2015 after completing 12 of the 15 planned WDA events. The program planned to complete all 15 WDA events by the end of October 2014, but delays in implementing software fixes for deficient performance of mission systems sensors and fusion delayed progress. Three events were deferred to Block 3i (one event) and Block 3F (two events) developmental testing.
  - Eleven of the 12 events required intervention by the developmental test control team to overcome system deficiencies and ensure a successful event (i.e., acquire and identify the target and engage it with a weapon). The program altered the event scenario for three of these events, as well as the twelfth event, specifically to work around F-35 system deficiencies (e.g., changing target spacing or restricting target maneuvers and countermeasures).
  - The performance of the Block 2B-configured F-35, if used in combat, will depend in part on the degree to which the enemy's capabilities exceed the constraints of these narrow scenarios and the operational utility of the workarounds necessary for successful weapons employment.
- The Block 3F WDA events plan currently contains events that will test Block 3F capabilities to employ the GBU-12 Paveway II laser-guided bomb, GBU-31/32 Joint Direct Attack Munition (JDAM), Navy Joint Stand-off Weapon (JSOW)-C1, Small Diameter Bomb I (SDB-1), AIM-120C Advanced Medium-Range Air-to-Air Missile (AMRAAM), AIM-9X, and the gun in the full operating environment of each variant.
  - The Block 3F developmental test WDA plan contains 48 events in the approved Test and Evaluation Master Plan (TEMP), plus two WDA events deferred from Block 2B, for a total of 50. These 50 WDA events cannot be accomplished within the remaining time planned by the Program Office to complete Block 3F flight test (by May 2017, per the program's master schedule), nor by July 2017 (the most recent briefed date to complete Block 3F flight test from the Program Office), and support the date in the IMS for the Block 3F fleet release (August 2017). The past WDA event execution rate is approximately one event per month. The test team would need to triple this rate to complete all WDA events in the approved TEMP by May 2017. However, these Block 3F events are more complex than the Block 2B and 3i events.
  - In an attempt to meet the schedule requirements for weapon certification, the Program Office has identified 10 WDA events for the F-35A and 5 events for the F-35B and F-35C that must be accomplished during Block 3F developmental testing. The program still plans to accomplish the remaining 33 events, if schedule margin allows. The overall result of the WDA events must be that the testing yields sufficient data to evaluate Block 3F capabilities. Deleting numerous WDA events puts readiness for operational testing and employment in combat at significant risk.

Verification Simulation (VSim)

- Due to inadequate leadership and management on the part of both the Program Office and the contractor, the program has failed to develop and deliver a Verification Simulation (VSim) for use by either the developmental test team or the JSF Operational Test Team (JOTT), as has been planned for the past eight years and is required in the approved TEMP. Neither the Program Office nor the contractor has accorded priority to VSim development despite early identification of requirements by the JOTT, $250 Million in funding added after the Nunn-McCurdy-driven restructure of the program in 2010, warnings that development and validation planning were not proceeding in a productive and timely manner, and recent (but too late) intense senior management involvement.
- The Program Office's sudden decision in August 2015 to move the VSim to a Naval Air Systems Command (NAVAIR)-proposed, government-led Joint Simulation Environment (JSE), will not result in a simulation with the required capabilities and fidelity in time for F-35 IOT&E. Without a high-fidelity simulation, the F-35 IOT&E will not be able to test the F-35's full capabilities against the full range of required threats and scenarios. Nonetheless, because aircraft continue to be produced in substantial quantities (all of which will require some level of modifications and retrofits before being used in combat), the IOT&E must be conducted without further delay to evaluate F-35 combat effectiveness under the most realistic conditions that can be obtained. Therefore, to partially compensate for the lack of a simulator test venue, the JOTT will now plan to conduct a significant number of additional open-air flights during IOT&E relative to the previous test designs. In the unlikely event a simulator test venue is available, the additional flights would not be flown.

Suitability

- The operational suitability of all variants continues to be less than desired by the Services and relies heavily on contractor support and workarounds that would be difficult to employ in

a combat environment. Almost all measures of performance have improved over the past year, but most continue to be below their interim goals to achieve acceptable suitability by the time the fleet accrues 200,000 flight hours, the benchmark set by the program and defined in the Operational Requirements Document (ORD) for the aircraft to meet reliability and maintainability requirements.
- Aircraft fleet-wide availability continued to be low, averaging 51 percent over 12 months ending in October 2015, compared to a goal of 60 percent.
- Measures of reliability that have ORD requirement thresholds have improved since last year, but eight of nine measures are still below program target values for the current stage of development, although two are within 5 percent of their interim goal; one—F-35B Mean Flight Hours Between Maintenance Event (Unscheduled)—is above its target value.
- F-35 aircraft spent 21 percent more time than intended down for maintenance and waited for parts from supply for 51 percent longer than the program targeted. At any given time, from 1-in-10 to 1-in-5 aircraft were in a depot facility or depot status for major re-work or planned upgrades. Of the fleet that remained in the field, on average, only half were able to fly all missions of even a limited capability set.
- The amount of time required to repair aircraft and return them to flying status remains higher than the requirement for the system when mature, but there has been improvement over the past year.
- The program fielded new software for the Autonomic Logistics Information System (ALIS) during 2015. All fielded units transitioned from version 1.0.3 to 2.0.0 between January and April 2015. Additional increments were tested—2.0.1 and 2.0.1.1—which included software updates to correct deficiencies discovered in 2.0.1. Version 2.0.1.1 software was fielded to operational units between May and October 2015. These versions included new functions, improved interfaces, and fixes for some of the deficiencies in the earlier ALIS versions. However, many critical deficiencies remain which require maintenance personnel to implement workarounds to address the unresolved problems.

Live Fire Test and Evaluation (LFT&E)

- The F-35 LFT&E program completed one major live fire test series using an F-35C variant full-scale structural test article (CG:0001) with an installed Pratt and Whitney F135 engine. Preliminary test data analyses:
  - Demonstrated the tolerance of the F135 initial flight release (IFR) configured engine to threat-induced fuel discharge into the engine inlet
  - Confirmed the expected vulnerabilities of the fuel tank structure
- The program demonstrated performance improvements of the redesigned fuel tank ullage inerting system in the F-35B fuel system simulator (FSS). However, aircraft ground and flight tests, designed to validate the fuel system simulator tests and aircraft system integration, revealed design deficiencies that require further hardware and software modifications.
- The test plan to assess chemical and biological decontamination of pilot protective equipment is not adequate; no plans have been made to test either the Gen II or the Gen III HMDS. The Program Office is on track to evaluate the chemical and biological agent protection and decontamination systems in the full-up system-level decontamination test planned for FY16.
- The Navy completed vulnerability testing of the F-35B electrical and mission systems to the electromagnetic pulse (EMP).
- The F-35 program continues to collect data to support the lethality evaluation of the 25 mm x 137 mm PGU-48 Frangible Armor Piercing (FAP) round, a designated round for the F-35A variant, and the PGU-32/U Semi-Armor Piercing High Explosive Incendiary-Tracer (SAPHEI-T) ammunition currently designated for the F-35B and F-35C variants.

Air-Ship Integration and Ship Suitability

- The Marine Corps conducted a suitability demonstration with six operational F-35B aircraft onboard the USS *Wasp* from May 18 – 29, 2015.
  - As expected, the demonstration was not an operational test and could not demonstrate that the F-35B is operationally effective or suitable for use in combat. This is due to the following:
    - Lack of production-representative support equipment
    - Provision of extensive supply support to ensure replacement parts reached the ship faster than would be expected in deployed combat operations
    - Incompleteness of the available maintenance procedures and technical data, which required extensive use of contractor logistics support
    - Lack of flight clearance to carry and employ combat ordnance
    - Lack of the full complement of electronic mission systems necessary for combat on the embarked aircraft
    - No other aircraft, and their associated equipment, that would normally be employed with an Air Combat Element (ACE) were present, other than three MH-60S rescue helicopters
  - The USS *Wasp* demonstration event did, however, provide useful training for the Marine Corps and amphibious Navy with regards to F-35B operations onboard L-class ships, and also provided findings relevant to the eventual integration of the F-35B into the shipboard environment. However, aircraft reliability and maintainability were poor, so it was difficult for the detachment to keep more than two to three of the six embarked aircraft in a flyable status on any given day, even with significant contractor assistance. Aircraft availability during the deployment was approximately 55 percent. Around 80 percent availability

would be necessary to generate four-ship combat operations consistently with a standard six-ship F-35B detachment.

- The second phase of F-35C ship suitability testing on CVN class carriers, Developmental Test – Two (DT-2), was conducted from October 2 – 10, 2015. Ship availability delayed the start of DT-2 from the planned date in August 2015. The principal goal of DT-2 was to perform launch and recovery of the F-35C with internal stores loaded.
- The Navy continues to work on numerous air-ship integration issues including carrier Jet Blast Deflector (JBD) design limitations, as well as improving support equipment, hearing protection, and firefighting equipment.

Cybersecurity Testing

- In accordance with DOT&E and DOD policy, the JOTT developed and presented a cybersecurity operational test strategy to DOT&E for approval in February 2015. This strategy established a schedule and expectations for cybersecurity testing of the JSF air system through the end of SDD and IOT&E in late 2017. The strategy includes multiple assessments aligned with the blocks of capability as the program delivers them to the field in both the air vehicle and ALIS. The test teams will conduct the assessments on fielded, operational equipment. All testing requires coordination from the JSF Program Executive Officer, via an Interim Authority to Test (IATT). This testing is OT&E where DOT&E approves plans and independently reports results. The test strategy, approved by DOT&E, includes end-to-end testing of all ALIS components and the F-35 air vehicle.
- The JOTT began planning Cooperative Vulnerability and Penetration Assessments (CVPAs) and Adversarial Assessments (AAs) of all ALIS components in the latest configuration to be fielded—ALIS 2.0.1.1—as well as the F-35 air vehicle in the Block 2B configuration. The JOTT planned a CVPA for September 21 through October 2, 2015, and an AA from November 9 – 20, 2015. However, the test teams were not able to complete the CVPA as planned because the Program Office failed to provide an IATT due to insufficient understanding of risks posed to the operational ALIS systems by cybersecurity testing. This testing was postponed and combined with an AA, planned to take place in early November 2015. However, the Program Office approved only a partial IATT, which allowed a CVPA of the ALIS components at Edwards AFB, California, and a CVPA of the Operational Central Point of Entry (CPE)—a major network hub in the overall ALIS architecture—to proceed. Although authorized, the AA for the CPE was not accomplished because the IATT was approved too late for the AA team to make arrangements for the test. The limited testing that was permitted revealed significant deficiencies that must be corrected and highlighted the requirement to complete all planned cybersecurity testing.
- Only ALIS components were planned to be tested in these events in late 2015; inclusion of the air vehicle is planned for future events. An end-to-end enterprise event, which links each component system, including the air vehicle, is required for adequate cybersecurity operational testing.

Pilot Escape System

- The program conducted two sled tests on the pilot escape system in July and August 2015 that resulted in failures of the system to successfully eject a manikin without exceeding load/stress limits on the manikin. These sled tests were needed in order to qualify the new Gen III HMDS for flight release. In July 2015, a sled test on a 103-pound manikin with a Gen III helmet at 160 knots speed demonstrated the system failed to meet neck injury criteria. The program did not consider this failure to be solely caused by the heavier Gen III helmet, primarily due to similarly poor test results observed with the Gen II helmet on a 103-pound manikin in 2010 tests. The program conducted another sled test in August 2015 using a 136-pound manikin with the Gen III helmet at 160 knots. The system also failed to meet neck injury criteria in this test. Similar sled testing with Gen II helmets in 2010 did not result in exceedance of neck loads for 136-pound pilots.
- After the latter failure, the Program Office and Services decided to restrict pilots weighing less than 136 pounds from flying any F-35 variant, regardless of helmet type (Gen II or Gen III). Pilots weighing between 136 and 165 pounds are considered at less risk than lighter weight pilots, but still at an increased risk (compared to heavier pilots). The level of risk was labeled “serious” by the Program Office based on the probability of death being 23 percent, and the probability of neck extension (which will result in some level of injury) being 100 percent. Currently, the Program Office and the Services have decided to accept this level of risk to pilots in this weight range, although the basis for the decision to accept these risks is unknown.
- In coordination with the Program Office, the ejection seat contractor funded a proof-of-concept ejection sled test in October to assess the utility of a head support panel (HSP), a fabric mesh behind the pilot’s head and between the parachute risers, to prevent exceeding neck loads during the ejection sequence for lighter weight pilots. Based on the initial results, the Program Office and Services are considering seat modifications that would include the HSP, but they may take at least a year to verify improvement and install them onto aircraft. Additional testing and analyses are also needed to determine the risk to pilots of being harmed by the transparency removal system (which shatters the canopy before, and in order for, the seat and pilot leave the aircraft) during ejections in other than ideal, stable conditions (such as after battle damage or during out-of-control situations).
- The program began delivering F-35 aircraft with a water-activated parachute release system in later deliveries of Lot 6 aircraft in 2015. This system, common in current fighter aircraft for many years, automatically jettisons the parachute when the pilot enters water after ejection; in the case of pilot incapacitation, an automatic jettisoning of the

parachute canopy is essential for aircrew survival. In June 2012, while reviewing preparations to begin training pilots at Eglin AFB, Florida, the Program Office accepted the serious risk of beginning training without the water-activated release system installed in the early production lots of training aircraft. At that time, the Program Office expected the full qualification of the system to be completed by the end of 2012.

System

- The F-35 JSF program is a tri-Service, 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/Vertical-Landing (STOVL)
  - F-35C Aircraft Carrier Variant (CV)
- It is designed to survive in an advanced threat (year 2015 and beyond) environment using numerous advanced capabilities. It is also designed to have improved lethality in this environment 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 GBU-31/32 JDAM, GBU-39 SDB, Navy JSOW-C1, AIM-120C AMRAAM, and AIM-9X infrared-guided short-range air-to-air missile.
- The program provides mission capability in three increments:
  - Block 1 (initial training; two increments were fielded: Blocks 1A and 1B)
  - Block 2 (advanced training in Block 2A and limited combat capability in Block 2B)
  - Block 3 (limited combat in Block 3i and full combat capability in Block 3F)
- 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

- The Combatant Commander will employ units equipped with F-35 aircraft to attack targets during day or night, in all weather conditions, and in highly defended areas of joint operations.
- The F-35 will be used to attack fixed and mobile land targets, surface units at sea, and air threats, including advanced aircraft and cruise missiles.

Major Contractor

Lockheed Martin, Aeronautics Division – Fort Worth, Texas

Test Strategy, Planning, and Resourcing

- The Program Office continues to plan for a start of IOT&E in August 2017, three months after the program's planned completion of developmental flight test in May 2017, or one month later than the recently briefed date of July 2017. In the intervening three months, the program must complete all the analyses and certification requirements to allow final preparations for IOT&E to begin. There are clear indications that it is no longer possible to meet the requirements to start an adequate IOT&E at that time. Specifically:
  - The program's joint test plans for Block 3F mission systems testing contain more testing than can be completed by May 2017, which is the planned end of Block 3F flight test, according to the most recent program schedule. Even extending until the end of July 2017 to compete System Development and Demonstration (SDD) flight test is not realistic. Instead, the program will likely not finish Block 3F development and flight testing prior to January 2018, based on the following:
    - Continuing a six test point per flight accomplishment rate, which is equal to the CY15 rate observed through the end of November
    - Continuing a flight rate of 6.8 flights per month with the 6 mission systems developmental test aircraft assigned to Edwards AFB, as was achieved through the end of November 2015, exceeding the planned rate of 6 flights per month (if the flight rate deteriorates to the planned rate of 6 flights per month, then testing will not complete until May 2018)
    - Completing the full Block 3F mission systems test plan (i.e., all original 7,230 baseline and budgeted non-baseline test points in the Block 3F joint test plan)
    - Continuing the CY15 discovery rate of 5 percent
  - Based on these projected completion dates for Block 3F developmental testing, IOT&E would not start earlier than August 2018. The program could, as has been the case in testing previous software increments, determine that test points in the plan are no longer required for the Block 3F fleet release. However, the program will need to ensure that deleting and/or deferring testing from Block 3F before the end of SDD and the start of IOT&E does not result in increasing the likelihood of discovery in IOT&E or affect the assessment of mission capability. Whatever capability the program determines as ready for IOT&E will undergo the same realistic and rigorous combat mission-focused testing as a fully functioning system.
  - The 48 Block 3F developmental test weapons delivery accuracy (WDA) events in the approved Test and Evaluation Master Plan (TEMP), plus two test events deferred from Block 2B, will not be accomplished by the planned date of May 2017, according to the program's official schedule, nor by July 2017, a more recently briefed date for the completion of SDD flight test, unless the program is able to significantly increase their historic WDA completion rate. In order to meet the schedule requirements for weapon certification, the Program Office has identified 10 WDA events for the F-35A and 5 events

  for the F-35B and F-35C that must be accomplished during Block 3F developmental testing. The program plans to accomplish the remaining 33 events as schedule margin allows.
  - Modifying the fleet of operational test aircraft to the required production-representative Block 3F configuration, with the TEMP-required instrumentation capability, will not be complete before August 2017.
  - The Program Office did not put the Block 3F Verification Simulation (VSim) development on contract in early 2015, as was needed in order to complete development for IOT&E. The Program Office decided instead to move from VSim to the Joint Simulation Environment (JSE), which will result in a fully verified, validated, and accredited simulator not being ready in time for IOT&E.
- Comparison testing provides insight into the capabilities available from new weapon systems relative to the legacy systems they replace. Since the Department plans to retire a large portion of its tactical aircraft inventory and replace them over time with the F-35, comparison testing will be a part of the Block 3F IOT&E. The JSF Operational Test Team (JOTT), in coordination with DOT&E staff, began to develop test plans for IOT&E, which will include comparisons of the F-35 with the A-10 in the Close Air Support role and with the F-16C (Block 50) in the Suppression of Enemy Air Defense/Destruction of Enemy Air Defenses (SEAD/DEAD) mission area. Comparison testing involving other strike aircraft is under consideration by the JOTT and DOT&E.
- JSF follow-on development will integrate additional capabilities in Block 4, address deferrals from Block 3F to Block 4, and correct deficiencies discovered during Block 3F development and IOT&E.
  - The program plans to complete Block 3F software development in 2016 and flight testing in early 2017. The next planned software delivery will be a Block 4 build in 2020, creating a four year gap between planned software releases. Considering the large number of open deficiencies documented from Blocks 2B and 3i testing, the ongoing discovery of deficiencies during Block 3F testing, and the certainty of more discoveries from IOT&E, the program needs to plan for additional Block 3F software builds and follow-on testing prior to 2020.
  - As has been the case with the F-22, the F-35 program will remain on DOT&E oversight during follow-on development and therefore must plan for and fund an associated formal OT&E of each Block 4 increment prior to release to operational units.
- The program has proposed a "block buy" combining three production lots comprising as many as 270 U.S. aircraft purchases to gain near-term savings. A commitment to the "block buy" could be necessary before IOT&E is complete. In that case, entering a "block buy" would raise the following questions:
  - Is the F-35 program sufficiently mature to commit to the "block buy?" The program continues to discover significant problems during developmental testing that, if not addressed with corrections or, in some cases, labor-intensive workarounds, will adversely affect the operational effectiveness and suitability of all three variants; these deficiencies need to be corrected before the system is used in combat. To date, the rate of deficiency correction has not kept pace with the discovery rate. Examples of well-known significant problems include the immaturity of the Autonomic Logistics Information System (ALIS), Block 3F avionics instability, and several reliability and maintainability problems with the aircraft and engine. Much of the most difficult and time-consuming developmental testing, including approximately 50 complex WDA events, remains to be completed. Hence, new discoveries, some of which could further affect the design or delay the program, are likely to occur throughout the time the Department could commit to the "block buy." Recent discoveries that require design changes, modifications, and regression testing include the ejection seat for safe separation, wing fuel tank over-pressurization, and the life-limitations of the F-35B bulkhead. For these specific reasons and others, further program delays are likely.
  - Is it appropriate to commit to a "block buy" given that essentially all the aircraft procured thus far require modifications to be used in combat? Although still officially characterized as low-rate, F-35 production rates are already high. Despite the problems listed above, F-35 production rates have been allowed to steadily increase to large rates, well prior to the IOT&E and official Full-Rate Production (FRP) decision. Due to this concurrency of development and production, approximately 340 aircraft will be produced by FY17 when developmental testing is currently planned to end, and over 500 aircraft by FY19 when IOT&E will likely end and the FRP milestone decision should occur. These aircraft will require a still-to-be-determined list of modifications in order to provide full Block 3F combat capability. However, these modifications may be unaffordable for the Services as they consider the cost of upgrading these early lots of aircraft while the program continues to increase production rates in a fiscally-constrained environment. This may potentially result in left-behind aircraft with significant limitations for years to come.
  - Would committing to a "block buy" prior to the completion of IOT&E provide the contractor with needed incentives to fix the problems already discovered, as well as those certain to be discovered during IOT&E? Would it be preferred—and would it provide a strong incentive to fix problems and deliver fully combat-capable aircraft—to make the "block buy," as well as any additional increases in the already high annual production rate, contingent upon successful completion of IOT&E? Similarly, would the "block buy" also be consistent with the "fly before you buy" approach to acquisition advocated by the Administration, as well as with the rationale for the

operational testing requirements specified in Title 10 U.S. Code?

- This report includes assessments of the progress of testing to date, including developmental and operational testing intended to verify performance prior to the start of IOT&E.
  - For developmental flight testing, the program creates plans by identifying specific test points (discrete measurements of performance under specific flight test conditions) for accomplishment in order to determine capabilities as being compliant with contract specifications.
    - Baseline test points refer to points in the test plans that must be accomplished in order to evaluate if performance meets contract specifications.
    - Non-baseline test points are accomplished for various reasons. Program plans include a budget for some of these points within the capacity of flight test execution. The following describes non-baseline test points.
      - Development points are test points required to "build up" to, or prepare for, the conditions needed for specification compliance (included in non-baseline budgeted planning in CY15).
      - Regression points are test points flown to ensure that new software does not introduce discrepancies as compared to previous software (included in non-baseline budgeted planning in CY15).
      - Discovery points are test points flown to investigate root causes or characterize deficiencies so that the program can design fixes (not included in planning in CY15).
  - As the program developed plans for allocating test resources against test points in CY15, the program included a larger budget for non-baseline test points (development and regression points) for all test venues (i.e., each variant of flight sciences and mission systems). For CY15 mission systems testing, planners budgeted an additional 45 percent of the number of planned baseline test points for non-baseline test purposes (e.g., development and regression points). In this report, growth in test points refers to points flown in addition to the planned amount of baseline and budgeted non-baseline points (e.g., discovery points and any other added testing not originally included in the formal test plan). The program allocates budgeted non-baseline test points in specific quantities to test categories (i.e., variant flight science, Block 2B, 3i, and 3F mission systems).
  - The need to budget for non-baseline test points in the CY15 plan is a result of the limited maturity of capability in the early versions of mission systems software. In CY15, when the first versions of Block 3F software were planned to be introduced to flight testing, limited baseline test points could be completed and development points would be the majority of the type of points flown. Also, as three versions of Block 3F software were planned to be introduced to flight testing in CY15, the test centers would need to accomplish a large number of regression points.
  - Cumulative SDD test point data in this report refer to the total progress towards completing development at the end of SDD.

TEST FLIGHTS (AS OF NOVEMBER 2015)					
	All Testing	Flight Sciences			Mission Systems
	All Variants	F-35A	F-35B	F-35C	
2015 Actual	1,193	188	283	270	452
2015 Planned	1,281	231	311	256	483
Difference from Planned	7.4%	22.9%	9.9%	-5.2%	6.9%
Cumulative Planned	6,242	1,489	1,844	1,188	1,721
Cumulative Actual	6,416	1,466	1,893	1,193	1,864
Difference from Planned	2.8%	-1.5%	2.7%	0.4%	8.3%
Prior to CY15 Planned	5,049	1,301	1,561	918	1,269
Prior to CY15 Actual	5,135	1,235	1,582	937	1,381

TEST POINTS (AS OF NOVEMBER 2015)												
	All Testing	Flight Sciences[1]						Mission Systems				
	All Variants	F-35A		F-35B		F-35C		Block 2B	Block 3i	Block 3F	Budgeted Non-Baseline[2]	Other[3]
		Block 3F Baseline	Budgeted Non-Baseline[2]	Block 3F Baseline	Budgeted Non-Baseline[2]	Block 3F Baseline	Budgeted Non-Baseline[2]					
2015 Test Points Planned (by type)	8,673	1,221	113	2,181	211	1,819	130	143	514	575	1,097	669
2015 Test Points Accomplished (by type)	8,011	1,196	62	2,003	191	1,910	59	160	469	674	834	453
Difference from Planned	-7.6%	-2.0%	-45.1%	-8.2%	-9.5%	5.0%	-54.6%	11.9%	-8.8%	17.2%	-24.0%	-32.3%
Points Added Beyond Budgeted Non-Baseline (Growth Points)	457	0		0		0		93	364	0	0	0
Test Point Growth Percentage (Growth Points/Test Points Accomplished)	5.7%	0.0%		0.0%		0.0%		58.1%	77.6%	0.0%	0.0%	0.0%
Total Points (by type) Accomplished in 2015[4]	8,468	1,258		2,194		1,969		253	833	674	834	453
Cumulative Data												
Cumulative SDD Planned Baseline[5]	43,611	10,919		13,995		10,650		6,232	699	575	N/A	541
Cumulative SDD Actual Baseline	43,528	10,978		13,835		10,729		5,933	660	674	N/A	719
Difference from Planned	-0.2%	0.5%		-1.1%		0.7%		-4.8%	-5.6%	17.2%	N/A	32.9%
Estimated Test Baseline Points Remaining	12,905	1,597		3,250		2,428		0	0	4,841	N/A	789
Estimated Non-Baseline Test Points Remaining	2,175	139		443		270		0	0	1,323	N/A	0

1. Flight sciences test points for CY15 are shown only for Block 3F. Block 2B Flight Sciences testing was completed in CY14 for F-35A, May 2015 for F-35B, and January 2015 for F-35C. Cumulative numbers include all previous flight science activity.
2. These points account for planned development and regression test points built into the 2015 plan; additional points are considered "growth".
3. Represents mission systems activity not directly associated with Block capability (e.g., radar cross section characterization testing, test points to validate simulator).
4. Total Points Accomplished = 2015 Baseline Accomplished + Added Points
5. SDD – System Design and Development

F-35A Flight Sciences

Flight Test Activity with AF-1, AF-2, and AF-4 Test Aircraft

- F-35A flight sciences testing focused on:
  - Internal gun testing
  - Flight envelope expansion with external weapons required for Block 3F weapons capability
  - Air refueling qualification with Italian and Australian tanker aircraft
  - Testing to mitigate fuel system over-pressurization conditions caused by fuel and On-Board Inert Gas Generation System (OBIGGS) gas pressure stacking within the system

F-35A Flight Sciences Assessment

- Through the end of November, the test team flew 23 percent more flights than planned (231 flown versus 188 planned), but was 2 percent behind the plan for Block 3F baseline test point completion (1,196 test points accomplished versus 1,221 planned). By the end of November 2015, the test team flew an additional 62 test points for regression of new air vehicle software (which were part of the budgeted non-baseline test points allocated for the year) and 238 points for air refueling qualification with partner nation tanker aircraft (these points are not included in the table of test flights and test points above). All F-35A flight sciences testing accomplished in CY15 was relevant to Block 3F requirements.

- All Block 2B flight sciences test points were completed in CY14 and provided the basis for the F-35A Block 2B fleet release to the training and operational units in August 2015. The Block 2B flight sciences test points also provided the basis for Block 3i initial flight clearances needed for Lot 6 and Lot 7 production aircraft delivered in CY15. There is no additional flight envelope provided by Block 3i compared to Block 2B.
- The following details discoveries in F-35A flight sciences testing:
  - Testing to characterize the thermal environment of the weapons bays demonstrated that temperatures become excessive during ground operations in high ambient temperature conditions and in-flight under conditions of high speed and at altitudes below 25,000 feet. As a result, during ground operations, fleet pilots are restricted from keeping the weapons bay doors closed for more than 10 cumulative minutes prior to take-off when internal stores are loaded and the outside air temperature is above 90 degrees Fahrenheit. In flight, the 10-minute restriction also applies when flying at airspeeds equal to or greater than 500 knots at altitudes below 5,000 feet; 550 knots at altitudes between 5,000 and 15,000 feet; and 600 knots at altitudes between 15,000 and 25,000 feet. Above 25,000 feet, there are no restrictions associated with the weapons bay doors being closed, regardless of temperature. The time limits can be reset by flying 10 minutes outside of the restricted conditions (i.e., slower or at higher altitudes). This will require pilots to develop tactics to work around the restricted envelope; however, threat and/or weather conditions may make completing the mission difficult or impossible using the work around.
  - Testing to characterize the vibrational and acoustic environment of the weapons bays demonstrated that stresses induced by the environment were out of the flight qualification parameters for both the AIM-120 missile and the flight termination system (telemetry unit attached to the missile body required to satisfy range safety requirements for terminating a live missile in a flight test). This resulted in reduced service life of the missile and potential failure of the telemetered missile termination system required for range safety.
  - Deficiencies in the sequencing of release commands for the Small Diameter Bomb (SDB) from the Bomb Rack Unit-61, which provides the interface between the SDB and the aircraft, were discovered in the lab and verified in aircraft ground testing. The program will assess software corrections to address these deficiencies in future flight testing.
  - Mechanical rubbing between the gun motor drive and the wall of the gun bay was discovered during initial ground testing of the gun on the AF-2 test aircraft, requiring structural modifications to the bay and alterations to the flow of cooling air and venting of gun gasses.
  - Under certain flight conditions, air enters the siphon fuel transfer line and causes the pressure in the siphon fuel tank to exceed allowable limits in all variants. As a result, the program imposed an aircraft operating limitation (AOL) on developmental test aircraft limiting maneuvering flight for each variant (e.g. "g" load during maneuvering). F-35A developmental test aircraft with the most recent fuel tank ullage inerting system modifications are limited to 3.8 g's when the aircraft is fully fueled. The allowable g increases as fuel is consumed and reaches the full Block 2B 7.0 g envelope (a partial envelope compared to full Block 3F) once total fuel remaining is 10,213 pounds or less, or roughly 55 percent of full fuel capacity, for developmental test aircraft with test control team monitoring (through instrumentation) of the fuel system. For developmental test aircraft without fuel system monitoring, the full Block 2B 7.0 g envelope becomes available at 9,243 pounds, or roughly 50 percent of full fuel capacity. Flight testing to clear the F-35A to the full Block 3F 9.0 g envelope, planned to be released in late 2017, is being conducted with developmental test aircraft with fuel system monitoring. Fleet F-35A aircraft are limited to 3.0 g's when fully fueled and the allowable g is increased as fuel is consumed, reaching the full Block 2B 7.0 g envelope when approximately 55 percent of full fuel capacity is reached. The program modified the AF-4 test aircraft in October and November with the addition of a relief line, controlled by a solenoid valve, to vent the affected siphon tanks, and a check valve on the inert gas line feeding the tanks. The test team completed testing of the modified design in late November 2015; the results are under review. Until relieved of the g restrictions, operational units will have to adhere to a reduced maneuvering (i.e., less "g available") envelope in operational planning and tactics; for example, managing threat engagements and escape maneuvers when in the restricted envelope where less g is available. This restriction creates an operational challenge when forward operating locations or air refueling locations are close to the threat/target arena, resulting in high fuel weights during engagements.
  - Testing of operational "dog-fighting" maneuvers showed that the F-35A lacked sufficient energy maneuverability to sustain an energy advantage over fourth generation fighter aircraft. Test pilots flew 17 engagements between an F-35A and an F-16D, which was configured with external fuel tanks that limited the F-16D envelope to 7.0 g's. The F-35A remained at a distinct energy disadvantage on every engagement. Pitch rates were also problematic, where full aft stick maneuvers would result in less than full permissible g loading (i.e., reaching 6.5 g when limit was 9.0 g), and subsequent rapid loss of energy. The slow pitch rates were observed at slower speeds—in a gun engagement, for example—that restricted the ability of an F-35A pilot to track a target for an engagement.

- The program completed the final weight assessment of the F-35A air vehicle for contract specification compliance in April with the weighing of AF-72, a Lot 7 production aircraft. Actual empty aircraft weight was 28,999 pounds, 372 pounds below the planned not-to-exceed weight of 29,371 pounds. The program has managed the weight growth of the F-35A air vehicle with no net weight growth for the 76 months preceding the final weight assessment. Weight management of the F-35A is important for meeting performance requirements and structural life expectations. The program will need to continue disciplined management of the actual aircraft weight beyond the contract specification as further discoveries during the remainder of SDD may add weight and result in performance degradation that would adversely affect operational capability.

F-35B Flight Sciences

Flight Test Activity with BF-1, BF-2, BF-3, BF-4, and BF-5 Test Aircraft

- F-35B flight sciences focused on:
  - Completing Block 2B flight envelope testing by the end of May
  - Flight envelope expansion with external weapons, including Paveway IV bombs, required for Block 3F weapons capability
  - Testing to characterize and mitigate fuel system over-pressurization conditions caused by fuel and OBIGGS gas pressure stacking within the system
  - Air refueling testing, including low altitude air refueling with KC-130 tanker aircraft
  - Testing of control authority during landings in crosswind conditions, both with and without external stores

F-35B Flight Sciences Assessment

- Through the end of November, the test team was able to fly 10 percent more flights than planned (311 flown versus 283 planned), but accomplished 8 percent less than the planned Block 3F baseline test points (2,003 points accomplished versus 2,181 planned). The team flew an additional 191 test points for regression of new air vehicle software, which were part of the budgeted non-baseline points planned for CY15. The team also completed four test points needed to complete the Block 2B flight envelope. The program also declared that 23 planned Block 2B baseline points were no longer required.
- The following details discoveries in F-35B flight sciences testing:
  - Testing to characterize the thermal environment of the weapons bays demonstrated that temperatures become excessive during ground operations in high ambient temperature conditions. As a result, during ground operations, fleet pilots are restricted from keeping the weapons bay doors closed for more than 10 cumulative minutes prior to take-off when internal stores are loaded and the outside air temperature is above 90 degrees Fahrenheit. Time with the weapons bay doors closed in flight is currently not restricted.
  - Under certain flight conditions, air can enter the siphon fuel transfer line and cause the pressure in the siphon fuel tanks to exceed allowable limits in all variants. As a result, the program imposed an aircraft operating limitation (AOL) on developmental test aircraft limiting maneuvering flight for each variant. The program implemented a partial mitigation in software on the F-35B. For F-35B developmental aircraft with the most recent fuel tank ullage inerting system modifications, the AOL limits maneuvers to 5.0 g's when the aircraft is fully fueled, but the allowable g increases as fuel is consumed. The full Block 2B 5.5 g envelope (a partial envelope compared to Block 3F) is available once total fuel remaining is approximately 13,502 pounds, or roughly 96 percent fuel remaining for developmental test aircraft with ground station monitoring of the fuel system, and 7,782 pounds or less, or roughly 56 percent fuel remaining for developmental test aircraft without monitoring. Flight testing to clear the F-35B to the full Block 3F 7.0 g envelope, planned to be released in late 2017, is being conducted with developmental test aircraft with fuel system monitoring. Fleet F-35B aircraft are limited to 3.0 g's when fully fueled and the allowable g is increased as fuel is consumed, reaching the full Block 2B envelope of 5.5 g's at roughly 63 percent of fuel remaining. The program has successfully developed and tested a hardware change on the F-35B to correct the overpressure problem involving the addition of a relief line controlled by a check valve to vent the affected siphon tanks. Once installed in fleet aircraft, the relief line and check valve will prevent the pressure in the siphon tanks from exceeding the allowable limits. Until the F-35B aircraft have the modification that relieves the g restrictions, operational units will have to adhere to a reduced maneuvering (i.e., less "g available") envelope in operational planning and tactics; for example, managing threat engagements and escape maneuvers when in the restricted envelope where less g is available. This restriction creates an operational challenge when forward operating locations or air refueling locations are close to the threat/target arena.
  - Air refueling with strategic tankers (KC-135 and KC-10) was restricted to use of centerline boom-to-drogue adapter (BDA) refueling only. Refueling from tanker wing pods was prohibited due to response anomalies from the hose and reel assemblies and the F-35B aircraft with the air refueling receptacle deployed.
- Weight management of the F-35B aircraft is critical to meeting the Key Performance Parameters (KPPs) in the Operational Requirements Document (ORD), including the vertical lift bring-back requirement, which will be evaluated during IOT&E. This Key Performance Parameter (KPP) requires the F-35B to be able to fly an operationally representative profile and recover to the ship with the necessary fuel and balance of unexpended weapons (two 1,000-pound bombs and two AIM-120 missiles) to safely conduct a vertical landing.

- The program completed the final weight assessment of the F-35B air vehicle for contract specification compliance in May 2015 with the weighing of BF-44, a Lot 7 production aircraft. Actual empty aircraft weight was 32,442 pounds, only 135 pounds below the planned not-to-exceed weight of 32,577 pounds and 307 pounds (less than 1 percent) below the objective vertical lift bring-back not-to-exceed weight of 32,749 pounds.
- The program will need to continue disciplined management of weight growth for the F-35B, especially in light of the small weight margin available and the likelihood of continued discovery through the remaining two years of development in SDD.

F-35C Flight Sciences

Flight Test Activity with CF-1, CF-2, CF-3, and CF-5 Test Aircraft

- F-35C flight sciences focused on:
  - Completing Block 2B testing by the end of January 2015
  - Ship suitability testing in preparation for the next set of ship trials (DT-2), originally planned for August, but slipped to October 2015 due to carrier availability
  - Flight envelope expansion with external weapons, required for Block 3F weapons capability
  - Testing with wing spoilers to reduce the adverse effects of transonic roll off in the portions of the flight envelope where it occurs
  - High angle of attack testing
  - Testing of control authority during landings in crosswind conditions, both with and without external stores
  - Testing of landings on wet runways and the effectiveness of anti-skid braking procedures
  - Air refueling testing
  - Initial testing of the Joint Precision Approach and Landing System

F-35C Flight Sciences Assessment

- Through the end of November, the test team flew 5 percent less than planned flights (256 flown versus 270 planned), but accomplished 5 percent more than the planned Block 3F baseline test points (1,910 points accomplished versus 1,819 planned). The team flew an additional 59 test points for regression of new software, which were part of the budgeted non-baseline points planned for the year. With the exception of three high angle of attack test points in January for the Block 2B envelope, all testing in CY15 supported Block 3F testing requirements.
- The following details discoveries in F-35C flight sciences testing:
  - Under certain flight conditions, air can enter the siphon fuel transfer line and cause the pressure in the siphon fuel tank to exceed allowable limits in all variants. The program imposed an AOL on developmental test aircraft, limiting maneuvering flight for each variant. On F-35C developmental test aircraft with the most recent fuel tank ullage inerting system modifications, the AOL limits maneuvers to 4.0 g's when the aircraft is fully fueled and the allowable g increases as fuel is consumed. The full Block 2B 6.0 g envelope (a partial envelope compared to Block 3F) is available with 18,516 pounds or roughly 93 percent fuel remaining for developmental test aircraft with test control team monitoring (through instrumentation) of the fuel system, and 8,810 pounds or roughly 40 percent fuel remaining for developmental test aircraft without monitoring. Flight testing to clear the F-35C to the full Block 3F 7.5 g envelope, planned to be released in late 2017, is being conducted with developmental test aircraft with fuel system monitoring. The program has developed and tested a correction involving the addition of a relief line controlled by a check valve to vent the affected siphon tanks on the F-35B, which has very similar fuel system siphoning architecture as the F-35C. However, the program has not tested the pressure relief design in flight on an F-35C. Fleet F-35C aircraft are limited to 3.0 g's when fully fueled and the allowable g is increased as fuel is consumed, reaching the full Block 2B envelope of 6.0 g's at roughly 43 percent of total fuel quantity remaining. Until relieved of the g restrictions, operational units will have to adhere to a reduced maneuvering (i.e., less "g available") envelope in operational planning and tactics; for example, managing threat engagements and escape maneuvers when in the restricted envelope where less g is available. This restriction creates an operational challenge when forward operating locations or air refueling locations are close to the threat/target arena.
  - Air refueling with strategic tankers (KC-135 and KC-10) was restricted to use of centerline BDA refueling only. Refueling from tanker wing pods was prohibited due to response anomalies from the hose and reel assemblies and the F-35C aircraft with the air refueling receptacle deployed.
  - The Patuxent River test center (Maryland) conducted an assessment of the effects of transonic roll off (TRO), which is an un-commanded roll at transonic Mach numbers and elevated angles of attack. The test center also assessed buffet, which is the impact of airflow separating from the leading edge of the wing that collides and "buffets" aft areas of the wing and aircraft on basic fighter maneuvering. TRO and buffet occur in areas of the maneuvering envelope that cannot be sustained for long periods of time, as energy depletes quickly and airspeed transitions out of the flight region where these conditions manifest. However fleeting, these areas of the envelope are used for critical maneuvers. The testing determined that TRO, observed to cause up to 8 degrees angle of bank, adversely affected performance in defensive maneuvering where precise control of bank angles and altitude must be maintained while the F-35C is in a defensive position and the pilot is monitoring an offensive aircraft. The test pilots observed less of an effect when the F-35C is conducting offensive maneuvering. However, buffet degrades precise

aircraft control and the readability of heads-up-display symbology in the HMDS during execution of certain critical offensive and defensive tasks, such as defensive maneuvers.

- The program completed two test flights in February with CF-2, an instrumented flight sciences test aircraft modified with spoilers, to investigate the effects on flying qualities when using control laws to deploy spoilers in the flight regions where buffet and TRO manifest (between Mach 0.92 and 1.02 and above 6 degrees angle-of-attack).
  - Testing showed the spoilers reduced buffet at some flight conditions, but also may increase buffet under other flight conditions, and reduced the magnitude of TRO when experienced; an observation predicted by wind tunnel testing.
  - Pilots reported that spoilers made a measurable difference in the buffet-laden region of the flight envelope but, due to the transient nature of buffet, the operational significance may be low.
  - Operational testing of the F-35C will need to assess the effect of TRO and buffet on overall mission effectiveness.

- Weight management is important for meeting air vehicle performance requirements, including the KPP for recovery approach speed to the aircraft carrier, and structural life expectations. These estimates are based on measured weights of components and subassemblies, calculated weights from approved design drawings released for build, and estimated weights of remaining components. These estimates are used to project the weight of the first Lot 8 F-35C aircraft (CF-28) planned for delivery in March 2016, which will be the basis for evaluating contract specification compliance for aircraft weight.
  - The current F-35C estimate of 34,582 pounds is 286 pounds (less than 1 percent) below the planned not-to-exceed weight of 34,868 pounds.
  - The program will need to ensure the actual aircraft weight meets predictions and continue rigorous management of the actual aircraft weight beyond the technical performance measurements of contract specifications in CY16. The program will need to accomplish this through the balance of SDD to avoid performance degradation that would affect operational capability.

Mission Systems

Flight Test Activity with AF-3, AF-6, AF-7, BF-4, BF-5, BF-17, BF-18, CF-3, and CF-8 Flight Test Aircraft and Software Development Progress

- Mission systems are developed, tested, and fielded in incremental blocks of capability.
  - Block 1. The program designated Block 1 for initial training capability in two increments: Block 1A for Lot 2 (12 aircraft) and Block 1B for Lot 3 aircraft (17 aircraft). No combat capability is available in either Block 1 increment. The Services have upgraded a portion of these aircraft to the Block 2B configuration through a series of modifications and retrofits. As of the end of November, 9 F-35A and 12 F-35B aircraft had been modified to the Block 2B configuration and 4 F-35A were undergoing modifications. Two F-35B aircraft, which are on loan to the Edwards AFB test center to support mission systems developmental flight testing, have been modified to the Block 3F configuration, leaving one F-35A and one F-35B in the Block 1B configuration. Additional modifications will be required to configure these aircraft in the Block 3F configuration.
  - Block 2A. The program designated Block 2A for advanced training capability and delivered aircraft in production Lots 4 and 5 in this configuration. No combat capability is available in Block 2A. The U.S. Services accepted 62 aircraft in the Block 2A configuration (32 F-35A aircraft in the Air Force, 19 F-35B aircraft in the Marine Corps, and 11 F-35C aircraft in the Navy). Similar to the Block 1A and Block 1B aircraft, the Services have upgraded these aircraft to the Block 2B configuration with modifications and retrofits, although fewer modifications were required. By the end of September, all 62 Lot 4 and 5 aircraft had been modified to the Block 2B configuration. One F-35C aircraft, which is on loan to the Edwards AFB test center, has been modified to the Block 3F configuration to support mission systems developmental flight testing. Additional modifications will be required to fully configure these aircraft in the Block 3F configuration.
  - Block 2B. The program designated Block 2B for initial, limited combat capability for selected internal weapons (AIM-120C, GBU-31/32 JDAM, and GBU-12). This block is not associated with the delivery of any lot of production aircraft. Block 2B mission systems software began flight testing in February 2013 and finished in April 2015. Block 2B is the software that the Marine Corps accepted for the F-35B Initial Operational Capability (IOC) configuration.
  - Block 3i. The program designated Block 3i for delivery of aircraft in production Lots 6 through 8, as these aircraft include a set of upgraded integrated core processors (referred to as Technical Refresh 2, or TR-2). The program delivered Lot 6 aircraft with a Block 3i version that included capabilities equivalent to Block 2A in Lot 5. Lot 7 aircraft are being delivered with capabilities equivalent to Block 2B, as will Lot 8 aircraft. Block 3i software began flight testing in May 2014 and completed baseline testing in October 2015, eight months later than planned in the Integrated Master Schedule (IMS). The program completed delivery of the U.S. Service's Lot 6 aircraft in 2015 (18 F-35A, 6 F-35B, and 7 F-35C aircraft). The delivery of Lot 7 aircraft began in August 2015, with four F-35A aircraft delivered to the U.S. Air Force. By the end of November, the program had delivered 13 F-35A

Lot 7 aircraft to the U.S. Air Force and two F-35B Lot 7 aircraft to the Marine Corps.
  - Block 3F. The program designated Block 3F as the full SDD capability for production Lot 9 and later. Flight testing with Block 3F software on the F-35 test aircraft began in March 2015. Aircraft from production Lots 2 through 5 will need to be modified, including the installation of TR-2 processors, to have Block 3F capabilities.
- Mission systems testing focused on:
  - Completing Block 2B flight testing
  - Completing Block 3i flight testing
  - Beginning Block 3F flight testing
  - Regression testing of corrections to deficiencies identified in Block 2B and Block 3i flight testing
  - Testing of the Gen III HMDS
- The six mission systems developmental flight test aircraft assigned to the Edwards AFB test center flew an average rate of 6.8 flights per aircraft, per month in CY15 through November, exceeding the planned rate of 6.0 by 13 percent, and flew 107 percent of the planned flights (483 flights accomplished versus 452 planned).
- The program prioritized flight test activity early in the year to complete Block 2B flight testing. The program declared testing complete on Block 2B software at the end of April. The program made the decision, in part, based on schedule, to support the need for moving forward with Block 3i and Block 3F testing, which required modifying the mission systems test aircraft with upgraded TR-2 processors.
- The Edwards AFB test center used production operational test aircraft, assigned to the operational test squadron there, to assist in accomplishing developmental test points of Block 2B capabilities throughout the year, including augmenting testing requiring formation flight operations.

Mission Systems Assessment
- Block 2B Development
  - The program completed Block 2B mission systems testing and provided a fleet release version of the software with deficiencies identified during testing.
  - The program attempted to correct deficiencies in the fusion of information—from the sensors on a single aircraft and between aircraft in formation—identified during flight testing in late CY14 and early CY15 of the planned final Block 2B software version. The test team flew an "engineering test build" (ETB) of the software designated 2BS5.2ETB. on 17 test flights using 3 different mission systems test aircraft in March. Although some improvement in performance was observed, distinguishing ground targets from clutter continued to be problematic. As a result, the program chose to field the final (prior to the ETB) version of Block 2B software and defer corrections to Block 3i and Block 3F.
  - Five mission systems deficiencies were identified by the Air Force as "must fix" for the final Block 3i software release, while the Marine Corps did not require the deficiencies to be fixed in Block 2B. These deficiencies were associated with information displayed to the pilot in the cockpit concerning performance and accuracy of mission systems functions related to weapon targeting, radar tracking, status of fused battlespace awareness data, health of the integrated core processors, and health of the radar. Another deficiency was associated with the time it takes to download files in order to conduct a mission assessment and debriefing.
  - Continuing to work the Block 2B deficiencies would have delayed the necessary conversion of the labs and the developmental test aircraft to the Block 3i and Block 3F configuration, delaying the ability for the program to complete Block 3i testing needed for delivery of aircraft from production Lots 6 and 7, and starting flight testing of Block 3F software.
  - The program deferred two WDA events from Block 2B to Block 3F as a result of the decision to stop Block 2B testing in April. This deferred work will add more pressure to the already demanding schedule of Block 3F WDA events.
  - The program attempted to correct known deficiencies from flight testing of Block 2B software in the Block 3i software product line (i.e., mission systems labs and Block 3i flight test aircraft). The program corrected some of these deficiencies and, as of the end of November 2015, planned to transfer these corrections to a new version of Block 2B software (2BS5.3) for a release in CY16. In order to accomplish this, the program needs to use aircraft from the operational test fleet, which will still be in the Block 2B configuration, to test the 2BS5.3 software. However, this entire process introduces inefficiencies in the program's progress for developing and testing Block 3F software.
- Block 2B Fleet Release
  - The program finished Block 2B developmental testing in May (mission systems testing completed in April, and F-35B flight sciences testing completed in May) and provided the necessary data for the Service airworthiness authorities to release Block 2B capabilities to their respective fleets. The Marine Corps released Block 2B to the F-35B fielded units in June, the Air Force to the F-35A units in August, and the Navy to the F-35C units in October. The fleet release enabled the Services to load Block 2B software on their aircraft, provided they had been modified at least in part to the Block 2B configuration.
  - Because of the limited combat capability provided in Block 2B, if the Block 2B F-35 aircraft will be used in combat, it will need the support of a command and control system that will assist in target acquisition and to control weapons employment for the limited weapons carriage available. If in an opposed combat scenario, the F-35 Block 2B aircraft would need to avoid threat engagement and would require augmentation by other friendly forces. The Block 2B fleet release carries maneuver and envelope restrictions that, although agreed to by the Services during requirements reviews, will also limit effectiveness:

    - For the F-35A, the airspeed at which the weapons bay doors can be open in flight (550 knots or 1.2 Mach) is less than the maximum aircraft speed allowable (700 knots or 1.6 Mach). Such a restriction will limit tactics to employment of weapons at lower speeds and may create advantages for threat aircraft being pursued by the F-35A.
    - For the F-35A, the airspeed at which countermeasures can be used is also less than the maximum speed allowable, again restricting tactical options in scenarios where F-35A pilots are conducting defensive maneuvers
  - The program formally vets deficiency reports submitted by test and operational organizations. The formal process assigns deficiency reports to categories correlating to urgency for correction. Category I deficiencies are those which may cause death, severe injury, or severe occupational illness; may cause loss or major damage to a weapon system; critically restrict the combat readiness capabilities of the using organization; or result in a production line stoppage. Category II deficiencies are those that impede or constrain successful mission accomplishment (but do not meet the safety or mission impact criteria of a Category I deficiency). As of the end of October 2015, 91 Category 1 (mission or safety of flight impact, 27) and Category 2 (mission impact, 64) high-severity deficiencies in the full Block 2B configuration (air vehicle, propulsion, mission systems) were not yet resolved by the program. Of these 91, 43 are assigned to mission systems engineering for resolution.
  - In addition to the mission systems deficiencies cited above, the Block 2B fleet aircraft are restricted by fuel system deficiencies:
    - All variants of the fleet Block 2B aircraft are restricted from exceeding 3 gs in symmetric maneuvers when fully fueled in order to avoid exceeding the allowable pressure in the siphon fuel tanks. The allowable g increases as fuel is consumed. The program has developed and tested a hardware correction to the problem for the F-35B; corrections for the F-35A and F-35C are still in work. Modification kits for installation on fielded production aircraft are currently in production for the F-35B and aircraft delivered in production Lot 8 will include the correct hardware. This modification will restore the envelope of the F-35B.
    - The program lifted the restriction preventing the F-35B from flying within 25 nautical miles of known lightning prior to the declaration of IOC; however, the program has added a restriction from taxiing or taking off within 25 nautical miles of known lightning because of only a partial software mitigation to the siphon tank overpressure problem. The program plans to field a new software release in 1QCY16, which will enable a hardware correction to the overpressure problem, once fielded F-35B aircraft are retrofitted with the hardware modification.
- Block 3i
  - Block 3i flight testing began in May 2014 with version 3iR1, derived from Block 2A software, six months later than planned in the IMS. The latest version of Block 3i software—3iR6—began flight testing in July 2015 and was derived from the latest version of Block 2B software. Block 3i mission systems flight testing completed in October 2015, eight months later than planned in the IMS.
  - Since the program planned to not introduce new capabilities in Block 3i, the test plan was written to confirm Block 3i had equivalent capabilities to those demonstrated in Block 2A (for 3iR1) and Block 2B (for subsequent versions of Block 3i software). The program's plan required completion of 514 baseline test points by mid-February 2015, with additional development, regression, and discovery points flown as necessary for each increment of software to address deficiencies. The program completed Block 3i mission systems testing by accomplishing 469 of the 514 baseline Block 3i test points, or 91 percent. Of the 45 test points remaining, 6 were transferred for completion in Block 3F and the remaining 39 were designated as "no longer required." The program executed an additional 515 test points. Of those 515 points, 151 were allocated in the budgeted non-baseline points for the year, and the 364 additional points represent growth in Block 3i testing. These 364 additional points, needed to accomplish the 469 baseline test points, represent a growth of 78 percent, which is much higher than the non-baseline budgeted of 30 percent planned by the program to complete Block 3i testing.
  - Results from 3iR6 flight testing demonstrated partial fixes to the five "must fix for Air Force IOC" deficiencies, showing some improved performance. Poor stability in the radar, however, required multiple ground and flight restarts, a condition that will reduce operational effectiveness in combat.
  - Instabilities discovered in the Block 3i configuration slowed progress in testing and forced development of additional software versions to improve performance. Two additional versions of the 3iR5 software were created in an attempt to address stability in start-up of the mission systems and inflight stability of the radar. Overall, radar performance has been less stable in the Block 3i configuration than in Block 2B. The test centers developed a separate "radar stability" series of tests—including both ground startup and inflight testing—to characterize the stability problems. Radar stability is measured in terms of the number of times per flight hour that either of these events occurred: a failure event requiring action by the pilot to reset the system; or, a stability event where the system developed a fault, which affected performance, but self-corrected without pilot intervention. For the last version of Block 2B software—2BS5.2—the test team measured a mean time between stability or failure event of 32.5 hours over nearly 200 hours of flight testing. For

3iR6, the time interval between events was 4.3 hours over 215 hours of flight testing. This poor radar stability will degrade operational mission effectiveness in nearly all mission areas.
  - Since no capabilities were added to Block 3i, only limited corrections to deficiencies, the combat capability of the initial operational Block 3i units will not be noticeably different than the Block 2B units. If the Block 3i F-35 aircraft will be used in combat, they will need equivalent support as for the Block 2B F-35 aircraft, as identified previously in this report.
  - As of the end of October, a total of nine Category 1 (three mission or safety of flight impact) and Category 2 (six mission impact) high-severity deficiencies in the full Block 3i configuration (air vehicle, propulsion, mission systems) were unresolved. Eight of these nine are assigned to mission systems engineering for resolution.
  - Based on these Block 3i performance issues, the Air Force briefed that Block 3i mission capability is at risk of not meeting IOC criteria to the Joint Requirements Oversight Council (JROC) in December 2015. The Air Force recently received its first Block 3i operational aircraft and is assessing the extent to which Block 3i will meet Air Force IOC requirements; this assessment will continue into mid-2016.
- Block 3F
  - Block 3F flight testing began in March 2015, six months later than the date planned by the program after restructuring in 2012.
  - As of the end of November, a total of 674 Block 3F baseline test points had been completed, compared to 575 planned (17 percent more than planned). An additional 653 development and regression points were flown, all of which were part of the budgeted non-baseline points for the year.
  - Since many of the baseline test points—which are used to confirm capability—cannot be tested until later versions of the Block 3F software are delivered in CY16 and CY17, the program allocated a large number of test points (979 for CY15) for development and regression of the software, while expecting to accomplish only 677 baseline test points in CY15. The total planned amount of baseline test points to complete Block 3F are approximately 5,467; combined with the planned non-baseline test points in the approved test plan, there are approximately 7,230 test points for Block 3F.
  - Due to the later-than-planned start of Block 3F mission systems testing (6 months late), the large amount of planned baseline test points remaining (88 percent), and the likelihood of the need for additional test points to address discoveries and fixes for deficiencies, the program will not be able to complete Block 3F missions systems flight test by the end of October 2016, as indicated by the IMS. Instead, the program will likely not finish Block 3F development and flight testing prior to January 2018, based on the following:
    - Continuing a six test point per flight accomplishment rate, which is equal to the CY15 rate observed through the end of November
    - Continuing a flight rate of 6.8 flights per month, as was achieved through the end of November 2015, exceeding the planned rate of 6 flights per month (if the flight rate deteriorates to the planned rate of 6 flights per month, then testing will not complete until May 2018).
    - Completing the full Block 3F test plan (i.e., all original 7,230 baseline and budgeted non-baseline test points in the Block 3F joint test plan)
    - Continuing the CY15 discovery rate of 5 percent
  - The program currently tracks 337 total Category 1 (42 mission or safety of flight impact) and Category 2 (295 mission impact) high-severity deficiencies in the full Block 3F configuration (air vehicle, propulsion, mission systems), of which 200 are assigned to the mission systems engineering area for resolution. An additional 100 Category 1 and Category 2 high-severity deficiencies are unresolved from Block 2B and Block 3i configurations, of which 51 are assigned to mission systems for resolution. It remains to be determined how many of these the program will be able to correct in later Block 3F versions. If any of these deficiencies are not resolved in the planned Block 3F design, additional efforts to isolate causes, and design and verify fixes will increase the amount of time needed to complete Block 3F development and testing.
  - The program could, as has been the case in testing previous software increments, determine test points in the plan are no longer required for the Block 3F fleet release. However, the program will need to ensure that deleting and/or deferring testing from Block 3F before the end of SDD and start of IOT&E does not increase the likelihood of discovery in IOT&E or affect the evaluation of mission capability. Whatever capability the program determines as ready for IOT&E will need to undergo the same rigorous and realistic combat mission-focused testing as a fully functioning system.
  - Block 3F mission systems capabilities require more complex test scenarios than prior versions of mission systems. It requires testing involving significantly more complex threat behavior and threat densities on the test ranges than was used in prior versions of mission systems. Additionally, Block 3F capability requires more testing in multi-ship formations.

Helmet Mounted Display System (HMDS)

- The HMDS is pilot flight equipment. It has a display on the visor that provides the primary visual interface between the pilot and the air vehicle and mission systems. The HMDS was envisioned to replace a traditional cockpit-mounted "heads-up display" and night vision goggles. It projects imagery from sensors onto the helmet visor, which is intended to enhance pilot situational awareness and reduce workload. In 2010, the Program Office identified significant deficiencies and technical risk in the HMDS.

- The program created a "dual-path" approach to recover required capability.
  - One path was to fix the existing Generation II (Gen II) HMDS through redesign of the night vision system/camera and electro-optical/infrared sensor imagery integration on the visor.
  - The second path was to switch to an alternate helmet design incorporating legacy night vision goggles and projecting sensor imagery only on cockpit displays.
  - The program terminated the dual path approach in 2013 and decided to move forward with fixes to the existing Gen II HMDS which created the Gen III HMDS
- The Gen II HMDS was fielded with Block 2 and earlier configurations of aircraft. The program developed and tested improvements to address deficiencies in stability of the display (referred to as "jitter"), latency in the projection of Distributed Aperture System (DAS) imagery, and light leakage onto the display under low-light conditions (referred to as "green glow"). However, adequate improvements to the night vision camera acuity were not completed and pilots were prohibited from using the night vision camera. Pilot use of the DAS imagery was also restricted.
- The Gen III HMDS is intended to resolve all of the above deficiencies. It is a requirement for Air Force IOC in 2016, and will be used to complete SDD and IOT&E in 2018. The following provide Gen III HMDS details:
  - It includes a new higher-resolution night vision camera, software improvements, faster processing, and changes to the imagery projection systems for the visor.
  - It requires aircraft with Block 3i hardware and software.
  - Developmental flight testing began in December 2014 and will continue into 2016 with primary flight reference testing.
  - Operational testing will occur in tests conducted to support the Air Force IOC in 2016 (Block 3i), and in IOT&E (Block 3F).
  - It will be used with all Lot 7 aircraft, which are being delivered now, and later deliveries.
  - Later-than-planned escape system qualification delayed Gen III HMDS deliveries to the field; the program plans full flight clearance to occur in 2016.
- Results of the Gen III HMDS performance during developmental testing thus far indicate the following:
  - Symbology jitter and alignment. Some corrections were made for jitter and alignment in the latest configuration of the fielded Gen II HMDS via modifications to the display management computer. These are carried into the Gen III design. Developmental test pilots report less jitter and proper alignment. However, jitter still occurs in regimes of high buffet (i.e., during high g or high angle of attack maneuvering). Operational testing in heavy maneuvering environments is needed to determine if further attention will be required.
  - Green glow (difficulty setting symbology intensity level without creating a bright green glow around perimeter of display). The Gen III HMDS includes new displays with higher contrast control, which has reduced green glow compared to Gen II; the phenomena still exists, but at a manageable level, according to developmental test pilots. Developmental test pilots were able to air refuel and operate in "no moon" low illumination conditions at night. Simulated carrier approaches were also conducted at San Clemente Island off the coast of California and during carrier trials in October 2015. Operational testing in high mission task loads is also needed to confirm if further adjustments are needed.
  - Latency (projected imagery lagging head movement/placement). The Gen III HMDS includes faster processing to reduce latency in night vision camera imagery and DAS imagery projected onto the visor. The update rate in the Gen III HMDS is twice that of the Gen II. Developmental test pilots reported improvement in this area. Nonetheless, pilots have to "learn" an acceptable head-movement rate; that is, they cannot move their heads too rapidly. However, operational testing in these environments is needed to determine if the problem is resolved and pilot workload is reduced, especially during weapons employment.
  - Night vision camera resolution. The Gen II camera included a single 1280 x 1024 pixel night vision sensor. The Gen III camera includes two 1600 x 1200 sensors and additional image processing software changes, which are intended to provide improved resolution and sensitivity. Developmental test pilots reported better acuity allowing pilots to accomplish mission tasks. Operational testing under high mission task loads will determine if further improvement is needed.

Mission Data Load Development and Testing

- F-35 effectiveness in combat relies on mission data loads— which are a compilation of the mission data files needed for operation of the sensors and other mission systems—working in conjunction with the system software data load to drive sensor search parameters so that the F-35 can identify and correlate sensor detections, such as threat and friendly radar signals. The contractor team produced an initial set of files for developmental testing during SDD, but the operational mission data loads—one for each potential major geographic area of operation—are being developed, tested, and produced by a U.S. government lab, the U.S. Reprogramming Lab (USRL), located at Eglin AFB, Florida, which is operated by government personnel from the Services. The Air Force is the lead Service. These mission data loads will be used for operational testing and fielded aircraft, including the Marine Corps and Air Force IOC aircraft. The testing of the USRL mission data loads is an operational test activity, as was arranged by the Program Office after the restructure that occurred in 2010.

- Significant deficiencies exist in the USRL that preclude efficient development of effective mission data loads. Unless remedied, these deficiencies will cause significant limitations for the F-35 in combat against existing threats. These deficiencies apply to multiple potential theaters of operation and affect all variants and all Services.
  - In February 2012, DOT&E recommended upgrades to the USRL to overcome the significant shortfalls in the ability of the lab to provide a realistic environment for mission data load development and testing. The Department provided a total of $45 Million in resources to overcome these shortfalls, with the funding beginning in 2013. Unfortunately, due to the Program Office leadership's failure to accord the appropriate priority to implementing the required corrections, not until last year did the program move to investigate the deficiencies in the lab and build a plan for corrections, and only recently did it initiate the process of contracting for improvements, which has yet to finalize at the time of this report. The status of the Department's investment is not clear.
  - The program's belated 2014 investigation confirmed the nature and severity of the shortfalls that DOT&E identified in 2012. The analysis also identified many other gaps, some of which are even more urgent and severe than those uncovered by DOT&E three years prior. Failure to aggressively address the deficiencies results in uncertainties in the aircraft's capabilities to deal with existing threats; uncertainties that will persist until the deficiencies have been overcome and which could preclude the aircraft from being operationally effective against the challenging threats it is specifically being fielded to counter. The program planned to complete upgrades to the lab in late 2017, which will be late to need if the lab is to provide a mission data load for Block 3F tactics development and preparation for IOT&E. It is important to note that many of these deficiencies apply equally to the contractor's mission systems development labs because the government lab is essentially a copy of one of the mission system software integration test labs at the contractor facility.
  - The findings of the program's 2014 investigation include:
    - Shortfalls in the ability to replicate signals of advanced threats with adequate fidelity and in adequate numbers
    - Inability to adequately and coherently stimulate all signal receivers in F-35 mission systems
    - Receiver scan scheduling tools do not function correctly when replicating complex threats
    - Mission data file generation tools errantly combine emitter modes
    - Important emitter data are ignored by the tools, which adversely affect the quality of the mission data files
    - Inability to edit existing mission data files, a condition which requires inefficient processes to make changes where the lab technicians must reconstruct the entire mission data file set with new/corrected information
  - The program must make these modifications before the USRL is required to provide the Block 3F mission data load for tactics development and preparations for IOT&E. The program's 2014 study, while agreeing with DOT&E that significant hardware upgrades are needed, has not resulted in a plan to procure those upgrades in time for Block 3F mission data load development and verification. Despite the $45 Million budget, the program has still not designed, contracted for, and ordered the required equipment—a process that will take at least two years, not counting installation and check-out. In addition, despite the conclusions of the 2014 study by the Program Office, the program has sub-optimized the upgrades it will eventually put on contract due to budgetary constraints. Procuring only a limited number of signal generators would leave the USRL with less capability than the F-35 Foreign Military Sales Reprogramming Lab. This decision constitutes a critical error on the part of the program's leadership.
  - An investment greater than the $45 Million recommended by DOT&E in 2012 is needed to address all necessary hardware and software corrections to the lab. Although over three years have already been lost to inaction, the Program Office still does not plan to put Block 3F upgrades to the USRL on contract until late in 2016. The program recently briefed that once the equipment is finally ordered in 2016, it would take at least two years for delivery, installation, and check-out—after IOT&E begins (according to the current schedule of the program of record). This results in a high risk to both a successful IOT&E and readiness for combat. When deficiencies were first identified in 2012, there was time to make early corrections and avoid, or at least significantly reduce, the risk that is now at hand. Instead, due to the failure of leadership, the opposite has occurred.
- The USRL staff submitted a plan in 2013 for the operational testing of the Block 2B mission data loads, which was amended by the test team per DOT&E instructions, and approved by DOT&E. The plan includes multi-phased lab testing followed by a series of flight tests before release to operational aircraft.
- Because the program elected to delay the arrival of the USRL equipment several years, a significant amount of schedule pressure on the development and testing of the Block 2B mission data loads developed in 2015. The USRL staff was required to truncate the planned testing, forgoing important steps in mission data load development, optimization, and verification, and instead, apply its resources and manpower to providing a limited mission data load in June 2015 for the Marine Corps IOC. The limited extent of lab and flight testing that occurred creates uncertainties in F-35 combat effectiveness that must be taken into consideration by fielded operational units until the lab is able to complete optimization and testing of a Block 2B mission data load in

accordance with the plan. This additional work is planned to occur in early 2016.

- A similar sequence of events may occur with the Air Force IOC, planned for August 2016 with Block 3i. Mission data loads must be developed to interface with the system data load, and they are not forwards or backwards compatible. Block 3i mission data load development and testing will occur concurrently with completion of Block 2B mission data loads, creating pressure in the schedule as the lab configuration will have to be changed to accommodate the development and testing of both blocks.

Weapons Integration

Block 2B

- The program terminated Block 2B developmental testing for weapons integration in December 2015 after completing 12 of the 15 planned WDA events. The program had planned to complete all 15 WDA events by the end of October 2014, but delays in implementing software fixes for deficient performance of the Electro-Optical Targeting System (EOTS), radar, fusion, Multi-function Advanced Data Link (MADL), Link 16 datalink, and electronic warfare mission systems slowed progress.
  - All three of the deferred events are AIM-120 missile shot scenarios. The program deferred one of the remaining events to Block 3i, awaiting mission systems updates for radar deficiencies. The program completed that missile shot scenario in September 2015 with Block 3i software. The program deferred the other two events to Block 3F due to mission systems radar, fusion, and electronic warfare system deficiencies. Fixes to Block 3F capability are needed in order to execute these scenarios.
  - Eleven of the 12 completed events required developmental test control team intervention to overcome system deficiencies to ensure a successful event (acquire and identify target, engage with weapon). The program altered the event scenarios to make them less challenging for three of these, as well as the twelfth event, specifically to work around F-35 system deficiencies (e.g., changing target spacing or restricting target maneuvers and countermeasures). The performance of the Block 2B configured F-35 in combat will depend in part on the degree to which the enemy conforms to these narrow scenarios, which is unlikely, and enables the success of the workarounds necessary for successful weapons engagement.
- Mission systems developmental testing of system components required neither operation nor full functionality of subsystems that were not a part of the component under test. The developmental test teams designed the individual component tests only to verify compliance with contract specification requirements rather than to test the complete find-fix-identification (ID)-track-target-engage-assess-kill chain for air-to-air and air-to-ground mission success. The test team originally designed WDA events, however, purposefully to gather weapons integration and fire-control performance using all the mission systems required to engage and kill targets in the full kill chain. WDA events, therefore, became the developmental test venue that highlighted the impact of the backlog of deficiencies created by focusing prior testing only on contract specification compliance, instead of readiness for combat.
- Each WDA event requires scenario dry-runs in preparation for the final end-to-end event to ensure the intended mission systems functionality, as well as engineering and data analysis requirements (to support the test centers and weapon vendors), are available to complete the missile shot or bomb drop. Per the approved TEMP, the preparatory and end-to-end WDA events must be accomplished with full mission systems functionality, including operationally realistic fire control and sensor performance. However, as stated above, the program executed all 12 of the Block 2B WDA events using significant procedural and technical workarounds to compensate for the deficiencies resident in the Block 2B configuration.
  - Deficiencies in the Block 2B mission systems software affecting the WDA events were identified in fusion, radar, passive sensors, identification friend-or-foe, EOTS, and the aircraft navigation model. Deficiencies in the datalink systems also delayed completion of some events. Developmental test team intervention was required from the control room to overcome deficiencies in order to confirm surface target coordinates, confirm actual air targets among false tracks, and monitor/advise regarding track stability (which could not be determined by the pilot). Overall, these deficiencies continued to delay the CY15 WDA event schedule and compromised the requirement to execute the missions with fully functional integrated mission systems. Obviously, none of this test team intervention would be possible in combat.
  - The first table on the next page shows the planned date, completion or scheduled date, and the number of weeks delayed for each of the Block 2B WDA preparatory and end-to-end events. Events completed are shown with dates in bold.
- The accumulated delays in the developmental testing WDA schedule have delayed the initiation of the operation test WDA events. The JSF Operational Test Team (JOTT) had planned on starting their full system integrated WDA event testing in July 2015; however, due to the delays in delivery of operationally representative mission systems software, coupled with delays in modifications of the operational test aircraft to the full Block 2B configuration, this operational test activity will not start until CY16. This is six months after the program and the Services fielded initial Block 2B capability, and three months later than the JOTT had planned to start.

BLOCK 2B WEAPON ACCURACY DELIVERY EVENTS

Weapon	WDA Number	Preparatory Events			End-to-End Event		
		Planned	Completed/ *Scheduled*	Weeks Delayed	Planned	Completed/ *Scheduled*	Weeks Delayed
AIM-120	102	Sep 13	**Sep 13**	2	Oct 13	**Oct 13**	2
	112	Sep 13	**Sep 13**	3	Oct 13	**Nov 13**	3
GBU-12	113	Sep 13	**Oct 13**	3	Oct 13	**Oct 13**	0
GBU-32	115	Sep 13	**Nov 13**	6	Nov 13	**Dec 13**	3
AIM-120	108	Oct 13	**Dec 13**	7	Dec 13	**Feb 14**	12
	110	Oct 13	**Aug 13**	43	Dec 13	**Nov 14**	50
	111	Dec 13	*Deferred to Block 3F*	--	Jan 14	*Deferred to Block 3F*	--
	106	Dec 13	**Sep 14**	40	Jan 14	**Nov 14**	43
GBU-31	114	Dec 13	**May 14**	45	Feb 14	**Nov 14**	41
			Jun 14				
			Oct 14				
AIM-120	104	Feb 14	**Aug 14**	28	Mar 14	*Deferred to Block 3i*	71
			Sep 14	30			
	107	Mar 14	**Jun 14**	12	May 14	**Feb 15**	30
	101	May 14	**May 14**	17	Jun 14	**Jan 15**	26
			Sep 14				
	103	Jun 14	**Mar 14**	-4	Aug 14	**May 14**	-10
			May 14				
	109	Jul 14	**Jan 14**	-29	Sep 14	**Mar 14**	-27
	105	Sep 14	*Deferred to Block 3F*	-	Oct 14	*Deferred to Block 3F*	-

1. Some WDA events require more than one preparatory event.

Block 3i

- The program planned that Block 3i would not incorporate any new capability or fixes from the Block 2B development/fleet release. The block 3i WDA events were capability demonstrations to confirm translation of Block 2B performance to the Block 3i TR-2 hardware. The one AIM-120 missile shot scenario deferred from Block 2B was completed in September 2015.
- The table to the right shows the planned date, completion or scheduled date, and weeks delayed for each of the WDA preparatory and end-to-end events.

BLOCK 3I WEAPON ACCURACY DELIVERY EVENTS

Weapon	WDA Number	Preparatory Events			End-to-End Event		
		Planned	Completed/ *Scheduled*	Weeks Delayed	Planned	Completed/ *Scheduled*	Weeks Delayed
AIM-120	104 (deferred from 2B)	Feb 14	**Sep 15**	82	Mar 14	**Sep 15**	78
	201	May 15	**May 15**	0	Jun 15	**Jul 15**	3
	204	Jul 15	**Jul 15**	0	Aug 15	**Sep 15**	4
GBU-12	202	May 15	**May 15**	0	May 15	**Aug 15**	11
GBU-31	203	May 15	**May 15**	0	Jun 15	**Jun 15**	0

1. Some WDA events require more than one preparatory event.

Block 3F

- The Block 3F weapons delivery plan currently contains 48 events that will test required Block 3F capabilities. Twenty-nine of these weapon profiles accommodate full Block 3F expanded envelope employment and systems integrated testing of the GBU-12, GBU-31/32 JDAM, Navy JSOW, GBU-39 SDB-1, AIM-120, and AIM-9X. Nineteen of the Block 3F WDA events test air-to-air and air-to-ground gun employment in all three variants (F-35A internal gun; F-35B and F-35C external gun pod). Including the two deferred events from Block 2B creates a total of 50 required weapons delivery accuracy events to be accomplished in approximately 15 months. These Block 3F events are more complex than the Block 2B and 3i events because of additional capability in mission systems such as advanced geolocation, multiple weapon events, enhanced radar modes, and expanded weapons envelopes and loadouts. As will be needed in combat employment, Block 3F WDA events will require reliable and stable target tracking, full MADL shoot-list sharing, Link 16 capability, and predictable fusion performance in integrated systems operation.

- While the program has instituted several process changes in mission systems software testing, maintaining the necessary WDA event tempo to complete the Block 3F events will be extremely challenging. The current build plans for each Block 3F software version show that the most challenging scenarios will not be possible until the final software version. This increases the likelihood of late discoveries of deficiencies, as occurred during Block 2B WDA testing.
- Completing the full set of Block 3F WDA events by May 2017, the planned end of Block 3F flight test according to the most recent program schedule, will require an accomplishment rate of over 3 events per month, more than 3 times the rate observed in completing the 12 Block 2B WDA events (approximately 0.8 events per month). Extending by two months to the end of July 2017, as has recently been briefed by the Program Office as the end of SDD flight test, is still unrealistic. Unless the accomplishment rate increases over the rate during the Block 2B testing period, completing all Block 3F WDA events will not occur until November 2021. In order to meet the schedule requirements for weapon certification, the Program Office has identified 10 high priority WDA events for the F-35A and 5 events for the F-35B and F-35C that must be accomplished during Block 3F developmental testing. The program plans to accomplish the remaining 35 events as schedule margin allows. The overall result of the WDA events must be that the testing yields sufficient data to evaluate Block 3F capabilities. Deleting numerous WDA events places successful IOT&E and combat capability at significant risk.

Static Structural and Durability Testing

- Structural durability testing of all variants using full-scale test articles is ongoing, with each having completed at least one full lifetime (8,000 equivalent flight hours, or EFH). All variants are scheduled to complete three full lifetimes of testing before the end of SDD; however, complete teardown, analyses, and Damage Assessment and Damage Tolerance reporting is not scheduled to be completed until August 2019. The testing on all variants has led to discoveries requiring repairs and modification to production designs and retrofits to fielded aircraft.
- F-35A durability test article (AJ-1) completed the second lifetime of testing, or 16,000 EFH in October 2015. While nearing completion of the second lifetime, testing was halted on August 13, 2015, when strain gauges on the forward lower flange of FS518, an internal wing structure, indicated deviations from previous trends. Inspections showed cracking through the thickness of the flange, so the program designed an interim repair to allow testing to continue and finish the second lifetime.
- F-35B durability test article (BH-1) completed 11,915 EFH by August 13, 2015, which is 3,915 hours (48.9 percent) into the second lifetime. The program completed the 11,000 hour data review on August 5, 2015.
  - Two main wing carry-through bulkheads, FS496 and FS472, are no longer considered production-representative due to the extensive existing repairs. The program plans to continue durability testing, repairing the bulkheads as necessary, through the second lifetime (i.e., 8,001 through 16,000 EFH) which is projected to be complete in mid-2016.
  - Prior to CY15, testing was halted on September 29, 2013, at 9,056 EFH, when the FS496 bulkhead severed, transferred loads to, and caused cracking in the adjacent three bulkheads (FS518, FS472, and FS450). The repairs and an adequacy review were completed on December 17, 2014, when the program determined that the test article could continue testing. Testing restarted on January 19, 2015, after a 16-month delay.
  - The program determined that several of the cracks discovered from the September 2013 pause at 9,056 EFH were initiated at etch pits. These etch pits are created by the etching process required prior to anodizing the surface of the structural components; anodizing is required for corrosion protection. Since the cracks were not expected, the program determined that the etch pits were more detrimental to fatigue life than the original material design suggested. The program is currently developing an analysis path forward to determine the effect on the overall fatigue life.
  - Discoveries requiring a pause in testing during CY15 include:
    - Cracking in the left- and right-hand side aft boom closeout frames, which are critical structural portions at the very aft of the airframe on each side of the engine nozzle, at 9,080 EFH. The cracks were not predicted by modeling and required a three-week pause in testing for repair, which consisted of a doubler (i.e., additional supporting element) as an interim fix to allow testing to continue. Designs for retrofitting and cut-in for production are under development.
    - Damage to a significant number of Electro-Hydraulic Actuator System (EHAS) fasteners and grommets at 9,333 EFH. The EHAS drives the aircraft control surfaces based on the direction and demand input by the pilot through the control stick.
    - Inspections in April 2015 revealed that cracks at four previously-identified web fastener holes near the trunnion lug of the FS496 bulkhead, a component integral to the bulkhead that supports the attachment of the main landing gear to the airframe, had grown larger. FS496 was previously identified as a life-limited part and will be modified as part of the life-limited modification plans for production aircraft in Lots 1

through 8, and a new production design cut into Lot 9 and later lot aircraft.
    - Failure of the left 3-Bearing Swivel Nozzle door uplock in April 2015; requiring replacement prior to restarting testing in May 2015.
    - Crack indication found at two fastener holes on the left side keel.
    - Crack reoccurrence at the Station 3 pylon at 10,975 EFH.
    - Cracks on the transition duct above the vanebox, a component of the lift fan, discovered in August 2015, requiring the jacks that transmit loads to the duct to be disconnected to allow cycling of the rest of the test article to continue.
    - During the repair activity in September 2015, a crack was discovered in a stiffener on the right-hand side of the mid-fairing longeron.
  - Testing has been paused since August 2015 to allow replacement and repair activities; a process estimated to take five months. Testing is planned to restart in January 2016.
- Testing of the F-35C durability test article (CJ-1) was paused at the end of October 2015 when cracks were discovered in both sides (i.e., the right- and left-hand sides) of one of the front wing spars after 13,731 EFH of testing. The Program Office considers this to be a significant finding, since the wing spar is a primary structural component and the cracking was not predicted by finite element modeling. Root cause analysis and options for repairing the test article are under consideration as of the writing of this report. Testing of the second lifetime (16,000 EFH) was scheduled to be completed by February 1, 2016, but discoveries and associated repairs over the last year put this testing behind schedule.
  - Additional discoveries since October 2014 include:
    - Cracking of the BL12 longerons, left and right sides, at 10,806 EFH, required a 10-week pause in testing for repairs. The effect to production and retrofit is still to be determined.
    - Cracks on the FS518 wing carry-through lower bulkhead at 11,770 EFH in May 2015.
    - A crack at butt line 23 on the right hand side of the FS496 bulkhead (initiating at a fastener hole).
    - A crack was discovered during the Level-2 inspection in the FS472 wing carry-through bulkhead after the completion of 12,000 EFH in June 2015. Repair work was completed prior to restarting testing in late August.
- The program plans to use Laser Shock Peening (LSP), a mechanical process designed to add compressive residual stresses in the materials, in an attempt to extend the lifetime of the FS496 and FS472 bulkheads in the F-35B. The first production line cut-in of LSP would start with Lot 11 F-35B aircraft. Earlier Lot F-35B aircraft will undergo LSP processing as part of a depot modification. Testing is proceeding in three phases: first, coupon-level testing to optimize LSP parameters; second, element-level testing to validate LSP parameters and quantify life improvement; and third, testing of production and retrofit representative articles to verify the service life improvements. All three phases are in progress, with full qualification testing scheduled to be completed in October 2017.

Verification Simulation (VSim)

- Due to inadequate leadership and management on the part of both the Program Office and the contractor, the program has failed to develop and deliver an adequate Verification Simulation (VSim) for use by either the developmental test team or the JSF Operational Test Team (JOTT), as has been planned for the past eight years and is required in the approved TEMP. Neither the Program Office nor the contractor has accorded VSim development the necessary priority, despite early identification of requirements by the JOTT, $250 Million in funding added after the Nunn-McCurdy-driven restructure of the program in 2010, warnings that development and validation planning were not proceeding in a productive and timely manner, and recent (but too late) intense senior management involvement. As a result, VSim development is another of several critical paths to readiness for IOT&E.
- The Program Office's subsequent decision in September 2015 to move the VSim to a Naval Air Systems Command (NAVAIR) proposal for a government-led Joint Simulation Environment (JSE) will not result in a simulation with the required capabilities and fidelity in time for F-35 IOT&E. Without a high-fidelity simulation, the F-35 IOT&E will not be able to test the F-35's full capabilities against the full range of required threats and scenarios. Nonetheless, because aircraft continue to be produced in substantial quantities (essentially all of which require modifications and retrofits before being used in combat), the IOT&E must be conducted without further delay to demonstrate F-35 combat effectiveness under the most realistic conditions that can be obtained. Therefore, to partially compensate for the lack of a simulator test venue, the JOTT will now plan to conduct a significant number of additional open-air flights during IOT&E, in addition to those previously planned. In the unlikely event a simulator is available in time for IOT&E, the additional flights would not be flown.
- VSim is a man-in-the-loop, mission systems software-in-the-loop simulation developed to meet the operational test requirements for Block 3F IOT&E. It is also planned by the Program Office to be used as a venue for contract compliance verification prior to IOT&E. It includes an operating system in which the simulation runs, a Battlespace Environment (BSE), models of the F-35 and other supporting aircraft, and models of airborne and ground-based threats. After reviewing a plan for the government to develop VSim, the Program Office made the decision in 2011 to have the contractor develop the simulation instead.
- The Program Office began a series of tests in 2015 to ensure that the simulation was stable and meeting the reduced set of requirements for limited Block 2B operational activities. Though the contractor's BSE and operating system had improved since last year, deficiencies in specific F-35 sensor

models and the lack of certain threat models would have limited the utility of the VSim for Block 2B operational testing, had it occurred. The program elected instead to provide a VSim capability for limited tactics development. The Air Force's Air Combat Command, which is the lead for developing tactics in coordination with the other services, planned two VSim events for 2015.

- Air Combat Command completed the first event in July which included one- and two-ship attack profiles against low numbers of enemy threats. This event was planned to inform the tactics manual that will support IOT&E and the operational units, but validation problems prevented detailed analysis of results (i.e., minimum abort ranges).
- The second event, led by the JOTT with Marine Corps pilots flying, was completed in October 2015 for the limited use of data collection and mission rehearsals to support test preparation for IOT&E. While valuable lessons were learned by the JOTT and the Marine Corps, the lack of accreditation made it impossible for the JOTT to make assessments of F-35 system performance.

- Verification, Validation, and Accreditation (VV&A) activity completely stalled in 2015 and did not come close to making the necessary progress towards even the reduced set of Block 2B requirements.
  - Less than 10 percent of the original validation points were collected from flight test results, and a majority of those showed significant deviations from installed system performance. The vehicle systems model, which provides the aircraft performance and flying qualities for the simulation, and certain weapons and threats models, were generally on track. However, mission systems, composed of the sensor models and fusion, had limited validation data and were often unstable or not tuned, as required, to represent the installed mission systems performance, as measured in flight-testing.
  - The contractor and program management failed to intervene in time to produce a simulation that met even the reduced set of user requirements for Block 2B and, although they developed plans to increase VV&A productivity, they did not implement those plans in time to make a tangible difference by the time of this report. As the focus changed to Block 3F and IOT&E, the contractor and the Program Office made little progress; no VV&A plans materialized, data that had been collected were still stalled at the test venues awaiting review and release, alternative data sources had not yet been identified for new threats, and contract actions needed to complete VSim for Block 3F IOT&E were not completed.
- In September 2015, the Program Office directed a change in responsibility for VSim implementation, reassigning the responsibility from the contractor, Lockheed Martin, to a government team led primarily by NAVAIR. This was triggered by a large increase in the contractor's prior proposed cost to complete VSim, a cost increase which included work that should already have been completed in Block 2B and mitigations intended to overcome prior low productivity. The path to provide an adequate validation of the simulation for Block 3F IOT&E carries risk, regardless of who is responsible for the implementation of the simulation. That risk was increased by the Program Office's decision to move the simulation into a government controlled (non-proprietary) facility and simulation environment. After analyzing the steps needed to actually implement the Program Office's decision to move the VSim to the JSE, it is clear that the JSE will not be ready, with the required capabilities and fidelity, in time for F-35 IOT&E in 2018. It is also clear that both NAVAIR and the Program Office significantly underestimated the scope of work, the cost, and the time required to replace Lockheed Martin's proprietary BSE with the JSE while integrating and validating the required high-fidelity models for the F-35, threats, friendly forces, and other elements of the combat environment.
  - The JSE proposal abandons the BSE that is currently running F-35 Block 2B.
  - The JSE proposal does not address longstanding unresolved issues with VSim, including the ability of the program to produce validation data from flight test, to analyze and report comparisons of that data with VSim performance, and to "tune" VSim to match the installed system performance demonstrated in flight-testing.
  - While the JSE might eventually reach the required level of fidelity, it will not be ready in time for IOT&E since the government team must re-integrate into the JSE the highly detailed models of the F-35 aircraft and sensors, and additional threat models that the contractor has "hand-built" over several years.
  - The current VSim F-35 aircraft and sensor models interact directly with both the BSE and the current contractor's operating system. A transition to the JSE will require a re-architecture of these models before they can be integrated into a different environment. The need to do this, along with the costs of contractor support for the necessary software models and interfaces, will overcome the claims of cost savings in NAVAIR's proposal.
  - The highly integrated and realistic manned "red air" simulations in VSim, which were inherited from other government simulations, cannot be replicated in the limited time remaining before IOT&E.
  - The large savings estimates claimed by NAVAIR as the basis for their JSE proposal are not credible, and, the government team's most recent estimates for completion of the JSE have grown substantially from its initial estimate. Nearly all the costs associated with completing VSim in its current form would also transfer directly to JSE, with significant additional delays and risk. Any potential savings in the remaining costs from government-led integration are far outweighed by the additional costs associated with upgrading or building new facilities, upgrading or replacing the BSE, re-hosting the F-35 on government infrastructure, and paying Lockheed Martin to build interfaces between their F-35 models and the JSE.

- The JSE proposal adds significant work and schedule risk to the contractor's ability to deliver a functioning and validated Block 3F aircraft model in time for IOT&E. Besides being required to complete integration of Block 3F capabilities, validate the simulation, and tune the sensor models to installed system performance, the contractor must also simultaneously assist the government in designing new interfaces and re-hosting the F-35 and hand-built threat models into the JSE to all run together in real-time so they can be validated and accredited.
- Abandoning VSim also affects the F-22 program, as the various weapons and threat models being developed were planned to be reused between the two programs. The upcoming F-22 Block 3.2B IOT&E depends on the BSE currently in development.

• For the reasons listed above, the Program Office's decision to pursue the NAVAIR-proposed JSE, without the concurrence of the operational test agencies (OTAs) or DOT&E, will clearly not provide an accredited simulation in time for F-35 IOT&E, and the OTAs have clearly expressed their concerns regarding the risks posed to the IOT&E by the lack of VSim. Nonetheless, so as not to delay IOT&E any further while substantial numbers of aircraft are being produced, DOT&E and the OTAs have agreed on the need to now plan for the F-35 IOT&E assuming a simulator will not be available. This will require flying substantial additional open-air flights for tactics development, mission rehearsal, and evaluation of combat effectiveness relative to previous plans for using VSim. Even with these additional flights, some testing previously planned against large-scale, real-world threat scenarios in VSim will no longer be possible.

Live Fire Test and Evaluation (LFT&E)

F-35C Full-Scale Fuel Ingestion Tolerance Vulnerability Assessment

• The F-35 LFT&E Program completed the F-35C full-scale, fuel ingestion tolerance test series. The Navy's Weapons Survivability Laboratory (WSL) in China Lake, California, executed four tests events using the CG:0001 test article. Two of the test events were conducted with a Pratt and Whitney F-135 initial flight release (IFR)-configured engine installed in the aircraft. A preliminary review of the results indicates that:
  - The F135 IFR-configured engine is tolerant of fuel ingestion caused by single missile-warhead fragment impacts in the F1 fuel tank. The threat-induced fuel discharge into the engine inlet caused temporary increases in the nominal engine temperature, but did not result in any engine stalls or long-term damage.
  - Missile fragment-induced damage is consistent with predictions and the tanks are tolerant of single-fragment impacts. The threat-induced damage to the F1 fuel tank caused fuel leak rates that are consistent with tests conducted in FY07 using flat panels.

PAO Shut-Off Valve

• The program has not provided an official decision to reinstate this vulnerability reduction feature. There has been no activity on the development of the PAO-shut-off valve technical solution to meet criteria developed from 2011 live fire test results. As stated in several previous reports, this aggregate, 2-pound vulnerability reduction feature, if installed, would reduce the probability of pilot incapacitation, decrease overall F-35 vulnerability, and prevent the program from failing one of its vulnerability requirements.

Fuel Tank Ullage Inerting System and Lightning Protection

• The program verified the ullage inerting design changes, including a new pressurization and ventilation control valve, wash lines to the siphon tanks, and an external wash line, and demonstrated improved inerting performance in F-35B fuel system simulator tests. A preliminary data review demonstrated that the system pressurized the fuel tank with nitrogen enriched air (NEA) while maintaining pressure differentials within design specifications during all mission profiles in the simulator, including rapid dives. The Program Office will complete and document a detailed data review and analyses that evaluate NEA distribution and inerting uniformity between different fuel tanks and within partitioned fuel tanks.

• The program developed a computational model to predict inerting performance in the aircraft based on the F-35B simulator test results. Patuxent River Naval Air Station completed the ground inerting test on a developmental test F-35B aircraft to verify the inerting model. Preliminary analyses of the results indicate that there is good correlation between the ground inerting test and the F-35B fuel system simulator. The program will use this model, in conjunction with the completed F-35A and F-35C ground tests, to assess the ullage inerting effectiveness for all three variants. The confidence in the final design's effectiveness will have to be reassessed after the deficiencies uncovered in the aircraft ground and flight tests, including small uninerted fuel tank ullage spaces, have been fully resolved.

• When effective, ullage inerting protects the fuel tanks from not just threat-induced damage but also lightning-induced damage. The ullage inerting system does not protect any other components or systems from lightning-induced damage.

• The program has made progress completing lightning tolerance qualification testing for line-replaceable units needed to protect the remaining aircraft systems from lightning-induced currents. Lightning tolerance tests using electrical current injection tests are ongoing, and the program expects to complete the tests by 2QFY16.

Vulnerability to Unconventional Threats

• The full-up, system-level chemical-biological decontamination test on an SDD aircraft planned for 4QFY16 at Edwards AFB is supported by two risk-reduction events:

- A System Integration Demonstration of the proposed decontamination equipment and shelter was conducted on an F-16 test article during 1QFY15 at Edwards AFB to simulate both hot air chemical and hot/humid air biological decontamination operations. Extensive undesirable condensation inside the shelter and on the test article during the hot/humid air biological decontamination event indicated the need for process and shelter modifications.
- A demonstration of an improved shelter is planned for 2QFY16 to demonstrate that a modified system process and better insulated shelter can maintain adequate temperature and humidity control inside the shelter, even in a cold-weather environment.

- The test plan to assess chemical and biological decontamination of pilot protective equipment is not adequate. Compatibility testing of protective ensembles and masks has shown that the materials survive exposure to chemical agents and decontamination materials and processes, but the program has neither tested nor provided plans for testing the Helmet Mounted Display Systems (HMDS) currently being fielded. Generation II HMDS compatibilities were determined by analysis, comparing HMDS materials with those in an extensive DOD aerospace materials database. A similar analysis is planned for the Generation III HMDS design. However, even if material compatibilities were understood, there are no plans to demonstrate a process that could adequately decontaminate either HMDS from chemical and biological agents.
- The Joint Program Executive Office for Chemical and Biological Defense approved initial production of the F-35 variant of the Joint Service Aircrew Mask (JSAM-JSF) during 1QFY16. This office and the F-35 Joint Program Office are integrating the JSAM-JSF with the Helmet-Mounted Display, which is undergoing Safety of Flight testing.
- The Navy evaluated an F-35B aircraft to the EMP threat level defined in MIL-STD-2169B. Follow-on tests on other variants of the aircraft, including a test series to evaluate any Block 3F hardware/software changes, are planned for FY16.

Gun Ammunition Lethality and Vulnerability

- The program completed the terminal ballistic testing of the PGU-47 APEX round against a range of target-representative material plates and plate arrays. Preliminary test observations indicated expected high levels of fragmentation when passing through multiple layer, thin steel or aluminum targets, along with a deep penetration through more than an inch of rolled homogeneous armor steel by the nose of the penetrator. The program will evaluate the effect of these data on the ammunition lethality assessment.
- The 780th Test Squadron at Eglin AFB has completed the ground-based Frangible Armor Piercing (FAP) and initiated the PGU-32 lethality tests. The APEX rounds will be tested in FY16 against a similar range of targets, including armored and technical vehicles, aircraft, and personnel in the open. Ground-based lethality tests for the FAP showed expected high levels of penetration against all targets, with slightly less internal target fragmentation than originally anticipated, and low levels of lethality against personnel in the open (unless impacted directly). The program will determine the effect of these data on the ammunition lethality assessment.
- Per the current mission systems software schedule, the weapons integration characterization of the gun and sight systems will not be ready for the air-to-ground gun strafe lethality tests until 1QFY17. Strafing targets will include a small boat, light armored vehicle and technical vehicle (pickup truck), one each for each round type tested. Because the APEX round is not currently a part of the program of record, funding for developmental or operational air-to-ground flight testing of the APEX round is not planned at this time.

Operational Suitability

- Operational suitability of all variants continues to be less than desired by the Services, and relies heavily on contractor support and workarounds that would be difficult to employ in a combat environment. Almost all measures of performance have improved over the past year, but most continue to be below their interim goals to achieve acceptable suitability by the time the fleet accrues 200,000 flight hours, the benchmark set by the program and defined in the Operational Requirements Document (ORD) for the aircraft to meet reliability and maintainability requirements. This level of maturity is further stipulated as 75,000 flight hours for the F-35A, 75,000 flight hours for the F-35B, and 50,000 flight hours for the F-35C.
  - Aircraft fleet-wide availability averaged 51 percent for 12 months ending October 2015, compared to a goal of 60 percent.
  - Availability had been in mid-30s to low-40s percent for the 2-year period ending September 2014. Monthly availability jumped 12 percent to 51 percent by the end of October 2014, one of the largest month-to-month spikes in program history, and then peaked at 56 percent in December 2014. Since then it has remained relatively flat, centering around 50 percent, although it achieved 56 percent again in September 2015. The significant improvement that occurred around October 2014 was due in roughly equal measure to a reduction in the time aircraft were undergoing maintenance and a reduction in the time aircraft were awaiting spare parts from the supply system. The aircraft systems that showed the greatest decreases (improvement) in maintenance downtime during the month of October 2014 were the engine and the ejection seat.
  - It would be incorrect to attribute the still-low availability the F-35 fleet has exhibited in 2015, specifically the failure to meet the goal of 60 percent availability, solely to issues stemming from the additional engine inspections required since the June 2014 engine failure on AF-27. Availability did drop immediately after the engine failure, partly due to these inspections, but has since recovered to pre-engine failure levels, and improved only slightly from there when considered as a long-term trend. For the three months

ending October 2015, the fleet was down for the 3rd Stage Integrally Bladed Rotor (IBR) inspections—required due to the engine failure—less than 1 percent of the time.

- Measures of reliability that have ORD requirement thresholds have improved since last year, but eight of nine measures are still below program target values for the current stage of development, although two are within 5 percent of their interim goal; one—F-35B Mean Flight Hours Between Maintenance Events (Unscheduled)—is above its target value. In addition to the nine ORD metrics, there are three contract specification metrics, Mean Flight Hour Between Failures scored as "design controllable" (one for each variant). Design controllable failures are equipment failures due to design flaws considered to be the fault of the contractor, such as components not withstanding stresses expected to be found in the normal operational environment. It does not include failures caused by improper maintenance, or caused by circumstances unique to flight test. This metric continues to see the highest rate of growth, and for this metric all three variants are currently above program target values for this stage in development.
- Although reliability, as measured by the reduced occurrence of design controllable failures, has shown strong growth, this has only translated into relatively minor increases in availability for several reasons. These reasons include the influences of a large amount of time spent on scheduled maintenance, downtime to incorporate required modifications, waiting longer for spare parts than planned, and potentially longer-than-expected repair times, especially if units have to submit Action Requests (ARs) for instructions on repairs with no written procedures yet available. Finally, aircraft in the field become unavailable for failures not scored as design controllable as well. All of these factors affect the final availability rate the fleet achieves at any given time, in addition to the effect of improved reliability.
- F-35 aircraft spent 21 percent more time than intended down for maintenance, and waited for parts from supply for 51 percent longer than the program targeted. At any given time, from 1-in-10 to 1-in-5 aircraft were in a depot facility or depot status for major re-work or planned upgrades, and of the fleet that remained in the field, on average, only half were able to fly all missions of even a limited capability set.

• Accurate suitability measures rely on adjudicated data from fielded operating units. A Joint Reliability and Maintainability Evaluation Team (JRMET), composed of representatives from the Program Office, the JOTT, the contractor (Lockheed Martin), and Pratt and Whitney (for engine records), reviews maintenance data to ensure consistency and accuracy for reporting measures; government representatives chair the team. However, the Lockheed Martin database that stores the maintenance data, known as the Failure Reporting and Corrective Action System (FRACAS), is not in compliance with U.S. Cyber Command information assurance policies implemented in August 2015. Because of this non-compliance, government personnel have not been able to access the database via government networks, preventing the JRMET from holding the planned reviews of maintenance records. As a result, the Program Office has not been able to produce Reliability and Maintainability (R&M) metrics from JRMET-adjudicated data since the implementation of the policy. The most current R&M metrics available for this report are from the three-month rolling window ending in May 2015. The Program Office is investigating workarounds to enable the JRMET to resume regular reviews of maintenance records until Lockheed Martin can bring the FRACAS database into compliance.

F-35 Fleet Availability

• Aircraft availability is determined by measuring the percent of time individual aircraft are in an "available" status, aggregated over a reporting period (e.g., monthly). The program assigns aircraft that are not available to one of three categories of status: Not Mission Capable for Maintenance (NMC-M); Not Mission Capable for Supply (NMC-S); and Depot status.
  - Program goals for these "not available" categories have remained unchanged since 2014, at 15 percent for NMC-M, 10 percent for NMC-S, and 15 percent of the fleet in depot status. Depot status is primarily for executing the modification program to bring currently fielded aircraft closer to their expected airframe structural lifespans of 8,000 flight hours and to incorporate additional mission capability. The majority of aircraft in depot status are located at dedicated depot facilities for scheduled modification periods that can last several months, and they are not part of the operational or training fleet during this time. A small portion of depot status can occur in the field when depot field teams conduct a modification at a main operating base, or affect repairs beyond the capability of the local maintenance unit.
  - These three "not available" category goals sum to 40 percent, leaving a targeted fleet-wide goal of 60 percent availability for 2015. At the time of this report, this availability goal extended uniformly to the individual variants, with each variant having a target of 60 percent availability as well. For a period during 2015, however, the program set variant-specific availability goals to account for the fact that the variants were cycling through the depots at different rates. A particularly large portion of the F-35B fleet was in depot in early 2015 to prepare aircraft for Marine Corps IOC declaration, for example. From February to August 2015, the variant-specific availability goals were reported as 65 percent for the F-35A, 45 percent for the F-35B, and 70 percent for the F-35C, while the total fleet availability goal remained 60 percent.

• Aircraft monthly availability averaged 51 percent for the 12-month period ending October 2015 in the training and operational fleets. This is an increase over the 37 percent availability reported in both of the previous two DOT&E Annual Reports from FY13 and FY14.

- However, in no month did the fleet exceed its goal of 60 percent availability. In several months, individual variants beat either the 60 percent goal, or their at-the-time variant-specific goal. The F-35A achieved 63 percent availability in December 2014, but never surpassed 65 percent. The F-35C was above 60 percent availability from November 2014 to June 2015, and again in September and October 2015, and was above 70 percent in four of these months. The F-35B was above 45 percent availability in only one month, October 2015, when it achieved 48 percent. This was after the program returned its variant-specific availability target to 60 percent.
- The table below summarizes aircraft availability rates by operating location for the 12-month period ending October 2015. The first column indicates the average availability achieved for the whole period, while the maximum and minimum columns represent the range of monthly availabilities reported over the period. The number of aircraft assigned at the end of the reporting period is shown as an indicator of potential variance in the rates. Sites are arranged in order of when each site began operation of any variant of the F-35, and then arranged by variant for sites operating more than one variant. In February 2015, the Marine Corps terminated operations of the F-35B at Eglin AFB and transferred the bulk of the aircraft from that site to Marine Corps Air Station (MCAS) Beaufort, South Carolina. As a result, the number of F-35B aircraft assigned to Eglin AFB as of September 2015 was zero.

F-35 AVAILABILITY FOR 12-MONTH PERIOD ENDING OCTOBER 2015[1]

Operational Site	Average	Maximum	Minimum	Aircraft Assigned[2]
Whole Fleet	51%	56%	46%	134
Eglin F-35A	55%	62%	39%	25
Eglin F-35B[3]	43%	48%	26%	0
Eglin F-35C	66%	79%	57%	17
Yuma F-35B	39%	62%	16%	17
Edwards F-35A	32%	66%	17%	8
Edwards F-35B[4]	19%	27%	0%	6
Nellis F-35A	51%	77%	33%	10
Luke F-35A	62%	75%	50%	30
Beaufort F-35B[5]	46%	60%	24%	18
Hill F-35A[6]	80%	81%	79%	3

1. Data do not include SDD aircraft.
2. Aircraft assigned at the end of October 2015.
3. Eglin AFB F-35B ended operations in February 2015.
4. Edwards AFB F-35B operational test operations began in October 2014.
5. Beaufort MCAS F-35B operations began in July 2014.
6. Hill AFB F-35A operations began September 2015.

  - Statistical trend analysis of the monthly fleet availability rates from August 2012 through October 2015 showed a weak rate of improvement of approximately 5 percent growth per year over this period, but the growth was not consistent. For example, from August 2012 through September 2014, availability was relatively flat and never greater than 46 percent, but from September 2014 through December 2014, it rose relatively quickly month-on-month to peak at 56 percent in December. Availability then dropped a bit, and remained near 50 percent through October 2015 with no increasing trend toward the goal of 60 percent.
  - Due to concurrency, the practice of producing operational aircraft before the program has completed development and finalized the aircraft design, the Services must send the current fleet of F-35 aircraft to depot facilities to receive modifications that have been designed since they were originally manufactured. Some of these modifications are driven by faults in the original design that were not discovered until after production had started, such as major structural components that break due to fatigue before their intended lifespan, and others are driven by the continuing improvement of the design of combat capabilities that were known to be lacking when the aircraft were first built. This "concurrency tax" causes the program to expend resources to send aircraft for major re-work, often multiple times, to keep up with the aircraft design as it progresses. Since System Development and Demonstration (SDD) will continue to 2017, and by then the program will have delivered nearly 200 aircraft to the U.S. Services in other than the 3F configuration, the depot modification program and its associated concurrency burden will be with the Services for years to come.
  - Sending aircraft to depot facilities for several months at a time to bring them up to Block 2B capability and life limits, and eventually to 3F configuration, reduces the number of aircraft at field sites and thus decreases fleet availability. For the 12-month period ending in October 2015, the proportion of fleet in depot status averaged 16 percent. The depot percentage generally increased slowly at first, reaching a maximum value of 19 percent for the month of May 2015, and then started to decline around summer 2015. The depot inductions were largely in support of modifying aircraft to the Block 2B configuration for the Marine Corps IOC declaration at the end of July 2015.
  - Current program plans indicate the proportion of the fleet in depot will remain between 10 and 15 percent throughout CY16. Projections of depot rates beyond 2016 are difficult, since testing and development are ongoing. The program does not yet know the full suite of modifications that will be necessary to bring currently produced aircraft up to the envisioned final Block 3F configuration.
  - To examine the suitability performance of fielded aircraft, regardless of how many are in the depot, the program reports on the Mission Capable and Full Mission Capable (FMC) rates for the F-35 fleet. The Mission Capable rate represents the proportion of the fleet that is not in depot status and that is ready to fly any type of mission (as

opposed to all mission types). This rate includes aircraft that are only capable of flying training flights, however, and not necessarily a combat mission. Aircraft averaged 65 percent for the 12-month window considering all variants.

- The FMC rate calculates only the proportion of aircraft not in depot status that are capable of flying all assigned missions and can give a better view into the potential combat capability available to the field. It averaged 46 percent for the 12-month window considering all variants, but started to drop steadily from a peak of 62 percent achieved in December 2014, reaching a minimum value of 32 percent in October 2015. The rate declined for 8 of the 10 months from January to October 2015.
- The monthly NMC-M rate averaged 18 percent over the period, and exhibited the most variability of the non-available status categories. The NMC-M rate started out at 17 percent in November 2014, was as high as 24 percent in August 2015, and as low as 14 percent in September 2015. The Program Office set a threshold goal of 15 percent for 2015, but the fluctuations in month-to-month rates make it difficult to determine whether the goal for NMC-M can be achieved for a sustained period.
- Modifying aircraft also affects the NMC-M rate. Squadron maintainers, instead of the depot, are tasked to complete a portion of the required modifications by accomplishing Time Compliance Technical Directives (TCTDs). The "time compliance" requirements for these directives vary, normally allowing the aircraft to be operated without the modification in the interim and permit maintenance personnel to work the directive as able. While maintainers accomplish these TCTDs, the aircraft are logged as NMC-M status. Incorporating these TCTDs will drive the NMC-M rate up (worse) until these remaining modifications are completed. Publishing and fielding new TCTDs is expected for a program under development and is needed to see improvement in reliability and maintainability.
- The NMC-S rate averaged 15 percent and showed little trend, either up or down, over the period. The NMC-S rate started at 15 percent in November 2014 and ended at 16 percent in October 2015, ranging from between 12 to 19 percent in the months between. The Program Office set a threshold goal of 10 percent for 2015, but the NMC-S trend is not currently on track to achieve this.
- Modifying aircraft also has an effect on the NMC-S rate. Parts are taken from aircraft in depot status at the dedicated modification facilities in order to provide replacements for failed parts in the field, a process known as depot cannibalization. This usually occurs when replacement parts are not otherwise available from normal supply channels or stocks of spare parts on base. With the large number of aircraft in depot status, the program may have been able to improve the NMC-S rate by using depot cannibalizations, instead of procuring more spare parts, or reducing the failure rate of parts installed in aircraft, or improving how quickly failed parts are repaired and returned to circulation. If the Services endeavor to bring all of the early lot aircraft into the Block 3F configuration, the program will continue to have an extensive modification program for several years. While this will continue to provide opportunities for depot cannibalizations during that time, once the 3F modifications are complete, there will be fewer aircraft in the depot serving as spare parts sources and more in the field requiring parts support. If demand for spare parts remains high, this will put pressure on the supply system to keep up with demand without depot cannibalization as a source.
- Low availability rates are preventing the fleet of fielded operational F-35 aircraft from achieving planned, Service-funded flying hour goals. Original Service bed-down plans were based on F-35 squadrons ramping up to a steady state, fixed number of flight hours per tail per month, allowing for the projection of total fleet flight hours.
- Since poor availability in the field has shown that these original plans were unexecutable, the Program Office has since produced "modeled achievable" projections of total fleet flight hours, basing these projections on demonstrated fleet reliability and maintainability data, as well as expectations for future improvements. The most current modeled achievable projection is from November 2014.
  - Through November 23, 2015, the fleet had flown approximately 82 percent of the modeled achievable hours. This is an improvement since October 2014, the date used in the FY14 DOT&E Annual Report, when the fleet had flown only 72 percent of modeled achievable hours, but it is still below expectation.
  - The F-35B variant has flown approximately 11 percent more hours than its modeled achievable projection, in part due to a ramped up level of flying to produce trained pilots for the Marine Corps IOC declaration.

• The following table shows by variant the planned versus achieved flight hours for both the original plans and the modeled-achievable for the fielded production aircraft through November 23, 2015.

F-35 FLEET PLANNED VS. ACHIEVED FLIGHT HOURS AS OF NOVEMBER 23, 2015

Variant	Original Bed-Down Plan Cumulative Flight Hours			"Modeled Achievable" Cumulative Flight Hours		
	Estimated Planned	Achieved	Percent Planned	Estimated Planned	Achieved	Percent Planned
F-35A	26,000	16,768	65%	22,000	16,768	76%
F-35B	14,000	12,156	87%	11,000	12,156	111%
F-35C	5,500	2,949	54%	6,000	2,949	49%
Total	45,500	31,873	70%	39,000	31,873	82%

F-35 Fleet Reliability

- Aircraft reliability assessments include a variety of metrics, each characterizing a unique aspect of overall weapon system reliability.
  - Mean Flight Hours Between Critical Failure (MFHBCF) includes all failures that render the aircraft not safe to fly, and any equipment failures that would prevent the completion of a defined F-35 mission. It includes failures discovered in the air and on the ground.
  - Mean Flight Hours Between Removal (MFHBR) gives an indication of the degree of necessary logistical support and is frequently used in determining associated costs. It includes any removal of an item from the aircraft for replacement with a new item from the supply chain. Not all removals are failures, and some failures can be fixed on the aircraft without a removal. For example, some removed items are later determined to have not failed when tested at the repair site. Other components can be removed due to excessive signs of wear before a failure, such as worn tires.
  - Mean Flight Hours Between Maintenance Event Unscheduled (MFHBME Unsch) is a useful reliability metric for evaluating maintenance workload due to unplanned maintenance. Maintenance events are either scheduled (e.g., inspections, planned removals for part life) or unscheduled (e.g. maintenance to remedy failures, troubleshooting false alarms from fault reporting or defects reported but within limits, unplanned servicing, removals for worn parts—such as tires). One can also calculate the mean flight hours between scheduled maintenance events, or total events including both scheduled and unscheduled. However, for this report, all MFHBME Unsch metrics refer to the mean flight hours between unscheduled maintenance events only, as it is an indicator of aircraft reliability and the only mean-flight-hour-between-maintenance-event metric with an ORD requirement.
  - Mean Flight Hours Between Failure, Design Controllable (MFHBF_DC) includes failures of components due to design flaws under the purview of the contractor, such as the inability to withstand loads encountered in normal operation. Failures induced by improper maintenance practices are not included.
- The F-35 program developed reliability growth projections for each variant throughout the development period as a function of accumulated flight hours. These projections are shown as growth curves, and were established to compare observed reliability with target numbers to meet the threshold requirement at maturity, defined by 75,000 flight hours for the F-35A and F-35B, and by 50,000 flight hours for the F-35C, and 200,000 cumulative fleet flight hours. In November 2013, the program discontinued reporting against these curves for all ORD reliability metrics, and retained only the curve for MFHBF_DC, which is the only reliability metric included in the JSF Contract Specification (JCS). DOT&E reconstructed the growth curves for the other metrics analytically for this report and shows them in the tables on the following page for comparison to achieved values.
- As of late November 2015, the F-35, including operational and flight test aircraft, had accumulated approximately 43,400 flight hours, or slightly below 22 percent of the total 200,000-hour maturity mark defined in the ORD. Unlike the following table, which accounts only for fielded production aircraft, the flight test aircraft are included in the fleet hours which count toward reliability growth and maturity. By variant, the F-35A had flown approximately 22,300 hours, or 30 percent of its individual 75,000-hour maturity mark; the F-35B had flown approximately 15,800 hours, or 21 percent of its maturity mark; and the F-35C had flown approximately 5,300 hours, or 11 percent of its maturity mark.
- The program reports reliability and maintainability metrics on a three-month rolling window basis. This means for example, the MFHBR rate published for a month accounts only for the removals and flight hours of that month and the two previous months. This rolling three-month window provides enough time to dampen out variability often seen in month-to-month reports, while providing a short enough period to distinguish current trends.
- The first table on the following page compares current observed and projected interim goal MFHBCF values, with associated flight hours. It shows the ORD threshold requirement at maturity and the values in the FY14 DOT&E Annual Report for reference as well.
- The following similar tables compare current observed and projected interim goals for MFHBR, MFHBME Unsch, and MFHBF_DC rates for all three variants. MFHBF_DC is contract specification, and its JCS requirement is shown in lieu of an ORD threshold.
- Note that more current data than May 2015 are not available due to the Lockheed Martin database (FRACAS) not being compliant with all applicable DOD information assurance policies mandated by U.S. Cyber Command.
- Reliability values increased for 11 of 12 metrics between August 2014 and May 2015. The only metric which decreased in value was MFHBCF for the F-35C. A more in-depth trend analysis shows, however, that MFHBCF for the F-35C is likely increasing over time, albeit erratically. The MFHBCF metric shows particularly high month-to-month variability for all variants relative to the other metrics, due to the smaller number of reliability events that are critical failures. For the F-35C in particular, the August 2014 value was well above average, considering the preceding and following months, while the May 2015 value was below average for the past year.
- Despite improvements over the last year, 8 of the 12 reliability metrics are still below interim goals, based on their reliability growth curves, to meet threshold values by maturity. Two of these eight metrics however, are within 5 percent of their goal, F-35B MFHBCF and F-35C MFHBME Unsch. The remaining four are above their growth curve interim values. Of the four metrics above their growth curve interim values, three are the contract specification metric MFHBF_DC for each variant; and for this specific metric, the program is

reporting F-35B and F-35C reliability currently at or above the threshold at maturity. The fourth metric that is above the growth curve interim value is F-35B MFHBME Unsch. This is the only one of nine ORD metrics that is above its interim growth curve value. This pattern indicates that, although reliability is improving, increases in the contract specification reliability metric are not translating into equally large improvements in the other reliability metrics, which are operational requirements that will be evaluated during IOT&E.

- The F-35B is closest to achieving reliability goals, while the F-35A is furthest. For the F-35B, two of four reliability metrics are above their growth curves, one is within 5 percent, and one is below, MFHBR. MFHBR is the only metric where all three variants are less than 95 percent of their interim goal. For the F-35A and F-35C, the only metrics above their growth goals are the contract specification metrics, MFHBF_DC. One of three F-35C ORD metrics is within 5 percent of its growth goal, and all remaining F-35A and F-35C ORD metrics are below their interim targets for this stage of development.
- The effect of lower MFHBCF values is reduced aircraft full mission capability, mission capability, and availability rates. MFHBR values lagging behind their growth targets drive a higher demand for spare parts from the supply system than originally envisioned. When MFHBME Unsch values are below expectation, there is a higher demand for maintenance manpower than anticipated.
- DOT&E updated an in-depth study of reliability growth in MFHBR and MFHBME Unsch provided in the FY14 DOT&E Annual Report. The original study examined the period from July 2012 through October 2013, and modeled reliability growth using the Duane Postulate, which characterizes growth by a single parametric growth rate. Mathematically, the Duane Postulate assesses growth rate as the slope of the best-fit line when the natural logarithm of the cumulative failure rate is plotted against the natural logarithm of cumulative flight hours. A growth rate of zero would indicate no growth, and a growth rate of 1.0 is the theoretical upper limit, indicating instantaneous growth from a system that exhibits some failures to a system that never fails. The closer the growth rate is to 1.0 the faster the growth, but the relationship between assessed growth rates is not linear, due to the logarithmic nature of the plot.

F-35 RELIABILITY: MFHBCF (HOURS)

Variant	ORD Threshold		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBCF	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBCF	Observed MFHBCF (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBCF (3 Mos. Rolling Window)
F-35A	75,000	20	15,845	16.1	10.2	63%	8,834	8.2
F-35B	75,000	12	11,089	9.2	8.7	95%	7,039	7.5
F-35C	50,000	14	3,835	10.0	7.4	74%	2,046	8.3

F-35 RELIABILITY: MFHBR (HOURS)

Variant	ORD Threshold		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBR	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBR	Observed MFHBR (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBR (3 Mos. Rolling Window)
F-35A	75,000	6.5	15,845	5.3	4.7	89%	8,834	3.1
F-35B	75,000	6.0	11,089	4.6	3.9	85%	7,039	2.5
F-35C	50,000	6.0	3,835	4.3	3.4	79%	2,046	2.3

F-35 RELIABILITY: MFHBME Unsch (HOURS)

Variant	ORD Threshold		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBME Unsch	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBME Unsch	Observed MFHBME Unsch (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBME Unsch (3 Mos. Rolling Window)
F-35A	75,000	2.0	15,845	1.60	1.18	74%	8,834	0.85
F-35B	75,000	1.5	11,089	1.15	1.32	115%	7,039	0.96
F-35C	50,000	1.5	3,835	1.02	1.00	98%	2,046	0.84

F-35 RELIABILITY: MFHBF_DC (HOURS)

Variant	JCS Requirement		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBF_DC	Cumulative Flight Hours	Interim Goal to Meet JCS Requirement MFHBF_DC	Observed MFHBF_DC (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBF_DC (3 Mos. Rolling Window)
F-35A	75,000	6.0	15,845	4.6	4.8	104%	8,834	4.0
F-35B	75,000	4.0	11,089	2.9	4.3	148%	7,039	3.5
F-35C	50,000	4.0	3,835	2.6	4.0	154%	2,046	3.6

For example, a growth rate of 0.4 would indicate reliability growth much higher than twice as fast as a growth rate of 0.2.

- The updated analysis extended the period examined from July 2012 through May 2015. The analysis investigated only the F-35A and F-35B variants due to the still low number of flight hours on the F-35C. The study evaluated the current growth rate, then, using that rate, projected the reliability metric to the value expected at maturity.
- The study also evaluated the growth rate needed to meet the ORD threshold value at maturity from the current observed value of the reliability metric. The first table below shows the results of this updated study, along with the growth rates determined through October 2013 from the original study for comparison.
- The currently exhibited growth rates for three of the evaluated metrics are faster than the growth rates exhibited through October 2013. The growth rate for F-35A MFHBME Unsch reduced slightly. For both F-35A metrics and for F-35B MFHBR, the growth rate is still too low to meet the ORD threshold by maturity. The analyses project that if the current growth rate holds constant, the F-35A MFHBR metric will achieve within 90 percent of its requirement, while F-35B MFHBME Unsch will significantly exceed its requirement. DOT&E does not expect the F-35B MFHBME Unsch growth to sustain its current rate out through 75,000 flight hours, but there is plenty of margin for the rate to drop and still exceed the requirement by maturity.

Metric	Variant	May 2015 Value	Current Growth Rate from Duane Postulate	Projected Value at 75,000 Flight Hours	ORD Threshold	Projected Value as % ORD Threshold	October 2013 Growth Rate from Duane Postulate	Growth Rate Needed to Meet ORD
MFHBR	F-35A	4.7	0.204	6.0	6.5	93%	0.129	0.228
	F-35B	3.9	0.243	4.8	6.0	81%	0.210	0.297
MFHBME	F-35A	1.18	0.142	1.34	2.0	67%	0.162	0.281
	F-35B	1.32	0.427	2.74	1.5	183%	0.347	0.244

- The above growth rates were calculated with around 16,000 hours for the F-35A, and 11,000 hours for the F-35B. For comparison, observed MFHBME Unsch growth rates for several historical aircraft are shown in the table to the right.

Aircraft	MFHBME Growth Rate
F-15	0.14
F-16	0.14
F-22 (at 35,000 flight hours)	0.22
B-1	0.13
"Early" B-2 (at 5,000 flight hours)	0.24
"Late" B-2	0.13
C-17 (at 15,000 flight hours)	0.35

- These growth rates can still change, either increase or decrease, as the program introduces more reliability improvement initiatives and depending on how well they pan out in the field. Also, the Block 2B release expanded the aircraft's flight envelope and delivered initial combat capabilities. As a result, the fielded units will likely fly their aircraft more aggressively to the expanded envelope, and use mission systems more heavily than in the past. This change in operational use may uncover new failure modes that have an impact on sustaining or increasing reliability growth rates. Note that the above analysis covers a time span preceding Block 2B fleet release.
- The growth rates that the F-35 must achieve and sustain through 75,000 flight hours, in order to comply with ORD performance thresholds by maturity, have been demonstrated in the past, but mostly on bombers and transports. The F-22 achieved a MFHBME Unsch growth rate of 0.22, slightly less than the slowest growth rate the F-35 must sustain, for F-35A MFHBR, and only with an extensive and dedicated reliability improvement program.
- A number of components have demonstrated reliability much lower than predicted by engineering analysis. This drives down the overall system reliability and can lead to long wait-times for re-supply as the field demands more spare parts than the program planned to provide. Aircraft availability is also negatively affected by longer-than-predicted component repair times. The table below, grouped by components common to all variants, shows some of the high-driver components affecting low availability and reliability, followed by components failing more frequently on a particular variant or which are completely unique to it.

HIGH DRIVER COMPONENTS AFFECTING LOW AVAILABILITY AND RELIABILITY		
	Common to All Variants	Additional High Drivers by Variant
F-35A	• Avionics Processors • Nutplate and Engine Heat Blanket Cure Parameters • Low Observable Maintenance • Main Landing Gear Tires • Fuel System Components (Pumps and Valves)	• Exhaust Nozzle Converging-Diverging Link • Data Transfer Cartridge
F-35B		• Upper Lift Fan Door Actuator[1] • Flexible Linear Shaped Charge
F-35C		• Lightning Strike Damage • Nose Landing Gear Launch Bar Bolt[2]

1. Unique to the F-35B.
2. Unique to the F-35C.

Maintainability

- The amount of time needed to repair aircraft to return them to flying status remains higher than the requirement for the system when mature, but has improved over the past year. The program assesses this time with several measures, including Mean Corrective Maintenance Time for Critical Failure (MCMTCF) and Mean Time To Repair (MTTR) for all unscheduled maintenance. MCMTCF measures active maintenance time to correct only the subset of failures that prevent the F-35 from being able to perform a specific mission, and indicates how long it takes, on average, for maintainers to return an aircraft to Mission Capable status. MTTR measures the average active maintenance time for all unscheduled maintenance actions, and is a general indicator of the ease and timeliness of repair. Both measures include active touch labor time and cure times for coatings, sealants, paints, etc., but do not include logistics delay times such as how long it takes to receive shipment of a replacement part.

- The tables below compare measured MCMTCF and MTTR values for the three-month period ending in May 2015 to the ORD threshold and the percentage of the value to the threshold for all three variants. The tables also show the value reported in the FY14 DOT&E Annual Report for reference. For all variants, the MCMTCF and MTTR times decreased (improved), with particularly strong decreases for the F-35A and F-35B MCMTCF. The F-35A improved to a much larger degree than either the F-35B or F-35C. Nonetheless, both maintainability measures for all variants were well above (worse than) the ORD threshold value required at maturity. Note that more current data than May 2015 are not available due to the Lockheed Martin database (FRACAS) not being compliant with all applicable DOD information assurance policies mandated by U.S. Cyber Command.

F-35 MAINTAINABILITY: MCMTCF (HOURS)				
Variant	ORD Threshold	Values as of May 31, 2015 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of August 2014 (3 Mos. Rolling Window)
F-35A	4.0	9.7	243%	15.6
F-35B	4.5	10.2	227%	15.2
F-35C	4.0	9.6	240%	11.2

F-35 MAINTAINABILITY: MTTR (HOURS)				
Variant	ORD Threshold	Values as of May 31, 2015 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of August 2014 (3 Mos. Rolling Window)
F-35A	2.5	4.9	196%	8.6
F-35B	3.0	7.1	237%	7.5
F-35C	2.5	5.8	232%	6.6

- More in-depth analysis between May 2014 and May 2015, in order to capture longer-term one-year trends, shows that MCMTCF and MTTR for all three variants are decreasing (improving), but with high month-to-month variability. For MCMTCF, the rate of decrease for the F-35A and F-35B is the highest, while improvements for the F-35C have been slower to manifest. For MTTR, the rate of improvement has been greatest for the F-35A, and slightly slower for the F-35B and F-35C.
- Several factors contribute to lengthy maintenance durations, especially adhesive cure times for structural purposes, such as attaching hardware (e.g., nutplates and installing heat blankets around the engine), as well as long material cure times for low observable repairs. From July 2014 to June 2015, program records show that maintenance on "attaching hardware," such as nutplates and heat blankets, absorbed approximately 20 percent of all unscheduled maintenance time, while low observable repairs accounted for 15 percent; these were the two highest drivers. The increased use of accelerated curing procedures, such as blowing hot air on structural adhesives or low observable repair pastes to force a quicker cure, may account for some of the decrease in repair times over the past year, but much room remains for improvement. The third highest driver of unscheduled maintenance, work on the ejection seat, by contrast, only accounted for 3 percent of all unscheduled maintenance hours.
- The immature state of the maintenance manuals and technical information maintainers use to fix aircraft may also negatively affect long repair times. The program is still in the process of writing and verifying Joint Technical Data (JTD) (see separate section in this report). Whenever maintainers discover a problem with no solution yet in JTD, and this problem prevents the aircraft from flying, the maintainers must submit a "Category I" Action Request (AR) to a joint government/Lockheed Martin team asking for tailored instructions to fix the discrepancy. This team can take anywhere from several days to nearly a month to provide a final response to each AR, depending on the severity and complexity of the issue. The number of final Category I AR responses per aircraft per month has been slowly increasing from December 2014 through August 2015. This trend indicates that, as the fleet matures, maintainers are continuing to face failure modes not adequately addressed by the JTD or that require new repair instructions. However, there are other reasons for submitting an AR, which may also partly account for this increasing trend. For example, depot teams submit ARs for depot-related repair work. More aircraft cycling through the modifications program, therefore, drives some of this increase. In addition, supply occasionally delivers parts with missing, incomplete, or incorrect electronic records, known as Electronic Equipment Logs (EELs), preventing those parts from being incorporated into the aircraft's overall record in Autonomic Logistics Information System (ALIS). In these cases, squadron maintenance personnel cannot electronically certify the aircraft safe for flight until supply delivers correct EELs, and maintenance personnel submit an AR to request these EELs.
- A learning curve effect is also likely improving repair times. As maintainers become more familiar with common failure modes, their ability to repair them more quickly improves over time.
- Maintainers must dedicate a significant portion of F-35 elapsed maintenance time to scheduled maintenance activities as well, which also affects aircraft availability

rates in addition to repair times. Scheduled maintenance accounted for 55 percent of all maintenance time from June 2014 to July 2015. (Scheduled maintenance time does not appear in either the MCMTCF or MTTR metrics.)
- Reducing the burden of scheduled maintenance by increasing the amount of time between planned in-depth and lengthy inspections that are more intrusive than routine daily inspections and servicing, will have a positive effect on how often aircraft are available to fly missions, provided experience from the field warrants such increases. An example is the engine borescope inspection, which were required after the engine failure on AF-27 in June 2014. The interval for these inspections increased after the program determined a fix to the cause of the failure and began implementing it on fielded aircraft. It will take more time and experience with field operations to collect data that show whether the program can increase inspection intervals without affecting aircraft safety for flight though.

Autonomic Logistics Information System (ALIS)
- The program develops and fields the ALIS in increments, similar to the method for fielding mission systems capability in the air vehicle. In 2015, the program fielded new versions of both hardware and software to meet requirements for the Marine Corps IOC. Although the program adjusted both schedule and incremental development build plans for ALIS hardware and software multiple times in 2014, it held the schedule more stable in 2015 by deferring capabilities to later software versions. The Program Office released several new versions of the software used in ALIS in 2015. However, each new version of software, while adding some new capability, failed to resolve all the deficiencies identified in earlier releases. Throughout 2015, formal testing of ALIS software has taken place at the Edwards AFB flight test center on non-operationally representative ALIS hardware, which relies on reach-back capability to the prime contractor at Fort Worth. The program still does not have a dedicated end-to-end developmental testing venue for ALIS, but has begun plans to develop one at Edwards AFB. This test venue, referred to as the Operationally Representative Environment (ORE), will operate in parallel with the ALIS squadron unit assigned to the operational test squadrons. The program plans to have the ORE in place as early as spring 2016. The ORE is planned to be a replicate of a full ALIS system and is needed to complete developmental testing of ALIS hardware and software in a closed environment to manage discoveries and corrections to deficiencies prior to OT&E and fielding to operational units. Meanwhile, formal testing, designated as Logistics Test and Evaluation (LT&E), remains limited and differs from how field units employ ALIS. For example, the flight test center at Edwards AFB does not use Prognostic Health Management (PHM), Squadron Health Management (SHM), Anomaly and Failure Resolution System (AFRS), and the Computerized Maintenance Management System (CMMS), each of which are modules within ALIS that the operational units use routinely.

ALIS Software Testing and Fielding in 2015
- During 2015, the program accomplished the following with ALIS software:
  - The program transitioned all fielded units from ALIS 1.0.3 to 2.0.0 between January and April 2015. This software includes integrated exceedance management, improved interfaces with legacy government systems, an upgrade to Microsoft Windows 7 on laptop and other portable devices, fixes to deficiencies, and reduced screen refresh and download times. Testing of software 2.0.0 identified two Category 1 deficiencies (same categorization as previously explained in this report in "Mission Systems" section), both of which remained uncorrected when the program delivered the software to field units. According to the program's LT&E report on ALIS 2.0.0, the test team identified the following deficiencies:
    - A deficiency in the air vehicle's maintenance vehicle interface (MVI)—the hardware used to upload aircraft data files—corrupted the aircraft software files during the upload process. Technical manuals in ALIS direct the process for loading aircraft files. The contractor addressed this deficiency by creating a fix in the final Block 2B aircraft software, and the program fielded it in 2015.
    - The Mission Capability Override (MCO) feature gives maintenance supervisors the authority and ability to override an erroneous mission capability status in ALIS. The LT&E of ALIS 1.0.3, conducted in September and October 2012, revealed a discrepancy in the mission capability status between two modules of ALIS. The Computerized Maintenance Management System (CMMS), which uses Health Reporting Codes (HRCs) downloaded from the aircraft, can report an aircraft as Mission Capable. Meanwhile, another module within ALIS, the Squadron Health Management (SHM), which makes the mission capable determination based on the Mission Essential Function List, could categorize the aircraft as Non-Mission Capable (NMC). This discrepancy is a result of errors in the interfaces between HRCs and the list of mission essential functions. When this discrepancy occurs, maintenance supervisors should be able to use the MCO feature to override either status within ALIS, which makes the aircraft available for flight. However, the Mission Capability Override is deficient because it does not allow override of the status within SHM (the override functions properly for CMMS). In ALIS 2.0.0, the same deficiency remains. However, ALIS 2.0.0 adds capabilities using the aircraft status in SHM to collect the mission capable status of aircraft across the fleet. Using SHM status to generate fleet availability metrics may be inaccurate because of the MCO deficiency.

- In addition to the Category 1 deficiencies listed above, the LT&E test team also identified 56 Category 2 deficiencies (same categorization as previously explained in this report in "Mission Systems" section) in the ALIS 2.0.0 report. The following list highlights deficiencies, either singly or in related groups, which affect aircraft maintenance and sortie generation rates:
  - » Parts management functionality within CMMS, which alerts ALIS users if maintainers attempt to install an incorrect part on an aircraft after the aircraft has undergone modification (i.e., modifications needed due to concurrency of development with production), is deficient. Once an aircraft has undergone modification, maintainers should install only specific, newer types and models of parts. However, CMMS incorrectly authorizes older/inappropriate replacement parts, changing the aircraft to an unauthorized configuration, which lacks the attributes of the modification. The configuration management function of CMMS is also deficient, as it does not maintain accurate configuration records of aircraft with completed modifications when CMMS has permitted the installation of infidel parts on the aircraft.
  - » Maintainers must use manual workarounds to ensure the aircraft mission capable status is accurate if they determine additional maintenance is required beyond that dictated by the HRCs from the post-mission download. For example, if maintenance personnel find or cause additional problems while performing maintenance, they must create new work orders with appropriate severity codes indicating that an aircraft is no longer mission capable. However, CMMS and SHM will not reflect that new aircraft status, requiring a maintenance supervisor to open each work order to review the actual, current aircraft status.
  - » The heavy maintenance workload, required to enter pertinent maintenance data into ALIS, causes field units to create workarounds, including creating task templates outside of ALIS to get maintenance records into ALIS.
  - » AFRS, designed to provide a library of possible maintenance actions for each HRC does not have the troubleshooting solutions for approximately 45 percent of the HRCs.
  - » Data products that ALIS is dependent on to make mission capable determinations, such as HRCs, the HRC nuisance filter list, AFRS troubleshooting libraries, and the mission essential function list, do not sufficiently manage configuration by including version, release date, applicability, or record of changes. As a result, maintenance personnel spend additional time correlating the data files to the individual aircraft—a process which increases the risks of errors and loss of configuration management of the aircraft assigned to the units.
  - » Long wait times to synchronize the Portable Maintenance Aid to transfer work order data to the ALIS squadron unit.
  - » Long wait times needed to complete data searches, export reports, and apply processes within ALIS.
- The program developed ALIS 2.0.1 to upgrade to Windows Server 12, add new capabilities required to support the Marine Corps' IOC declaration in mid-2015, and address ALIS 2.0.0 deficiencies. The program completed the LT&E of ALIS 2.0.1 in May 2015, but results were poor, so the program did not release the software to the field. As of the writing of this report, the program had not signed out the ALIS 2.0.1 LT&E report. According to their "quick look" briefing, the test team discovered five new Category 1 deficiencies and confirmed that the contractor did not correct in ALIS 2.0.1 the two Category 1 deficiencies identified during ALIS 2.0.0 testing (listed above). According to the briefing, the five new Category 1 deficiencies are:
  - The Integrated Exceedance Management System, designed to assess and report whether the aircraft exceeded limitations during flight, failed to function properly. The Services require proper functioning of this capability to support post-flight maintenance/inspections and safe turnaround for subsequent flights.
  - AFRS, which is critical to troubleshooting and maintenance repairs, demonstrated unstable behavior and frequently failed because of interface problems and a system licensing configuration issue.
  - ALIS randomly prevented user logins.
  - The maintenance action severity code functionality in CMMS—designed to automatically assign severity codes to work orders as maintenance personnel create them—did not work correctly.
  - ALIS failed to process HRCs correctly when maintenance personnel used CD media to input them into ALIS at sites that do not use PMD readers (described below) to download maintenance data.
- The program developed another version of ALIS, version 2.0.1.1, which contained numerous software "patches" designed to correct the five Category 1 deficiencies discovered by the test team during the LT&E of ALIS 2.0.1. The test team conducted an LT&E in May and June 2015 specifically to determine if Lockheed Martin had resolved each deficiency. The test team evaluated the correction for each deficiency as the contractor delivered the software patches. As of the end of November, the program had not signed out the LT&E report on ALIS 2.0.1.1, but according to the test team's "quick look" briefing, they recommended releasing ALIS 2.0.1.1 to the fielded units, which the program completed between July and October 2015. In their "quick look" briefing, the test team also noted failures of redundant systems and workarounds that were required to address other unresolved problems. These included:

    - Frequent failures of the aircraft memory device, which serves as a back up to the PMD, to download into ALIS when the PMD is corrupted.
    - CMMS and SHM exhibited disparities in tracking on-aircraft equipment usage which required maintainers to develop and operate a parallel tracking system independent of ALIS.
    - Managing data loads associated with mission planning required extensive contractor support as the maintenance-vehicle interface did not support direct loading to the aircraft as designed.
    - Air vehicle data transfer between squadron hardware, required for deployments and aircraft induction to and from depots, required extensive contractor support.
    - Air vehicle lockdown capability, needed for impounding an aircraft in the event of an investigation, did not work.
  - All versions of ALIS have demonstrated persistent problems with data quality and integrity, particularly in the Electronic Equipment Logbooks (EELs), which allow usage tracking of aircraft parts. Frequently, EELs are not generated correctly or do not transfer accurately, requiring manual workarounds that extend aircraft repair and maintenance times. Without accurate EELs data, ALIS can improperly ground an aircraft or permit an aircraft to fly when it should not.

ALIS Hardware Fielding in 2015

- During CY15, the program demonstrated progress in the development and fielding of ALIS hardware and aligning hardware versions with the software versions noted above.
  - The program delivered the first deployable version of the Squadron Operating Unit (SOU), deemed SOU V2 (Increment 1), aligned with ALIS software 2.0.1, to MCAS Yuma to support Marine Corps IOC. The originally fielded unit-level hardware, SOU V1, failed to meet ORD deployability requirements due to its size and weight. SOU V2 incorporates modular components that meet two-man-carry transportation requirements and decrease set-up time. Additionally, field units can tailor the SOU V2 by adjusting the number of components with which they deploy depending on projected duration. SOU V2 allowed the program to meet requirements for Marine Cops IOC. It will support Block 2B, 3i, and 3F aircraft. The program plans to field one set of SOU V2 hardware for each F-35 unit and an additional set of SOU hardware for each F-35 operating location. During partial squadron deployments, the unit will deploy with their SOU V2 while the remainder of the squadron's aircraft will transfer to the base-level SOU.
  - Because the Edwards AFB flight test center does not have an SOU V2, the program conducted the hardware portion of the LT&E at Fort Worth in May 2015. Testing included demonstrating that PMDs from aircraft at the flight test center downloaded correctly into the SOU V2.
  - The program continued to field PMD readers to operating locations. As designed, maintainers download aircraft PMDs post flight to ALIS through a Ground Data Security Assembly Receptacle (GDR). However, it takes between 1.0 and 1.2 hours to download all data from a 1-hour flight. PMD readers download maintenance data only within 5 minutes, permitting faster servicing of aircraft.
  - The program delivered an SOU V2 to the JOTT at Edwards AFB in November 2015. This SOU V2 will be "on loan" from Hill AFB, Utah, and is planned to be used in an F-35A deployment to Mountain Home AFB, Idaho, in March 2016 with six Air Force F-35A aircraft.
  - Lockheed Martin delivered full SOU V2 kits to MCAS Yuma in May 2015 and to the Pilot Training Center at Luke AFB, Arizona (for Norway) in October. Because Israel did not require an SOU V2 when scheduled for delivery, the Program Office arranged for it to go to MCAS Yuma in November 2015, so the squadron could use it in an assessment of the F-35B's capabilities at an austere location. The program delivered an SOU V2 deployment kit to Nellis AFB and a Central Point of Entry (CPE) kit, which included a CPE and an SOU V1, for United Kingdom lab use, in December 2015. A full SOU kit includes more peripheral equipment than a deployment kit.

Cross Ramp Deployment Demonstration May 2015

- During April and May 2015, the Air Force's Air Combat Command tasked the 31st Test and Evaluation Squadron (TES) at Edwards AFB to conduct a limited deployment of F-35A aircraft as part of the de-scoped Block 2B operational test activity. This deployment, from one hangar on the flight line at Edwards AFB to another hangar, termed the Cross Ramp Deployment Demonstration (CRDD), gave the program and the Air Force an opportunity to learn how to deploy the F-35 air system and ALIS. Originally, the 31st TES planned to use ALIS 2.0.1, but delays in releasing that software resulted in the need to use ALIS 2.0.0 instead. Overall, the CRDD showed that ALIS 2.0.0 deficiencies, plus difficulties encountered during the CRDD in downloading and transferring data files from home station to a deployed location, will negatively affect sortie generation rate if they remain uncorrected. The CRDD also demonstrated that getting ALIS 2.0.0 online with current maintenance information while also conducting flying operations is time consuming, complex, and labor intensive. Working around ALIS 2.0.0 deficiencies in this manner was possible for this demonstration of limited duration; however, it would not be acceptable for deployed combat operations.
  - The 31st TES deployed across the ramp on the flightline by packing and moving an ALIS SOU V1 loaded with ALIS 2.0.0 software, mission planning hardware, maintenance personnel, support equipment, and tools. Three F-35A aircraft "deployed" to the cross ramp location after the ALIS SOU V1 was in place. For supply support, maintenance personnel obtained spare parts from the base warehouse as though they had not deployed (i.e., the 31st TES did not deploy in this demonstration with a

pre-planned set of spares as an operational unit would have for an actual deployment).
- Transfer of aircraft data from the SOU at the main operating location to the SOU at the "deployed" location and getting the SOU online took several days to complete and required extensive support from Lockheed Martin ALIS administrators, a level of effort not planned for the deployment and not operationally suitable. Although not finalized by the Services, deployment concepts of operation will include procedures for transferring aircraft data between SOUs via secure electronic methods. The test team attempted the primary electronic method, but the configuration of the deployed SOU caused it to fail. Ultimately, data transfer occurred using the physical transfer of back-up CDs to the deployed location, but the 31st TES could not load the files until the end of the third of the five days of flight operations, because administrators had to load multiple software patches, and resolve ALIS account problems for every authorized user. After loading the aircraft data on the deployed SOU, administrators also had to enter manually all maintenance performed on the aircraft during this time into the SOU before bringing ALIS online to support operations.
- Flight operations did take place without the support of normal ALIS operations for the three days while the test team worked to get the SOU online. During this period, maintenance personnel prepared and recovered aircraft without a full post-mission download of maintenance data, including health and fault codes normally captured and transmitted to ALIS 2.0.0. The deployed aircraft generally required only routine maintenance such as tire changes, which maintainers could complete without access to all maintenance instructions. One aircraft experienced a radio failure, which did not require an HRC download to diagnose, and did not fly again until maintainers replaced the radio.
- To prepare for the deployment, the 31st TES did not fly the aircraft designated for the deployment during the week prior, allowing maintenance personnel to prepare the aircraft and ensure all inspections were current and maintenance actions complete. This preparation allowed the unit to conduct flight operations for three days during the deployment while the SOU remained offline.
- At the end of the demonstration, the 31st TES successfully transferred data to the Autonomic Logistics Operating Unit at Fort Worth—per one of the electronic methods of transfer expected for deployed operations—but staffing levels at Lockheed Martin were insufficient to complete the transfer all the way back to the home station SOU. Instead, the 31st TES transferred data back to the home station SOU via an alternative, web-based, secure, online file transfer service operated by the Army Missile Research and Development Center, referred to as "AMRDEC."
- The CRDD showed that although cumbersome, field units could relocate the SOU V1 hardware to a deployed operating location and eventually support operations with that hardware. However, difficulties in transferring data between home station and a deployed SOU made the deployment and redeployment processes time consuming and required extensive support from the contractor to complete. Although ALIS 2.0.1.1 added improvements to data transfer capabilities, the program has not yet demonstrated those improvements in a Service-led deployment exercise. Therefore, it is unknown the extent to which ALIS 2.0.1.1 improves data transfer capabilities.

Marine Corps Austere Assessment Deployment Demonstration, December 2015

- The Marine Corps deployed eight production F-35B aircraft—six from VMFA-121 at Marine Corps Air Station (MCAS) Yuma, Arizona, and two from VMX-22 at Edwards AFB, California—to the Strategic Expeditionary Landing Field (SELF) near MCAS Twentynine Palms, California, from December 8 – 15, 2015, to assess deployed operations to an austere, forward-base location. The Marine Corps aligned the deployment with a combined arms live fire exercise, Exercise Steel Knight, to have the F-35 detachment provide close air support for the rest of the exercise participants as the forward deployed air combat element (ACE). The SELF had an airfield constructed of AM2 matting (aluminum paneling engineered for rapid runway construction to support austere operations) and minimal support infrastructure, which required the Marine Corps to deploy the necessary support equipment, spare parts, and personnel; and set up secure facilities on the flightline to conduct F-35B flight operations. Although it was not a formal operational test event, the JOTT and DOT&E staff observed operations and collected data to support the assessment.
  - While deployed, and in support of the exercise, the Marine Corps flew approximately 46 percent of the planned sorties (28 sorties flown versus 61 sorties planned), not including the deployment, redeployment, and local familiarization sorties. Accounting for all sorties (i.e., deploying and redeploying, local training, aircraft diverts and swapping one aircraft at home station) the Marine Corps flew approximately 54 percent of scheduled sorties (82 scheduled versus 44 flown). Weather, particularly high winds, aircraft availability, and problems transferring aircraft data from the home station to the deployed ALIS SOU all contributed to the loss of scheduled sorties.
  - The Marine Corps planned to employ inert GBU-12 and GBU-32 weapons in the CAS role during the exercise. The Marine Corps ordnance loading teams completed multiple GBU-12 and GBU-32 upload and download evolutions at the SELF. However, pilots released fewer weapons than planned due to weather and range limitations.
  - Two aircraft experienced foreign object damage to their engines from debris ingested during operations, grounding them until the end of the deployment. The engine damage on both aircraft was not severe enough to cause an engine

change, but required a Pratt and Whitney technician, certified in blending out damage to engine blades, to repair the engines on both aircraft at Twentynine Palms so they could return to flyable status, allowing the aircraft to return to home station at the end of the deployment. No further action was required for the engine repairs on either aircraft. It was still unknown at the time of this report how these types of engine repairs would be conducted during deployed or combat operations.
- The deployment was the first to use the ALIS Standard Operating Unit Version 2 (SOU V2), which is smaller, lighter weight and more modularized than Version 1. Although Marine Corps ALIS personnel were able to set up the SOU V2 (i.e., place and connect the modules and apply power) within a few hours after arrival, setting up connectivity with the broader Autonomic Logistics Global Support (ALGS) function did not occur for quite some time. The Customer Relations Module (CRM) of ALIS, used to submit action requests to the contractor for resolving maintenance actions, operated only intermittently during the deployment.
- The transfer of data from home station to the deployed ALIS SOU took several days to fully complete, a process that is not affected by the version of SOU being used. Since the SOU V2 lacked connectivity to the Autonomic Logistics Operating Unit, which is required for transferring data via the preferred method of keeping the data entirely within the infrastructure of ALIS, initial data transfers for the six aircraft from MCAS Yuma were AMRDEC. Files were transferred to workstations at the deployed site and then loaded into ALIS via CDs. The downloading of files from AMRDEC was slowed several times when SATCOM connectivity was lost during the process. The aircraft from Edwards AFB, however, brought CD's with them for transfer into ALIS.
- The deployment provided valuable "lessons learned" for the Marine Corps as it develops concepts of operation for forward basing and austere operations. While the SOU V2 proved to be easier and quicker to set up than the SOU V1, transferring aircraft data from home station to the deployed location continued to be problematic. Poor aircraft availability reduced the support the F-35B ACE was able to provide to the large force exercise.

ALIS Software and Hardware Development Planning through the End of SDD

- In CY15, the program continued to struggle with providing the planned increments of capability to support the scheduled releases of ALIS software 2.0.x and 3.0.x. The program approved changes to the content of the ALIS developmental software release plan in April 2015 for ALIS 2.0.1 and 2.0.2. To adhere to the previously approved software release schedule for ALIS 2.0.1, the program deferred several capabilities, including cross-domain solutions for information exchange requirements and firewall protections for low observable and mission planning data, to a later fix release. The Marine Corps, which required ALIS 2.0.1 for IOC, supported the Program Office's plan to defer these capabilities until after IOC.
  - These deferrals are in addition to decisions in 2014 to defer life-limited parts management capabilities to ALIS 2.0.2 and ALIS 3.0.0.
  - Although the re-plan included a two-month delay in the LT&E dates for ALIS 2.0.1 from March to May 2015, the program did not change the initial fielding date of July 2015, the planned date for Marine Corps IOC. The program also approved a fix release of this software to follow almost immediately.
  - The program had previously scheduled fielding of software 2.0.2, beginning in December 2015, but approved a nearly eight-month delay to late July 2016. The Air Force IOC requirement is for ALIS software 2.0.2 to be fielded. Since the Air Force also requires operationally representative hardware and software 90 days before declaring IOC, the delayed schedule does not support the Air Force IOC objective date of August 2016. An additional potential problem is that the program currently does not plan to conduct cybersecurity penetration testing during the development of this ALIS release or any future developmental releases, but will instead rely on previous, albeit limited, cybersecurity test results. This decision increases the risk that the program will not be aware of ALIS vulnerabilities before making fielding decisions. However, the JOTT will complete operational cybersecurity testing of fielded ALIS components.
  - At an April 2015 review, the program projected initial fielding of ALIS 3.0.0 in June 2017 and indicated they would propose combining ALIS 3.0.0 and 3.0.1 (previously planned for December 2017) into a single release in June 2018. Should this occur, ALIS software will not include full life limited parts management, a capability planned for Marine Corps IOC, until nearly three years after Marine Corps IOC. All fielded locations will require high levels of contractor support until the program integrates life limited parts management capability into ALIS. In November 2015, the program proposed changing the content of ALIS 3.0.0 to reflect service and partner priorities and moving the fielding date forward by approximately six months.
  - The program has deferred the PHM downlink originally planned for release in ALIS 2.0.0 indefinitely because of security concerns.
- The program plans the following hardware releases to align with software releases noted above:
  - The program plans SOU V2 (Increment 2) to align with ALIS 2.0.2 and include additional SOU V2 hardware improvements to support Air Force IOC, including dynamic routing to deliver data via alternate network paths and sub-squadron reporting to allow deployed assets to report back to a parent SOU.

- The third increment of SOU V2 hardware will address Service requirements for decentralized maintenance, allowing personnel to manage maintenance tasks whether or not they connect their portable maintenance aid (PMA) to the main SOU (the PMA provides connectivity between maintenance personnel and the aircraft, enabling them to do maintenance tasks on the aircraft by viewing technical data and managing work orders downloaded from the SOU). Increment 3 will also permit units to conduct deployments without SOU hardware, instead relying on PMAs. This increment of SOU V2 will align with ALIS release 3.0.0.

Prognostic Health Management (PHM) within ALIS

- The PHM system collects air system performance data to determine the operational status of the air vehicle and, upon reaching maturity, will use data collected across the F-35 enterprise and stored within PHM to predict maintenance requirements based on trends. The PHM system provides the capability to diagnose and isolate failures, track and trend the health and life of components, and enable autonomic logistics using air vehicle HRCs collected during flight and saved on aircraft PMDs. The F-35 PHM system has three major components: fault and failure management (diagnostic capability), life and usage management (prognostic capability), and data management. PHM diagnostic and data management capabilities remain immature. The program does not plan to integrate prognostic capabilities until ALIS 2.0.2.
  - Diagnostic capability should detect true faults within the air vehicle and accurately isolate those faults to a line-replaceable component. However, to date, F-35 diagnostic capabilities continue to demonstrate poor accuracy, low detection rates, and a high false alarm rate. Although coverage of the fault detection has grown as the program has fielded each block of F-35 capability, all metrics of performance remain well below threshold requirements. The table below compares specific diagnostic measures from the ORD with current values of performance through June 2015.
  - PHM affects nearly every on- and off-board system on the F-35. It must be highly integrated to function as intended and requires continuous improvements for the system to mature.
- Poor diagnostic performance increases maintenance downtime. Maintainers often conduct built-in tests to see if the fault codes detected by the diagnostics are true faults. False failures (diagnostics detecting a failure when one does not exist) require service personnel to conduct unnecessary maintenance actions and often rely on contractor support to diagnose system faults more accurately. These actions increase maintenance man-hours per flight hour, which in turn can reduce aircraft availability rates and sortie generation rates. Poor accuracy of diagnostic tools can also lead to desensitizing maintenance personnel to actual faults.

METRICS OF DIAGNOSTIC CAPABILITY
(6-month rolling window as of June 2015. Data provided by the Program Office are considered "preliminary" as they have not completed the formal adjudication process by the data review board.)

Diagnostic Measure	Threshold Requirement	Demonstrated Performance		
		Block 1	Block 2	Block 3
Developmental Test and Production Aircraft				
Fault Detection Coverage (percent mission critical failures detectable by PHM)	N/A	65	73	84
Fault Detection Rate (percent correct detections for detectable failures)	98	65	73	85
Fault Isolation Rate (percentage): Electronic Fault to One Line Replaceable Component (LRC)	90	68	69	72
Fault Isolation Rate (percentage): Non-Electronic Fault to One LRC	70	76	72	79
Fault Isolate Rate (percentage): None-Electronic Fault to 3 or Fewer LRC	90	82	87	87
Production Aircraft Only				
Mean Flight Hours Between False Alarms	50	0.20	0.60	0.18
Mean Flight Hours Between Flight Safety Critical False Alarms	450	1,360	543	170
Accumulated Flight Hours for Measures	N/A	1,360	4,886	1,360
Ratio of False Alarms to Valid Maintenance Events	N/A	44:1	16:1	1079:1

  - Qualified maintenance supervisors can cancel an HRC without generating a work order for maintenance actions if they know that the HRC corresponds to a false alarm not yet added to the nuisance filter list. In this case, the canceled HRC will not result in the generation of a work order, and it will not count as a false alarm in the metrics in the above table. The program does not score an HRC as a false alarm unless a maintainer signs off a work order indicating that the problem described by the HRC did not occur. Because PHM is immature and this saves time, it occurs regularly at field locations but artificially lowers the true false alarms rate (i.e., actual rate is higher).
  - Comparing the values in the table above with previous reports, Mean Flight Hours Between Flight Safety Critical False Alarms is the only diagnostic metric that has shown significant improvement over the last year. Other metrics have stayed either flat or decreased (worsened) slightly.

- The following lists the systems most likely to result in missed fault detections, incorrect fault isolations, and false alarms as of June 2015:
  - Missed detections. Integrated Core Processor, power and thermal management system, panoramic color display, communications-navigation-identification (CNI) rack modules, and the Helmet Mounted Display System.
  - Incorrect isolation. Integrated Core Processor, power and thermal management system, electronic warfare, fuel system, CNI rack modules, and hydraulic power system.
  - False alarms. CNI system, propulsion, electronic warfare, suspension and release, displays and indicators in general.

Off-board Mission Support (OMS) within ALIS

- OMS provides F-35 ground mission planning, mission debrief, security, and sensor management capabilities. Similar to other components of ALIS, the program does not have a developmental test venue for OMS. Mission planning modules include the baseline Joint Mission Planning System software that pilots and tacticians use to develop files for uploading into the aircraft prior to flight. OMS includes separate hardware such as workstations and encryption/decryption devices and networks with ALIS for data management. In addition to mission planning, OMS provides the following functions:
  - Ground security that allows for secure data management and cryptologic key management at multiple classification levels
  - Sensor management and selection of mission data files to create a mission data load
  - Mission debrief capability for replaying audio and video from completed flights
- Until September 2015, the training center did not provide hands-on training on OMS, requiring the pilots to learn it through trial and error and by asking questions of the contractor. Also, the program has not yet provided OMS user manuals. As a result, field units will likely have difficulty providing the expertise to create tailored, theater-specific mission data loads during contingency operations. Few pilots currently possess the training and experience to build mission data loads from beginning to end.
- OMS deficiencies will have a negative impact on combat mission and training flight operational tempo. Long processing times create bottlenecks in both mission planning and mission debrief, particularly for multi-ship missions.
  - Pilots transfer a mission plan into the PMD using a GDR, which encrypts the information. The PMD loading process is unnecessarily complex, taking 25 to 45 minutes to transfer a mission data load from an OMS workstation to a PMD. If pilots transfer the same mission data load to multiple PMDs for a multi-ship mission, each PMD is encrypted separately with no time savings.
  - OMS requires excessive time for loading of PMDs and decryption of mission data and does not support timely mission debrief, particularly if pilots fly multiple missions in one day. For example, a 1-hour mission typically takes between 1.0 and 1.2 hours to decrypt, and depending on the amount of cockpit video recorded, can take longer.
  - Administrative functions in OMS, such as theater data load updates, user authentication file updates, cryptographic updates, and data transfers are inefficient and require excessive times to complete.
    - Because of cryptographic key expirations, OMS administrators must update the theater data load at least every 28 days. The OMS administrator builds the load on OMS equipment, transfers it to a separate laptop, creates a CD, and then uploads it to the SOU. Again, personnel cannot build cryptographic key loads on one OMS workstation and export it to others in the same unit; they must build them individually.
    - Personnel must install cryptographic keys on the aircraft, OMS workstations, GDRs, and GDR maintenance laptops.
    - Block 2B aircraft have 33 different cryptographic keys with varying expiration periods. When building a key for the entire jet, an error frequently means rebuilding from the beginning, which can take several hours.
    - The cryptographic key management tool is not intuitive, prone to errors, and does not have a validation function so the user can determine if a key load is accurate prior to transferring it to the aircraft.
    - Loading of incorrect keys can result in aircrew not having capabilities such as secure voice transmissions.
    - Local security policies vary, making hardware requirements and information technology processes different at each operating location.
  - Current OMS hardware does not have the necessary video processing and display capabilities to allow pilots to effectively debrief a multi-ship mission. Current debriefing capability via laptops does not provide adequate resolution or a large enough presentation for a four-ship debrief.

Joint Technical Data (JTD)

- Although the verification of Joint Technical Data (JTD) modules has proceeded through 2015, field units continue to face challenges where JTD is either not yet verified, is unclear, or includes errors. To work around these challenges, personnel must frequently submit ARs to the contractor and wait for the engineering disposition, a process that adds to maintenance time.
- The program identifies JTD modules and the primary contractors develop and verify them in the field. Once JTD modules complete verification, the program includes them in the JTD package distributed periodically to all field locations through ALIS. At the field locations, they are downloaded to unit-level SOUs and PMAs. JTD updates currently require

downloading of the entire JTD package (i.e., partial changes to JTD cannot be distributed to fielded units).
- ALIS release 2.0.0 included Trilogi Viewer 4.0, which supports delivery of partial builds and amendments to JTD to reduce the time required to install JTD updates at the unit level. However, the program determined that this version of Trilogi contains a software error, which prevented implementation of this capability until corrected. As of December 2015, the program continues to distribute only complete, bundled JTD packages.
- The total number of identified data modules grows each year as the program matures and low-rate initial production (LRIP) contracts include additional JTD delivery requirements. The air-vehicle JTD includes time compliance technical data, depot-level technical data, air vehicle diagnostics and troubleshooting procedures, complete structural field repair series data, aircraft battle damage assessment and repair, and maintenance training equipment. According to the most recent data from the Program Office, as of September 2015, propulsion JTD development is nearly complete and on schedule. To support Marine Corps IOC, the contractor focused on development of F-35B unit-level and Supportable Low Observable (SLO) JTD and deferred approximately 260 data modules, identified by the Marine Corps as not needed until after IOC, such as JTD modules for loading weapons not yet cleared for use.
- Although the program included development of support equipment JTD in the SDD contract, the program funded additional support equipment via another, separate contract, which requires approximately 1,700 more data modules. The contract began in July 2014 and the modules must be verified before the end of SDD.
- The program estimates that development of all JTD for each variant of the air vehicle and for propulsion will meet Service milestones.
- DOT&E sees risk in the ability of the program to complete air vehicle JTD verifications in time to meet Service needs. The program does not have a formal JTD verification schedule nor dedicated time to complete air vehicle JTD verifications. In addition, it depends on the availability of aircraft, primarily at Edwards and Eglin AFBs, to complete this work. JTD verifications have lower priority than maintaining the flight schedule, so verification teams normally cannot schedule dedicated events.
  - The program did focus on completing F-35B unit-level verifications during 2015 with verifications lagging development by fewer than 200 modules out of 5,157 developed.
  - The program will not complete highly invasive JTD verifications, such as those for removing fuel cells, until an aircraft requires this level of maintenance.
  - The program did not fund SLO JTD verifications until March 2014, so SLO JTD lags other verification efforts. However, most SLO JTD verification will take place using desktop analysis, and the program expects verification for all variants to proceed on schedule.
- As of September 2015, the program had verified approximately 94 percent of the identified air vehicle JTD modules for the F-35A, 93 percent of the F-35B, and 73 percent of the F-35C. The table below shows the number of JTD modules identified, developed, and verified for the air vehicle by variant, pilot flight equipment, support equipment, and SLO. Overall, approximately 77 percent of these modules have been identified, developed, and verified. The program tracks propulsion JTD separately.

F-35 SDD JOINT TECHNICAL DATA (JTD) DEVELOPMENT AND VERIFICATION STATUS
REQUIRED BY COMPLETION OF SYSTEM DEVEOLOPMENT AND DEMONSTRATION (SDD) CONTRACT
Air Vehicle, Pilot Flight Equipment (PFE), Support Equipment (SE), and Supportable Low Observable (SLO)
(as of end of September 2015)

	Module Type	Modules Identified	Modules Developed	Percent Identified Modules Developed	Number of Verification Events[1]	Percent Identified Modules Verified
F-35A[2]	Unit-level	4,603	4,326	94 %	4,328	Not Determined
F-35B[2]	Unit-level	5,335	5,157	97 %	4,966	93 %
F-35C[2]	Unit-level	4,766	4,009	84 %	3,488	73 %
Common (all variants)[3]	Unit-level	84	58	69 %	62	Not Determined
PFE	Common	326	318	98 %	274	84 %
SE	Common	2,345	1,596	68 %	1,351	58 %
SLO	F-35A	745	599	79 %	80	11 %
	F-35B	739	739	100 %	428	58 %
	F-35C	668	97	15 %	79	12 %
	Common	6	6	100 %	4	67 %
TOTAL		19,617	16,905	86 %	15,060	77 %

1. For F-35A and Common modules, multiple verifications are required for some single data modules, hence values represent verifications and exceed the number of modules developed.
2. Includes field- and depot-level JTD for operations and maintenance, on- and off-equipment JTD, and structured field repairs.
3. Includes aircraft JTD for general repairs, sealants, bonding, structured field repairs, and non-destructive investigations.

Air-Ship Integration and Ship Suitability Testing

F-35B

- The Marine Corps conducted a suitability demonstration with six operational (i.e., non-test fleet) F-35B aircraft onboard the USS *Wasp* from May 18 – 29, 2015.
  - Despite bearing the title "OT-1" for "Operational Test – One," as expected, the demonstration was not

an operational test and could not demonstrate that the F-35B is operationally effective or suitable for use in any type of limited combat situation. This was due to many factors concerning how the demonstration was structured including, but not limited to, the following major features that were not operationally representative:

  - Other aircraft of a standard Air Combat Element (ACE)—with which the F-35B would normally deploy—were not present, except for the required search and rescue helicopters, granting the F-35B unit practically sole use of the flight deck and hangar bay.
  - The embarked F-35B aircraft lacked the full complement of electronic mission systems necessary for combat, and not all the normal maintenance procedures necessary to keep those systems in combat-capable state of readiness were exercised.
  - The aircraft did not have the appropriate flight clearances to carry or employ any ordnance. Ordnance evolutions were limited to maintainers uploading and downloading inert bombs and missiles on the flight deck.
  - Uniformed maintainers had not yet been equipped with complete maintenance manuals and mature troubleshooting capabilities, necessitating the extensive use of contractor maintenance personnel that would not be present on a combat deployment.
  - Production-representative support equipment was not available. Instead, the demonstration used interim support equipment cleared for hangar bay use only and requiring workarounds for conducting maintenance, such as fueling operations, on the flight deck.
  - The operational logistics support system, known as the Autonomic Logistics Global Sustainment system, was not available. A potentially non-representative set of spare parts was loaded onboard the ship, and the program and Marine Corps provided extensive supply support to ensure replacement parts reached the ship faster than would be expected in deployed combat operations.

- The USS *Wasp* demonstration event did, however, provide useful training for the Marine Corps and amphibious Navy with regards to F-35B operations onboard L-class ships, and also provided findings relevant to the eventual integration of the F-35B into the shipboard environment.
- The Marine Corps and Lockheed Martin could not transfer data for the aircraft, support equipment, spare parts, and personnel from ashore sites to the SOU onboard the ship entirely within the ALIS network as originally envisioned, due to the immaturity of the Autonomic Logistics Operating Unit. An attempt was made to download the data onto the ship via other government and contractor networks, but the download rate over the ship's network proved too slow to efficiently move the numerous large files. Finally, the data were downloaded off-ship via commercial Wi-Fi access, burned to CDs, and imported directly onto the *Wasp*'s SOU. This method of transferring data would not be acceptable for routine combat deployments.
  - Similarly, once the USS *Wasp* was underway, service personnel noted that getting ALIS-related data to the ship to support flight operations, such as the EEL records for spare parts delivered by supply, was slow over satellite communications channels.
  - In addition to the difficulties moving the data back and forth between the *Wasp* SOU and ashore site SOUs, data discrepancies were introduced during the transfer process, including inconsistencies and lost data. Transfer of aircraft data from the shore-based SOU to the *Wasp* SOU took nearly two days to complete, and maintenance personnel were correcting discrepancies found in the aircraft data in ALIS for four additional days. For example, when the aircraft data files were finally received onboard the USS *Wasp*, all outstanding parts requisitions for the aircraft had been stripped. The transfer of support equipment data took 10 days to complete and maintenance personnel were correcting deficiencies in the data during the majority of the at-sea period.
- Aircraft reliability and maintainability were poor enough that it was difficult for the Marines to keep more than two to three of the six embarked aircraft in a flyable status on any given day, even with significant contractor assistance. Aircraft availability during the deployment was approximately 55 percent. Around 80 percent availability would be necessary to generate four-ship combat operations consistently with a standard six-ship F-35B detachment.
- Aircraft availability varied significantly from aircraft to aircraft, however, with some aircraft requiring no major maintenance, and other aircraft barely contributing to meaningful flight operations. In particular, one aircraft, designation BF-23, was reported "Full Mission Capable (FMC)" for the entire 11-day duration of the deployment. Another aircraft, BF-37, flew less than 5 hours, including diverting to shore and back for a landing gear malfunction, and was not flyable for 8 of the 11 days. BF-37 was notable for being in depot modification from December 8, 2014, to May 8, 2015, right before the start of the demonstration. Fleet units have reported initial reliability difficulties with aircraft after they come back from long stays at the depot, and the experience with BF-37 onboard USS *Wasp* would support these observations.
- Poor fuel system reliability proved particularly challenging, in part due to the nature of the shipboard environment. The detachment experienced two major fuel system failures, a fuel boost pump and a high level float valve. For fuel system maintenance, the aircraft must be drained of fuel and then certified gas-free of combustible fuel vapors before work can proceed. Onboard ship, this lengthy process must be done in the hangar bay and little work on other aircraft in the bay can occur, particularly

electrical work or hot-work, due to the risk of sparks igniting fuel vapors. This is less of an issue on land, where the aircraft can be moved far away from other aircraft while de-fueling. The Marines decided to fly one of these aircraft on a one-time waiver back to shore and swap it with a replacement aircraft in order to keep flying, and not over-burden maintenance. However, this would not be an option when deployed in a combat zone. The program should increase fuel system reliability, especially for the F-35B and F-35C variants.

- The detachment staged all necessary personnel, support equipment, tools, and ship's facilities to conduct engine and lift-fan removals and installations in the hangar bay, but did not actually conduct any, as a basic fit-check. The amount of space required for this heavy propulsion maintenance is substantial and could have a significant operational impact on ACE operations when far more aircraft are present in the hangar bay and on the flight deck.
- During the underway period, the Marines successfully delivered a mock spare F-35 engine power module to the USS *Wasp* via internal carry on an MV-22 tilt-rotor, and returned it back to shore. This concept demonstration opens up a potentially viable re-supply method for the F-35 engine power module, which is too large and heavy to deliver to a ship at sea using current, traditional replenishment methods. Work remains to be done to ensure that this method will not damage spare engine modules but, if successful, will ease logistical support of F-35's while onboard ship.
- Ordnance evolutions included uploading and downloading of inert AIM-120 missiles, and GBU-12 500-pound laser guided and GBU-32 1,000-pound Global Positioning System-guided bombs. In order to load the bombs to their appropriate stations in the internal weapons bay, the station had to be disconnected from the aircraft, lowered and coupled to the bomb, and then re-connected to the aircraft with the bomb attached. This procedure potentially invalidates pre-ordnance loading checks to ensure that the weapons stations are working properly (i.e., that they will provide appropriate targeting information to the weapon and release the weapon when commanded).
- The lack of production-representative support equipment prevented the detachment from providing cooling air on the flight deck, which is necessary to prevent the avionics from overheating while conducting maintenance and servicing while on external electrical power or internal battery power. This limited the ability to troubleshoot on the flight deck and made refueling operations less efficient. The program should demonstrate regular flight deck operations with the intended operational support equipment before an actual combat deployment.
- The program conducted several tests with a Handheld Imaging Tool (HIT) that uses a small radar to scan the aircraft and determine its degree of stealth. The HIT can be used to scan for areas where the Low Observable (LO) material needs to be repaired, as well as to verify repairs to LO materials. It is a replacement for a previous Radar Verification Radar, which was too large for efficient use in the crowded hangar bay of an aircraft carrier. Initial results of the HIT testing looked very promising, although further developmental work remains.
- Several other important findings surfaced from the USS *Wasp* demonstration:
  - When the aircraft is on jacks in the hangar bay, maintainers must securely tie it down to the deck with chains to ensure that the ship's rocking motion in the waves does not cause the aircraft to slip off. However, the tie down pattern used prevented the weapons bay doors from being opened while the aircraft is on jacks. This will prevent maintainers from connecting cooling air, since the intake port is located in the internal weapons bay, and may limit efficient completion of landing gear maintenance.
  - With the current software configuration, when maintainers apply external power to the aircraft, the anti-collision strobe lights come on automatically, flashing for a few seconds until maintainers can manually turn them off. This violates ship light's discipline, and at night, it can briefly blind flight deck personnel as well as potentially reveal the ship's position. The program must change the software to prevent this occurrence onboard ship.
  - The L-class ships currently lack the facilities to analyze any debris found on magnetic chip collectors in the engine oil system. Metal shavings in the engine oil could indicate that engine components such as bearings may be wearing out, which could cause the engine to seize in flight. Currently, if maintainers discover chips, they will have to down the aircraft and mail them out to a shore facility that can analyze the shavings to determine if the engine is up, or requires particular maintenance. This process could take several days.
  - When the aircraft is wet it is extremely slippery. The F-35 sits higher off the deck than legacy aircraft so falls off of it can cause greater injury, or at sea, can lead to a man-overboard. This is exacerbated by the plastic booties maintainers are supposed to wear when working on the aircraft to protect the LO coatings. The detachment decided, for safety reasons, to allow maintainers to work on the aircraft without wearing these booties. The program should investigate alternate footwear to continue to protect aircraft LO coatings while also ensuring the safety of maintainers.
  - When aircraft were landing nearby, the Maintenance Interface Panel door vibrated alarmingly. The maintainers have this door open in order to plug in their portable computers to get information from the aircraft and control it while conducting servicing and maintenance. The Marines resorted to assigning a maintainer to hold the door, while another worked on the computer if flight operations were ongoing nearby.

This was an inefficient use of manpower, and the door hinge should be stiffened to withstand the flight deck environment.

- The Navy made several modifications to the USS *Wasp* in order to support F-35B operations. The deployment demonstration provided the following observations on some of these ship modifications:
  - Naval Sea Systems Command installed a Lithium-Ion battery charging and storage facility. The F-35 relies on 270 Volts-Direct-Current and 28 Volts-Fully-Charged Lithium-Ion batteries, and other assets that will deploy onboard L-class ships are also predicted to make greater use of Lithium-Ion batteries. However, Lithium-Ion batteries can catch fire under certain circumstances, especially during charging and, due to their chemical nature, cannot be extinguished but must burn themselves out. The storage facility consisted of racks of lockers that resembled ovens, each with its own exhaust system that could flue smoke and heat from a battery undergoing "thermal runaway." Battery charging would occur only in these lockers. Despite a flaw relating to the facility's air conditioning system being installed improperly, the general design appeared robust and functional.
  - F-35 pilots must conduct much of their mission planning inside a Special Access Program Facility, a vault-like room that is protected against electronic eavesdropping and is highly secure. The Navy installed a small Special Access Program Facility to house several classified ALIS components and provide an area for pilot briefings and debriefings. This facility was adequate for the demonstration, but was stretched to capacity to support a six F-35B detachment. The Navy and Marine Corps are investigating concepts for equipping L-class ships with JSF "heavy" ACEs consisting of 16 to 20 F-35B's. In these cases, a much larger facility would be required.
  - The Navy applied a high-temperature coating called Thermion to the flight deck spots where F-35B aircraft will land, in lieu of the traditional "non-skid" coating, to withstand the F-35B's exhaust, which is hotter than the AV-8B. One week into flight operations, personnel noted several chips of the first of two layers of Thermion were missing along a weld seam and started monitoring the site after each landing. No further degradation of the Thermion was noted for the rest of the detachment. Naval Sea Systems Command is analyzing the performance of the coating.

F-35C

- The second phase of ship suitability testing—DT-2—was conducted from October 2 – 10, 2015. Ship availability delayed the start of DT-2 from the planned date in August 2015. The principal goal of DT-2 was to perform launch and recovery of the F-35C with internal stores loaded.
  - The F-35C sea trials are a series of developmental tests conducted by the program with the principal goal of supporting development of the aircraft launch and recovery bulletins, and the general goal of characterizing ship suitability for operating and maintaining F-35C on a CVN-class ship. During DT-2, only developmental test aircraft CF-3 and CF-5, transient aircraft needed for logistical support, and search and rescue helicopters deployed to the carrier. No air wing was present. The major contractor was responsible for maintenance. ALIS was not installed on the carrier; it was accessed via satellite link to a location ashore.
  - Testers accomplished 100 percent of threshold and objective test points (280 total test points) over the course of 17 flights totaling 26.5 flight hours. The results of the test are still in analysis. In addition to the principal goal, the test points addressed:
    - Minimum end airspeed for limited afterburner and military power catapult launches. For catapult launches that use afterburner, engine power is initially limited to less than full afterburner power while the aircraft is static in the catapult, but then automatically goes to full afterburner power once released. This power limitation was in place to reduce thermal loads on the Jet Blast Deflectors (JBDs) behind the aircraft.
    - Crosswinds catapults
    - Recovery in high headwinds
    - Initial Joint Precision Approach and Landing System testing
    - Qualities of the Gen III HMDS at night
    - Running the Integrated Power Package (IPP) and engine in the hangar bay
    - Engine and power module logistics in the hangar bay
  - There were 7 bolters (failure to catch an arresting wire) in 66 arrestments during DT-2. During DT-1 (Developmental Test – One), there were no unplanned bolters in 122 arrestments. The higher rate was expected since the carrier arresting gear was not fully operational during DT-2. The third arresting wire (i.e., the wire typically targeted in carrier landings), was removed from service during the test because of a malfunction.
  - Testers ran the aircraft's IPP, a miniature gas turbine engine that can provide ground power, in the hangar bay. They then performed a low-thrust engine run as well. This process simulated maintenance checkout procedures that frequently occur in the hangar bay with legacy aircraft. During these evolutions, crew position the aircraft with its tail pointing out of one of the set of hangar bay doors to the aircraft elevators to direct heat and exhaust away from the inside of the ship. For the F-35C, the unique concern is that the IPP exhaust vents up towards the hangar bay ceiling. The test team monitored the IPP exhaust gas temperature to ensure it would not damage the ceiling of the hangar bay. During both the IPP run and the engine-turn, this temperature remained within safe limits. Testers also collected noise data; analysis is ongoing. The team did not collect data on the potential build-up of IPP exhaust gases within the hangar bay atmosphere, but plans to collect these data during DT-3.

- DT-3, the third and final set of sea trials, will expand the carrier operating envelope further, including external stores, and is scheduled to occur in August 2016.
- The Navy is working on the following air-ship integration issues, primarily for carriers. Some of the following issues also apply to F-35B operations on L-class ships:
  - Flight deck JBDs may require additional side panel cooling in order to withstand regular, cyclic limited afterburner launches from an F-35C. JBDs are retractable panels that re-direct hot engine exhaust up and away from the rest of the flight deck when an aircraft is at high thrust for take-off. Even with this additional cooling, however, JBDs may be restricted in how many consecutive F-35C limited afterburner launches they can withstand before they will require a cool down period, which could affect the launch of large “alpha strikes” that involve every aircraft in the air wing, a combat tactic the Navy has used frequently in past conflicts. F-35C limited-afterburner launches are required when the F-35C is loaded with external weaponry and in a heavy, high-drag configuration. The Navy estimates that an F-35C will have 3,000 catapult launches over a 35 year expected lifespan, but that no more than 10 percent of these launches will be limited-afterburner.
  - The Navy continues to investigate the replacement of a mobile Material Handling Equipment crane for several purposes onboard carriers, including, and perhaps most importantly, facilitating F-35 engine module maintenance. In order to transfer spare F-35 engine modules from their containers onto a transportation trailer, so they can later be installed in an aircraft, or to take broken modules from a trailer and put them into a shipping container to send back to an ashore repair site, a heavy lift capable crane is required. Onboard L-class ships, the Navy will use an overhead bridge crane built into the hangar bay ceiling, but CVNs do not have any similar ship’s facility and the Navy intends to use a mobile crane. However, efforts to acquire a suitable crane have gone more slowly than originally expected. Given procurement timelines, the Navy must proceed without any further delays in order to have an appropriate crane onboard ship in time for the projected first deployment of an F-35C.
  - Work continues on developing triple hearing protection for flight deck crews, but with little update since the FY14 DOT&E Annual Report. Both the F-35C and F/A-18E/F produce around 149 decibels of noise where personnel are normally located when at maximum thrust during launch evolutions. The Navy has determined that 53 decibels of attenuation will be required from a triple hearing protection system to allow these personnel to be on deck for 38 minutes, or the equivalent of 60 launch and recovery cycles. Current designs only achieve in the mid-40s decibel range of attenuation, which allows less than 10 minutes of exposure before certain flight deck personnel reach their maximum daily limit of noise.
  - Two methods of shipboard aircraft firefighting for the F-35 with ordnance in the weapons bay are being developed, one for doors open and one for doors closed. Each will consist of an adapter that can fit to the nozzle of a standard hose. The open door adapter will also attach to a 24-foot aircraft tow bar so firefighters can slide it underneath the aircraft and spray cooling water up into the bay.
    - The Navy has produced four articles of the open bay firefighting device. This adapter performed well in preliminary tests conducted in 2014. Three of the production articles have been sent to Naval Air Station China Lake for further evaluation, and the fourth has been sent to a training command at Naval Air Station Norfolk to begin training flight deck personnel in its use and ship’s company personnel how to maintain it.
    - Developmental work continues on the closed bay adapter. The Navy is currently pursuing two different designs that would cut through the aircraft skin to flood the weapons bay with water as well as lock into place to allow firefighting crews to back away from the fire after the hose is securely attached to the aircraft. One design will require two sailors to use, and the other design is more aggressive, but would potentially only require a single sailor.

Climatic Lab Testing

- The program conducted climatic testing on an F-35B test aircraft (BF-5) in the McKinley Climatic Laboratory from October 2014 to March 2015. All the planned environments were tested, but logistics tests (low observable repair and weapon loading, for example) were not completed due to delays that occurred in test execution.
- Testing of timelines to meet alert launch requirements showed start-up to employment capabilities (both air-to-air and air-to-ground) exceeded the ORD requirements (i.e., took longer than required), in some cases up to several minutes. Cold alert launches performed better than predicted (and in some cases met requirements), while hot launch times were worse than predicted. The program has no plan to address these requirements during SDD.
- The program did not fully test some necessary functions, such as landing gear operations. Additionally, some major production support equipment was not available for testing. Portable enclosures for low-observable restoration did not meet expectations. The program has an additional test period planned for February 2016 using an operational aircraft.

Cybersecurity Operational Testing

- In accordance with DOT&E and DOD policy, the JOTT developed and presented a cybersecurity operational test strategy to DOT&E for approval in February 2015. This strategy established a schedule and expectations for cybersecurity testing of the JSF air system through the end of SDD and IOT&E in late 2017. The strategy includes multiple assessments aligned with the blocks of capability as the program delivers them to the field in both the air vehicle and ALIS. The test teams will conduct the assessments on fielded, operational equipment. All testing requires coordination from the JSF Program Executive Officer, via an Interim Authority to Test (IATT). This testing is OT&E; DOT&E approves the plans and independently reports results. The test strategy approved by DOT&E includes end-to-end testing of all ALIS components and the F-35 air vehicle.

- The Navy conducted a Cooperative Vulnerability and Penetration Assessment (CVPA) of the ALIS Squadron Kit 2.0.0.2 aboard the USS *Wasp* from May 26 through June 15, 2015. Findings were mostly administrative in nature and the test team recommended changes to the procedures for updating antivirus signatures, system restoral, and issuing user IDs and passwords prior to systems becoming operational at deployed or ship-based locations.
- Starting in early CY15, the JOTT began planning CVPAs and Adversarial Assessments (AA) of all ALIS components in the latest configuration to be fielded—ALIS 2.0.1.1—as well as the F-35 air vehicle in the Block 2B configuration. Consistent with the strategy, the JOTT planned a CVPA for September 21 through October 2, 2015, and an AA for November 9 – 20, 2015. Only the ALIS components were to be tested in these events, with an air vehicle to be included in a future test event. However, the test teams were not able to complete the CVPA as planned due to the failure of the Program Office to provide an IATT. According to the Program Office, an IATT was not granted due to insufficient understanding of risks posed to the operational ALIS systems by cybersecurity testing. As a result, the Program Office directed a more thorough risk assessment and restoration rehearsals on the ALIS systems undergoing testing to improve confidence in the identified risk mitigations.
- To recover progress on the test strategy, the JOTT coordinated with cybersecurity test teams for the November 2015 AA to be combined with a CVPA. However, the program approved only a partial IATT, which allowed a CVPA of the ALIS components at Edwards AFB and a CVPA of the Operational Central Point of Entry (CPE)—a major network hub in the overall ALIS architecture—to proceed. Although authorized, the AA for the CPE was not accomplished as the IATT was not provided in time for the AA team to make arrangements for the test. Although significantly limited in scope relative to original plans, the testing nonetheless revealed significant cybersecurity deficiencies that must be corrected.
- An end-to-end enterprise event, which links each component system, including the air vehicle, is required for cybersecurity operational testing to be adequate. The test teams are developing the needed expertise to conduct a technical vulnerability and penetration test of the air vehicle avionics and mission systems. Laboratory simulators at the U.S. Reprogramming Lab (USRL) and Lockheed Martin might be suitable environments for risk reduction and training, but will not take the place of testing on the vehicle. The Air Force Research Laboratory recently published an F-35 Blue Book of potential operational vulnerabilities that should help scope future air vehicle operational testing. The Program Office should accelerate the actions needed to enable cybersecurity operational testing of the fielded Block 2B and Block 3i systems that includes both ALIS and the air vehicle.
- The program plans to develop an ALIS test laboratory, referred to as the Operationally Representative Environment, to support developmental testing and risk reduction in preparation for future operational testing. This venue should be made available for cybersecurity testing as well, but will likely not be an adequate venue for cybersecurity testing for IOT&E.

Pilot Escape System

- In 2011, the program and Services elected to begin training and flight operations at fielded units with an immature pilot escape system by accepting risks of injury to pilots during ejection. These risks included pilots flying training missions with ejection seats that had not completed full qualification testing and flying overwater without the planned water-activated parachute release system (a system which automatically releases the parachute from the pilot's harness upon entry into water). Certain risks are greater for lighter weight pilots. Recent testing of the escape system in CY15 showed that the risk of serious injury or death are greater for lighter weight pilots and led to the decision by the Services to restrict pilots weighing less than 136 pounds from flying the F-35.
- Two pilot escape system sled tests occurred in July and August 2015 that resulted in failures of the system to successfully eject a manikin without exceeding neck loads/stresses on the manikin. These sled tests were needed in order to qualify the new Gen III HMDS for flight release.
  - A sled test in July on a 103-pound manikin with a Gen III helmet at 160 knots speed failed for neck injury criteria. The program did not consider this failure to be solely caused by the heavier Gen III helmet, primarily due to similarly poor test results having been observed with Gen II helmet on a 103-pound manikin in tests in 2010.
  - The sled test was repeated in August 2015 using a 136-pound manikin with the Gen III helmet at 160 knots. This test also failed for neck injury criteria. Similar sled testing with Gen II helmets in 2010 did not result in exceedance of neck loads for a 136-pound pilot.
- After the latter failure, the program and Services decided to restrict pilots weighing less than 136 pounds from flying any F-35 variant, regardless of helmet type (Gen II or Gen III). Pilots weighing between 136 and 165 pounds are considered at less risk than lighter weight pilots, but at an increased risk (compared to heavier pilots). The level of risk was

labeled "serious" risk by the Program Office based on the probability of death being 23 percent and the probability of neck extension (which will result in some level of injury) being 100 percent. Currently, the program and the Services have decided to accept the risk to pilots in this weight range, although the basis for the decision to accept these risks is unknown.

- The testing showed that the ejection seat rotates backwards after ejection. This results in the pilot's neck becoming extended, as the head moves behind the shoulders in a "chin up" position. When the parachute inflates and begins to extract the pilot from the seat (with great force), a "whiplash" action occurs. The rotation of the seat and resulting extension of the neck are greater for lighter weight pilots.
- The Gen III helmet weighs 5.1 pounds, approximately 6 ounces more than the Gen II helmet. The increased weight is primarily due to the larger/heavier night vision camera optics. The program has a weight reduction project ongoing to determine if approximately 5 ounces can be eliminated in the Gen III helmet by reducing structure and materials without affecting fit or optics.
- In coordination with the Program Office, the ejection seat contractor funded a proof-of-concept ejection sled test in October to assess the utility of a head support panel (HSP), a fabric mesh behind the pilots head and between the parachute risers, to prevent exceeding neck loads during the ejection sequence for lighter weight pilots. Based on the initial results, the Program Office and Services are considering seat modifications that would include the HSP, but they may take up to a year to verify improvement and install them onto aircraft.
- Additional testing and analysis are also needed to determine the risk of pilots being harmed by the transparency removal system (which shatters the canopy before, and in order for, the seat and pilot to leave the aircraft) during ejections in other than ideal, stable conditions (such as after battle damage or during out-of-control situations).
- The program began delivering F-35 aircraft with a water-activated parachute release system in later deliveries of Lot 6 aircraft in 2015. This system, common in current fighter aircraft, automatically jettisons the parachute when the pilot enters water after ejection and is particularly beneficial if the pilot is incapacitated at this point.

Progress in Modification of LRIP Aircraft

- Modification of early production aircraft is a major endeavor for the program, driven by the large degree of concurrency between development and production. Modifications are dependent on the production, procurement, and installation of modification kits, completed either at the aircraft depot locations or at the field units. If early production aircraft are to be used for IOT&E, as has been planned, the program will need to modify them in order to provide production representative Block 3F operational test aircraft for an adequate IOT&E. Current projections by the Program Office show that, even with accelerated contracting, the operational test fleet will not complete modifications until April 2019. This is 20 months past August 2017, the date currently planned by the Program Office for the start of IOT&E.
- The program maintains a complex modification and retrofit database that tracks modifications required by each aircraft, production break-in of modifications, limitations to the aircraft in performance envelope and service life, requirements for additional inspections until modifications are completed, and operational test requirements and concerns.
  - Major modifications take place at aircraft depots while depot field teams will travel to field unit to complete other modifications. Additional modifications will occur while aircraft undergo unit-level maintenance.
  - Some aircraft, primarily those assigned to operational test, will undergo modification first to a Block 2B and then to a Block 3F configuration, and will require two inductions to an aircraft depot for several months each.
- Upgrading F-35 aircraft to a Block 2B configuration includes modifications based on capability and life limits on hardware. Major modification categories include:
  - Structural life-limited parts, or Group 1 modifications
  - F-35B Mode 4 operations, including a modification to the Three Bearing Swivel Module (3BSM) so F-35B aircraft can conduct unrestricted Mode 4 operations
  - On-Board Inert Gas Generation System (OBIGGS), which provides the upgraded hardware for generating adequate nitrogen-enriched air to support lightning protection requirements and reduce vulnerability to fuel tank explosions from a live fire event; however, the aircraft will need additional modifications to the fuel system for full lightning and vulnerability protection
  - Upgrades to ALIS and training systems
- During the first half of 2015, Marine Corps IOC aircraft received top priority for Block 2B modifications. During the second half of 2015, the program prioritized modification of operational test aircraft.
  - To successfully modify Marine Corps aircraft in time for IOC, and because aircraft modifications frequently took longer than projected, the program, for the first time, sent Marine Corps aircraft to the Air Force depot at Hill AFB.
  - Because of the re-scoping of the Block 2B operational testing, the program delayed modifications to a number of aircraft assigned to operational test squadrons. As of December 2015, 8 of 14 aircraft assigned to operational test squadrons were in the full Block 2B configuration, which includes the OBIGGS modification, with 1 more undergoing depot modifications. One F-35B is not scheduled to complete this modification until June 2017. Twelve of the 14 aircraft have been at least partially modified to the Block 2B configuration, allowing them to fly with the Block 2B software.

- Modifying aircraft to a Block 3F configuration includes completing Block 2B modifications, Technical Refresh 2 (TR-2) upgrades, and Block 3F changes. The table below shows known requirements by production lot of aircraft and the number of those that are authorized and scheduled as of July 2015. Later lots of aircraft require fewer modifications because of changes incorporated into the production line.

KNOWN BLOCK 3 IOT&E MODIFICATION REQUIREMENTS IN LOTS 3 THROUGH 9[1]							
Variant	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
F-35A	124 (69)	100 (44)	83 (32)	38 (15)	15 (2)	10 (1)	2 (1)
F-35B	130 (77)	106 (56)	82 (38)	38 (19)	10 (2)	3 (0)	1 (0)
F-35C	-	96 (43)	80 (30)	38 (15)	14 (2)	8 (1)	2 (0)

1. Numbers in parentheses denote authorized and scheduled modifications.

- Current Program Office plans for modifications show that none of the operational test aircraft will have all Block 3F modifications completed by the Program Office's projected start of IOT&E in August 2017.
  - The program awarded an undefinitized contract action (UCA) for new TR-2 processors in September 2015 to support Block 3F retrofit modifications of the Block 2B operational test aircraft. However, the TR-2 hardware packages have a 26-month lead-time which, along with other required changes that do not yet have approved engineering or hardware solutions, will delay the complete modification of any operational test aircraft until after IOT&E is scheduled to start.
  - The program is analyzing options to reduce this timeline, including seeking authorization outside of normal acquisition practices to purchase hardware early, taking components from the production line before installation occurs for use on operational test aircraft, and installing instrumentation on later LRIP aircraft that will have already received this hardware during production.
  - The majority of aircraft assigned to operational test squadrons are LRIP 3 and 4 aircraft, which require extensive modifications to reach a Block 3F configuration.
- The program has had difficulty maintaining the planned induction schedule at the two F-35 depots located at MCAS Cherry Point, North Carolina, and Hill AFB, Utah, after structural modifications took 20 days longer than planned on early inductees, and Lockheed Martin delivered modification kits late. Transportation issues also resulted in retrograde assets not shipping in a timely manner for repairs and upgrades.
  - At MCAS Cherry Point, early F-35B aircraft inducted took 45 days longer than projected to complete modifications and, as of July 2015, the depot had used nearly 300 more cumulative maintenance days than projected to modify aircraft. To meet Marine Corps IOC requirements, the program sent two aircraft, BF-31 and BF-32, to Hill AFB to complete structural modifications. Prior to this, the program had not scheduled F-35A or F-35B aircraft to complete modifications at the other Service's depot. As of June 2015, the MCAS Cherry Point depot completed modifications on 16 aircraft, 5 of which the program needed for Marine Corps IOC.
  - The Hill AFB depot has stayed closer to projections on completing modifications. Although early inductees exceeded the planned timeline, later aircraft, including the two F-35B aircraft, have completed modifications in less time than projected. Fourteen aircraft have completed modifications at this depot, including two F-35B aircraft needed for Marine Corps IOC. Hill AFB, which began the year with three operational docks, expanded their depot capacity to eight docks in 2015 by accelerating the opening of four of these docks to reduce the risk of maintaining the modification schedule.
  - The program further reduced risk to the modification schedule by employing additional field teams to complete modifications previously planned to occur during aircraft inductions.
  - By July 2015, both depots showed improved tracking with the depot flow plan.

Recommendations

- Status of Previous Recommendations. The program addressed two of the previous recommendations. As discussed in the appropriate sections of this report, the program did not, and still should:
  1. Update program schedules to reflect the start of spin-up training for IOT&E to occur no earlier than the operational test readiness review planned for November 2017, and the associated start of IOT&E six months later, in May 2018.
  2. Complete lab testing of the mission data loads, as is planned in the mission data optimization operational test plan, prior to accomplishing the necessary flight testing to ensure the loads released to the fleet are optimized for performance. If mission data loads are released to operational units prior to the completion of the lab and flight testing required in the operational test plan, the risk to operational units must be clearly documented. Status: Lab testing in Block 2B is still in work; 2B build fielded to operational F-35B units, risk not documented.
  3. Complete the remaining three Block 2B weapon delivery accuracy (WDA) flight test events in a way that ensures full mission systems functionality is enabled in an operationally realistic manner.
  4. Provide adequate resourcing to support the extensive validation and verification requirements for the Block 3 VSim in time for IOT&E, including the data needed from flight test or other test venues.
  5. Extend the full-up system-level (FUSL) decontamination test to demonstrate the decontamination system effectiveness in a range of operationally realistic

environments. Status: The Program Office has elected not to address this recommendation: the FUSL test will be conducted only under ambient conditions at Edwards AFB during 4QFY16 through 1QFY17 preventing the assessment of this system in other, potentially more stressing ambient conditions.
6. Ensure adequate testing of ALIS software upgrades on operationally-representative hardware is complete prior to fielding to operational units.

- FY15 Recommendations. The program should:
  1. Acknowledge schedule pressures that make the start of IOT&E in August 2017 unrealistic and adjust the program schedule to reflect the start of IOT&E no earlier than August 2018.
  2. The Department should carefully consider whether committing to a "block buy," composed of three lots of aircraft, is prudent given the state of maturity of the program, as well as whether the block buy is consistent with a "fly before you buy" approach to defense acquisition and the requirements of Title 10 United States Code.
  3. Plan and program for additional Block 3F software builds and follow-on testing to address deficiencies currently documented from Blocks 2B and 3i, deficiencies discovered during Block 3F developmental testing and during IOT&E, prior to the first Block 4 software release planned for 2020.
  4. Significantly reduce post-mission Ground Data Security Assembly Receptacle (GDR) processing times, in particular, decryption processing time.
  5. Ensure the testing of Block 3F weapons prior to the start of IOT&E leads to a full characterization of fire-control performance using the fully integrated mission systems capability to engage and kill targets.
  6. Complete the planned climatic lab testing.
  7. Provide the funding and accelerate contract actions to procure and install the full set of upgrades recommended by DOT&E in 2012, correct stimulation problems, and fix all of the tools so the U.S. Reprogramming Lab (USRL) can operate efficiently before Block 3F mission data load development begins.
  8. Complete the planned testing detailed in the DOT&E-approved USRL mission data optimization operational test plan and amendment.
  9. Along with the Navy and Marine Corps, conduct an actual operational test of the F-35B onboard an L-class ship before conducting a combat deployment with the F-35B. This test should have the full Air Combat Element (ACE) onboard, include ordnance employment and the full use of mission systems, and should be equipped with the production-representative support equipment.
  10. Develop a solution to address the modification and retrofit schedule delays for production-representative operational test aircraft for IOT&E. These aircraft must be similar to, if not from the Lot 9 production line.
  11. Provide developmental flight test tracking products that clearly show progress on what has been accomplished and test activity remaining.
  12. Develop an end-to-end ALIS test venue that is production representative of all ALIS components.
  13. Ensure the necessary authorizations are provided in time to permit operational cybersecurity testing of the entire F-35 air system, including the air vehicle, as planned by the operational test community.
  14. Provide dedicated time on representative air vehicles to complete Joint Technical Data (JTD) verification.