

## 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,

# DOD PROGRAMS

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-air-speed 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.

# DOD PROGRAMS

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 through 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).

## DOD PROGRAMS

- 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.

# DOD PROGRAMS