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STATEMENT

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PROGRESS IN TESTING

Mr. Chairman, Senator Cochran, Members of the Committee, my testimony reviews the progress made in flight and ground testing over the past year and provides an update to my fiscal year 2012 (FY12) Annual Report on the Joint Strike Fighter (JSF) program. Testing has been productive in allowing expansion of the aircraft's flight envelope (the conditions under which aircraft are permitted to fly) in flight sciences and in demonstration of the limited mission systems capabilities provided by early software versions. However, problems revealed by ongoing testing, particularly of mission systems, have required additional time and effort to resolve relative to the program's plans, and the most challenging portions of the flight envelope and mission systems capabilities are yet to be tested. Consequently, if no relief is provided to current limits on the cost and schedule for completing System Design and Development (SDD), it is possible all the military capability now associated with the Block 3F versions of JSF will not be provided for operational testing in 2018. Nonetheless, since the conclusion of the 2011 re-planning of JSF testing that yielded Integrated Master Schedule 7, which in turn followed the 2010 technical baseline review, flight testing has been planned and executed using a much more realistic set of assumptions for achieving progress than had been used previously. Overall, through the past year, the rate of flight test sorties has met or slightly exceeded the plan and the volume of test points attempted nearly conforms to that planned. The resources added in test aircraft, staffing, instrumentation, and support equipment have made this possible. However, there have also been challenges that have required the program to add testing, such as to diagnose discoveries that have occurred in all types of flight test, regression testing (to verify corrections to problems did not create additional problems) of new mission systems and vehicle systems software, and investigations into unexpected shortcomings like that performed on the helmet mounted display system.

None of the analyses conducted to date, by the Program Office or discussed in this testimony, have accounted for the effects of sequestration. Reduced funding for test resources and infrastructure while the F-35 is in development—such as reductions or elimination of funding for the McKinley lab, the test chambers, and support aircraft—will only add to the pressure to either extend SDD or accept reductions in capability. Additionally, reductions in developmental testing, which I understand are being considered by the Program Office, without the appropriate matching reductions in capability, will not remedy this situation. This approach would likely result in significant discoveries in operational testing and cause the program to extend until the discoveries are diagnosed and remedied.

Flight Sciences Progress

Flight sciences testing in all three variants has focused on what is needed to provide the flight envelope expected for release of Block 2B capability to the Services in 2015, which will provide a limited subset of the combat capability planned for Block 3F. Testing has been underway to achieve air refueling capability, increase combat maneuverability by evaluating performance in high angle-of-attack regimes, perform weapons integration tests, and prepare for shipboard operations/suitability testing for the F-35B and F-35C.

The test centers were affected by two stop orders earlier this year. The F-35B-fleet was grounded after the first British production aircraft, BK-1, experienced a fueldraulic line failure in the Short Take-off Vertical Landing (STOVL)-unique swivel nozzle at Eglin Air Force Base (AFB) 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 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. The cause of the crack was determined to be a rupture due to thermal creep, a condition where 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. BF-2 experienced a polyalphaolefin (PAO) coolant leak in February, grounding the aircraft for 77 days. Inflight refueling for the F-35A test fleet was expanded in January to allow non-test wing based tankers to support test flight operations, allowing for more efficient use of the test aircraft at Edwards.

F-35A Flight Sciences. Testing on the F-35A has included envelope expansion for weapons, continued examination of flutter and loads, and some high angle-of-attack testing. 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. The updated control laws, once installed, permitted portions of the high angle-of-attack testing to continue; however, some portions of the testing will need to wait for the next update of software expected to be delivered to flight test in October. The result has been a delay in opening up high angle-of-attack portions of the envelope, which are required to realize the full capabilities, including flight envelope and weapons delivery, planned for Block 2B.

As of the end of April, progress in test points required for 2B envelope fleet release is behind the plan for the year, having completed 473 of 614 points planned for completion through the end of April 2013, or 77 percent. Progress in weapons integration is also behind schedule, having completed only 7 of 19 total separation events versus the plan to have completed 14 events by the end of April. Accounting for test activity prior to calendar year 2013, the program has completed approximately three-fourths of the total number of test points needed to clear the Block 2B flight envelope for the F-35A.

F-35B Flight Sciences. Testing this year has focused on STOVL mode operations, in preparation for the second set of ship trials planned for August onboard the USS *Wasp*, Block 2B envelope expansion, air refueling, and weapons separations. High angle-of-attack testing has not started in the F-35B. Progress on test points for Block 2B envelope in 2013 is behind the plan through the end of April, as the test center has completed 152 of 371 planned points, or 41 percent. Only 6 of the 24 total weapons separations for Block 2B had been completed, with 10 planned to be completed by the end of April. Accounting for prior test activity, the program has completed approximately two-thirds of the total number of test points needed to clear the 2B flight envelope for the F-35B.

F-35C Flight Sciences. Test point progress has proceeded as planned so far this year for Block 2B envelope expansion in the F-35C; however, no weapons separations or high angle-of-attack testing has been completed. The first set of sea trials are scheduled to start in the summer of 2014 (June 30), with two test aircraft from the flight test center. The first of these two aircraft is scheduled to be modified with the updated arresting hook system and upgraded nose landing gear brace later this year, which will permit catapult and arresting hook testing to begin again. The second aircraft is scheduled to be modified in the spring of 2014. Testing for electromagnetic environmental effects will need to be completed on both aircraft prior to the ship trials as well.

Progress on test points for the Block 2B envelope is slightly behind the plan through the end of April, as the test center has completed 574 of 599 planned points, or 96 percent. Accounting for prior test activity, the program has completed approximately 70 percent of the total number of test points needed to clear the Block 2B flight envelope for the F-35C.

Buffet and transonic roll off (TRO) (when lift is unexpectedly lost on a portion of one wing) continue to be a concern to achieving operational combat capability for all variants. Control laws have been changed to reduce buffet and TRO, with some success; however, both problems persist in regions of the flight envelope, and are most severe in the C model. The program plans to assess the effects of buffet and TRO by collecting data while flying operationally representative flight profiles later this year, after the next version of air vehicle software is released to flight test. No further changes to the control laws are being considered, as further changes will adversely affect combat maneuverability or unacceptably increase accelerative loading on the aircraft's structure.

Mission Systems Progress

Although mission systems testing has been able to keep pace with the program plans for generating sorties and accomplishing the test points, the program is falling behind in achieving progress in delivering capability. This lack of progress is caused in part by the need to add unplanned testing to evaluate problems, such as the 221 added points for dedicated testing of the helmet mounted display system, as well as for regression testing of new software loads delivered to flight test, where 366 test points have been added already in calendar year 2013 to evaluate four new software releases. The test centers began flight testing Block 2A software in March 2012, and, as of the end of May 2013—15 months of flight testing later— had completed about only 35 percent of the 2A test points, all of which should have been completed by the end of February 2013, according to the integrated master schedule. The first build of Block 2B software was delivered to flight test in February 2013, and, as of the end of May 2013, 54 of 2,974 Block 2B baseline test points—less than 2 percent—had been completed. As of the end of April 2013, 303 of 1,333 total planned baseline mission systems test points for the year with all versions of software had been accomplished. An additional 532 added (or "growth") points were flown to evaluate discoveries and for regression testing, which is 2.5 times the growth allotted in flight test plans through the end of April 2013. If this trend in added testing is maintained throughout Block 2B development, completing flight test by October 2014, as reflected in the program's current plans, will not be possible.

Additionally, mission systems software development and delivery to flight test have lagged behind the plan reflected in the program's integrated master schedule. The final Block 2B software configuration is now forecast to be delivered to flight test eight months later than expected by the current integrated master schedule—a delay from August 2013 to April 2014. The delay adds to the challenge of completing 2B flight test by October 2014, which is necessary to support an operational evaluation of Block 2B capability planned now to be conducted in calendar year 2015. Block 2B as now planned will provide limited capability to conduct combat. If Block 2B F-35 forces are used in combat, they would likely need significant support from other fourth-generation and fifth-generation combat systems to counter modern, existing threats, unless air superiority is somehow otherwise assured and the threat is cooperative. Reductions to this limited Block 2B capability, particularly if they are taken in the remaining, harder-to-achieve capabilities that are yet to be tested, could be difficult for operators to accept if they expect to use Block 2B aircraft in combat against a capable adversary.

Two of the additional aircraft expected by the program plan to support mission systems flight test, which were borrowed from operational test squadrons, were delivered to the test team in April 2013. The mission systems flight test teams are accomplishing testing in the final Block 2A and early Block 2B configurations, which are comparable in providing more combat-relevant functionality than Block 1, such as limited simulated weapons delivery, datalink, track fusion, and electronic warfare capability. Aircraft start-up problems continue during pre-flight operations. Flight test teams have also experienced several problems in flight such as lost data link messages, split target tracks, incorrectly fused tracks, and difficulty maintaining targets/scenes using the electro-optical tracking system. The program began a focused effort this year to determine the cause of position errors due to drift in the ownship kinematic model, which provides critical flight parameters and spatial situation awareness to the pilot. Errors from drift in vertical velocity must be resolved before certification for night or instrument meteorological flight is possible. In the coming weeks, testing of fixes and the capability to warn pilots drift is occurring will begin.

The program has also dedicated 42 flights to investigating deficiencies in the helmet mounted display system. Seven aircraft from all three variants flew test missions from October 2012 through May 2013 to investigate jitter in the helmet mounted display system, night vision camera acuity, latency in the Distributed Aperture System 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 according to comments from the test pilots. Testing could not be completed within the full operational flight envelope evaluating mission-related tasks, as the full combat flight envelope has not been released. 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 the ISIE-11 camera under consideration by the program. Latency with the Distributed Aperture System 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. Although not an objective of the dedicated testing, alignment and "double vision" problems have also been identified by pilots and were noted in my report earlier this year on the F-35A Ready for Training Operational Utility Evaluation (OUE). Whether the progress achieved in resolving the problems discussed immediately above has been adequate will likely not be known with confidence until the Block 2B operational evaluation is conducted in 2015.

Later this year, the program plans to begin testing mission systems Block 3i, which includes significant hardware changes to the aircraft's integrated core processor, electronic warfare processor, communications-navigation-identification processor, and the multi-function array (radar). Block 3i software is needed for Lot 6 (and beyond) production aircraft equipped with this new hardware to be able to fly. Initially, Block 3i capability will be more limited than the Block 2B capability that will be concurrently fielded. This is because the timeline to develop, test, and clear Block 3i for use in production aircraft next year requires that Block 3i start with an early Block 2B version in lab tests very soon this year; thus, the capability provided in Block3i will lag Block 2B by about six months. Maturing Block 3i hardware and software will be a significant challenge in the next 12 to 18 months. Simultaneously, the program will need to make progress on Block 3F development. The ability of the program to successfully execute this concurrent software development is the most significant source of uncertainty regarding what combat capability the JSF will actually provide in 2018.

Weapons Integration

Weapons integration progress has been very slow since it began last year. Safe separation testing for the laser-guided bomb, GBU-12, has been delayed until a new lanyard and lanyard routing procedure are available. Deficiencies, some of them recently discovered, in the electro-optical tracking system's ability to maintain a track have also hampered progress in laser-guided bomb employment testing. As a result, the first end-to-end GBU-12 weapons delivery test is not likely before October 2013. Integration of the AIM-120 medium-range missile has experienced problems that have been difficult to replicate in lab and ground testing. A safe separation event in which an AIM-120 missile was launched from a flight sciences aircraft occurred on June 5, 2013; this event was testing the ability to safely release the missile and ignite the rocket motor from the weapons bay—there was no target or sensor fusion providing track/guidance data. The first end-to-end weapons delivery test using AIM-120 missiles is not likely to occur before November 2013, and meeting this date depends upon implementing essential corrections to deficiencies in the mission systems software and completion of remaining safe separation testing. Testing with the Joint Direct Attack Munition (JDAM) found that the aircraft was not able to transfer position and velocity data accurately to the weapon, a procedure required to spatially align the weapon with the target and to determine launch parameters and support release. A fix to this alignment problem has been developed and recently tested, showing some improvement. However, additional fixes and testing are required to ensure the alignment problem is fully resolved and to permit JDAM weapons testing to proceed. The first end-to-end weapons delivery testing with the JDAM weapon is not likely to occur before December 2013. Several deficiencies of the mission systems and fire-control system have been identified as "must fix" by the test team in order for weapons integration to proceed. For example, a problem with erroneous target coordinates derived from the synthetic aperture radar mapping function, for which a potential fix has recently entered flight test, and problems with the electro-optical tracking system mentioned above, have significantly delayed weapons integration tests. The result is that approximately nine months of margin for regression and discovery in weapons integration test plans has been used before the first end-to-end developmental test event, and there is no margin remaining in the schedule for completing testing and achieving integrations of both the Block 2B or Block 3F weapons capabilities. Consequently, the final Block 3F weapon integration tests are likely to be completed in late 2017, instead of fall 2016. This will make beginning operational testing of Block 3F in January 2018 a challenge.

Fatigue Testing

Durability testing of all three variant ground test articles has progressed as scheduled and the number and frequency of discoveries have been consistent with what has been observed in testing of previous fighter aircraft. The first of two aircraft lifetimes of testing has been completed on the F-35A and F-35B; detailed inspections are ongoing. Discoveries this year on the F-35A test article include cracks in the engine thrust mount shear webs on both sides of the aircraft, which are designed to carry some of the fore and aft engine load, 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 Low-Rate Initial Production 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. Second lifetime testing for the F-35A is scheduled to start in September 2013. The program plans to conduct third lifetime testing on the F-35A test article beginning in the second quarter of calendar year 2015.

Discoveries in the F-35B 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. Second lifetime testing for the F-35B is schedule to start in August 2013. Durability testing of the redesigned auxiliary air inlet doors through two lifetimes (full test) was completed on March 29, 2013. The program is investigating two issues observed during testing, both of which involve the crank assembly used to open and close the doors and were awaiting resolution at the time of this testimony.

The F-35C fatigue test article restarted testing on January 9, 2013, after previously completing 4,000 hours of testing and associated inspections; it has now completed 6,869 equivalent flight hours of testing, or 86 percent of the first lifetime, as of May 21, 2013. The program expects to complete first lifetime testing in August 2013. Discovery of cracks in the floor of the avionics bay housing in February 2013 caused a two-month pause in testing while interim repairs were completed, allowing testing to continue. Less than 1,000 hours of testing later, more cracks were found in the floor of the avionics bay housing and, similar to the F-35B, cracking in the frame of the jack point stiffener was also discovered. Repairs, modifications, and retrofits need to resolve these discoveries are to be determined. The program plans to restart testing on June 12, 2013.

Training System

I reported on the F-35A Ready for Training OUE in February of this year. In mid-2010, the JSF Program Executive Officer (PEO) requested an assessment of the readiness to begin F-35A pilot training, which, at that time, was planned to begin in August 2011. Throughout 2011 and part of 2012, the JSF Program Office and the Air Force worked to achieve a flight clearance that would allow pilot training to begin. The JSF Operational Test Team (JOTT) completed a test plan using evaluation criteria developed by Air Force Air Education and Training Command (AETC) in mid-2011. The JSF PEO certified the system ready for test following an Operational Test Readiness Review in July 2012, leading to the start of the OUE in September.

The JOTT, JSF Program Office, and Air Force Air Education and Training Command designed the Ready for Training OUE to assess whether the F-35A aircraft and the training system were ready to begin training pilots in the Block 1A syllabus. The Block 1A syllabus includes basic aircraft systems training, emergency operating procedures, simulated instrument flying procedures, ground operations (taxi), and six flights in the F-35A, the last of which is a qualification and instrument procedures check ride.

The Block 1A training syllabus used during the OUE was substantially limited by the restrictions of the aircraft. Aircraft operating limitations prohibited flying the aircraft at night or in instrument meteorological conditions; hence, pilots needed to avoid clouds and other weather. However, the student pilots are able to simulate instrument flight in visual meteorological conditions to practice basic instrument procedures. These restrictions were in place because testing has not been completed to certify the aircraft for night and instrument flight. These restrictions are still in place on the training system.

The aircraft also were prohibited from flying close formation, aerobatics, and stalls, all of which would normally be in this early familiarization phase of transition training that typically is an introduction to aircraft systems, handling characteristics throughout the aircraft envelope, and qualification to operate/land in visual and instrument meteorological conditions. This familiarization phase is about one-fourth of the training in a typical fighter aircraft transition or requalification course. In a mature fighter aircraft, the familiarization phase is followed by several combat-oriented phases, such as air combat, surface attack, and night tactical operations. During the OUE, the F-35A did not have the capability to train in these phases, nor any actual combat capability, because it is still early in system development. The first F-35A aircraft configured in the Block 2A capability, which will possess a limited ability to simulate weapons deliveries, are being delivered to Eglin AFB this month. This may enable more combat-oriented training, albeit still limited by envelope restrictions and lacking integrated mission systems capability.

During the OUE, sustainment of the six Block 1A F-35A aircraft was sufficient to meet the student training sortie requirements of the syllabus, but with substantial resources and workarounds in place. Some aircraft subsystems, such as the radar, did not function properly during the OUE, although they were not required for accomplishing the basic syllabus events. Had the syllabus been more expansive, where these subsystems were required to complete training, these subsystem problems would have hampered the completion of the OUE. Three additional F-35A aircraft in the Block 1B configuration were also flown during the OUE, by the instructor pilots, to meet sortie requirements.

The limitations, workarounds, and restrictions in place in an air system this early in development limit the utility of training. Also, little can be learned from evaluating training in a system this immature. However, the evaluation indicated areas where the program needs to focus attention and make improvements. The radar, the pilot's helmet mounted display system, and the cockpit interfaces for controlling the radios and navigational functions should be improved. Discrepancies between the courseware and the flight manuals were frequently observed, and the timelines to fix or update courseware should be shortened. The training management system lags in development compared to the rest of the Integrated Training Center and does not yet have all planned functionality.

Since the OUE completed in November 2012, all six of the Block 1A F-35A aircraft have been modified to the Block 1B configuration. Training is ongoing at Eglin in the 9 Block 1B F-35As for the Air Force and in the 11 Block 1B F-35Bs assigned to the Marine Corps. Additionally, Eglin accepted its first Block 2A-configured F-35A in May, which will be used for training in an expanded syllabus currently under development. The Air Force intends to start training pilots in a Block 2A syllabus in early 2014.

Ship Integration

The program plans to conduct the second set of ship trials with two F-35B test aircraft in August 2013. Test objectives for this deployment include conducting night operations, carrying stores, evaluating the carrier landing system, and expanding the take-off and vertical landing envelope for varying wind-over-deck conditions and for a broader range of aircraft weight and center of gravity conditions. Flying qualities with an updated version of control software, based on data taken during the first deployment, will be assessed. Two SDD test aircraft will be operated by program test pilots during the test. Minimal changes to USS *Wasp* are anticipated, as this will be the second deployment to the ship. Some restrictions to the electromagnetic environment on the ship may be necessary as a result of the electromagnetic environmental effects testing on the aircraft. The logistics support environment will not be representative of fleet operations; rather, it will be similar to that used in the first ship trials in 2011 that employed workarounds to reach back to land-based systems and personnel as necessary to sustain operations.

The test center also plans to train additional test pilots to be qualified in STOVL operations for the deployment, and for conducting land-based work-up maneuvers.

The program intends to conduct the first set of carrier-based ship trials with two F-35C test aircraft in the summer of 2014. The prerequisite activity with the aircraft leading up to the sea-borne trials is extensive. The new arresting hook system – which has yet to start the planned verification, structural, or durability testing – will have to be installed on both aircraft, and shore-based roll-in testing and hook engagement testing completed with one aircraft, which will compose approximately six months of testing. An improved nose landing gear drag brace, required for catapult launches, will also be a part of the pre-deployment set of modifications. Both aircraft will need to undergo electromagnetic environmental effects testing prior to deployment. For the carrier, the Department of the Navy is working integration issues that will need to be resolved prior to the first operational deployment, but will not necessarily be solved prior to the first set of ship trials. Examples of integration issues include storage of the lithium-ion batteries on the carrier, resupplying engines while underway, and integration of the autonomic logistics information system. Some initial noise and thermal effects testing have been completed at land-based test facilities, and will be a part of the test activity during the first ship trial period. Modifications of the jet blast deflector system on the carrier may be necessary prior to the ship-borne trials to ensure adequate cooling of the deflector during JSF operations.

Live Fire Test and Evaluation (LFT&E)

F-35 survivability is heavily dependent on its low-observability features, advanced electronic systems (e.g., advanced sensors for situational awareness, multispectral data fusion, datalinks, etc.), and its advanced countermeasures. These features work together to reduce F-35 threat susceptibility. However, no amount of susceptibility reduction can eliminate the possibility of an F-35 being successfully engaged, either by ground-based threats or by enemy aircraft, particularly during high-risk missions such as visual close air support and within-visual-range air-to-air combat (i.e., "dog fighting"). In such cases, the F-35 survivability can largely depend on its ability to tolerate threat-induced damage; that is, its vulnerability reduction features.

Live fire tests and analyses conducted during the last year focused on the threats involved in these types of high-risk engagements to assess the vulnerability of the F-35 propulsion system and to identify any risks to propulsion integration, flight transition, stability and control, and airframe structure:

- A range of operationally realistic threat encounter conditions were considered in tests that evaluated engine vulnerability to fuel ingestion events. Tests have shown that the engine can tolerate ingestion of fuel leak rates representative of single-missile fragment-induced damage to fuel tanks surrounding the engine inlet. Further analysis is required to assess the impact of multiple fragments, which are probable in any case where a missile achieves a near miss on the aircraft, on engine response to fuel ingestion. A Concept Demonstrator Aircraft engine test in FY05 showed that the engine could not tolerate ingestion of fuel leak rates representative of damage from a larger gun projectile impacting at low-altitude, high-speed and high-engine thrust—a type of encounter that might be expected on a close-air support mission.

The program made no design changes in response to these test results. This vulnerability, accepted by the program leadership, remains in the final, production engine design. The implications of this vulnerability are exacerbated by the program's previous decision to remove a fuel tank ballistic liner during its weight-reduction efforts, saving 48 pounds. The ballistic liner could have reduced threat-induced fuel leakage to levels this single-engine aircraft can tolerate. A follow-on ballistic test is planned to re-evaluate vulnerability to fuel ingestion.

- F-35B lift system live fire testing showed the system is tolerant to selected single missile fragments. The single fragment-induced damage to the lift fan produced in this test did not degrade the overall propulsion system performance. Nonetheless, analysis predicts that fragment-induced damage could result in more severe effects that could lead to catastrophic lift system failure (e.g. more than 25 percent lift fan blade loss leading to fan disintegration) as a consequence of certain engagements. To preserve the test article for future engine tests, such engagement conditions were not tested. Other more severe threats expected to be encountered in low-altitude flights or air-to-air gun engagements, considered likely to cause critical system failures leading to aircraft loss, were not tested because their effects are well understood. Additional testing of the sensitivities of the F-35B propulsion system to clutch and shaft damage needs to be conducted.
- The tests also considered diagnostics to inform the pilot of propulsion system damage. Damage to the static lift system received in combat may not be detectable until the lift system is engaged for a landing. The quickly accelerating fan might fail catastrophically

before the pilot can react and return the aircraft to wing-borne flight. There are no sensors to warn the pilot of damage to the system to prevent this situation. Sensors in the Prognostics and Health Monitoring system monitor rotating component vibrations for maintenance purposes and could provide some warning, but they are not sufficiently qualified to provide information to the pilot nor any timely warning regarding damage to the vast majority of lift system components. To ensure no aircraft is lost due to lift system, engine, or control failures, it is imperative that the pilot be aware of damage that occurred during regular flight to the F-35B propulsion system at the earliest possible time when converting to STOVL flight. Data analyses are ongoing to identify controllability and damage indications that might be available to the pilot.

LFT&E activities have also focused on other concerns:

- **On-Board Inert Gas Generator System (OBIGGS)**. The program completed the OBIGGS/lightning protection Critical Design Review in February 2013. F-35B fuel system simulator testing and ground tests on all three variants will be conducted in the near term to verify that the redesigned system can provide fuel tank protection from lightning and from threat induced fuel tank explosion. Testing will include a spectrum of mission profiles including high decent-rate dives to ensure OBIGGS effectiveness without compromising fuel tank and wing structure integrity. Inflight inerting protects the aircraft against catastrophic fuel tank explosions, but not against damage to the airframe resulting from lightning-induced currents. While most line-replaceable units (e.g. actuators, components of the electrical power system) have passed lightning tolerance qualification testing, the existing F-35 airframe fasteners, selected to satisfy weight reduction criteria, are not lightning tolerant. Airframe inspections will be required following known lighting strikes, which may be costly since access to many fasteners is limited and penetrations though the aircraft skin will be required. Lightning tolerance qualification testing for any remaining components, along with current injection tests, still need to be completed before lifting the current restrictions upon aircraft operating within 25 miles of known lightning. The concept for providing lightning protection for aircraft on the ground requires periodic re-inerting of static aircraft using nitrogen bottle carts to purge combustible air that diffuses back into the fuel system over time. This approach could be very resource intensive for an operational F-35 unit, requiring manpower and sufficient nitrogen to re-inert each aircraft as often as every 24 hours. The program is evaluating the practicality of this approach before considering its implementation.

- **Polyalphaolefin (PAO) Shut-Off Valve**. In FY12, following live fire tests that demonstrated F-35 vulnerability to PAO fire (underneath the cockpit area), the program re-evaluated installing a PAO shutoff system. In 2008, the previous Director, Operational Test and Evaluation recommended retaining this design feature after the program decided on removal for weight reduction. Lockheed Martin is working to design a PAO shutoff system providing the sensitivity to detect leaks and respond with shut-off that testing has demonstrated is needed. However, the design solution details, results from cost/benefit studies, and the official decision to reinstate this vulnerability reduction feature, are not yet available.
- **Fueldraulic Fuses**. A live fire test in FY12 demonstrated the fueldraulics system is vulnerable to missile fragments resulting in potential fire and loss of aircraft. An F-35B engine fueldraulics line failure during a routine test flight in January 2013 demonstrated a

similar safety-related concern with the fueldraulics system. The F-35 program should reinstate an effective fueldraulics shutoff to inhibit fuel flow in the event of a system leak. The fueldraulic shutoff feature would mitigate a vulnerability that could be a result of either threat-induced damage or system/mechanical failure.

- **Chemical/Biological Vulnerability**. The program continues to make progress in the development of the decontamination system in preparation for the FY17 full-up system-level test. The Joint Service Aircrew Mask variant for the F-35, however, has a high schedule risk because of the requirements for integration with the F-35's helmet mounted display system.
- **Gun Ammunition Lethality**. The U.S. Air Force is leading an evaluation of a new frangible armor piercing design for the F-35A ammunition; the Navy is evaluating existing PGU-32 semi-armor piercing high explosive incendiary ammunition for the F-35B and F-35C; and the Norwegian Ministry of Defense is evaluating a new armor piercing explosive ammunition for its F-35A variant and possibly the U.S. F-35B and F-35C variants. Terminal ballistic tests of all ammunition variants against common vehicle armor and masonry wall designs will start in FY13 and continue in FY14. All test data will feed Joint Munitions Effectiveness Models.

Suitability

A logistics test and evaluation of the initial fielded release of the Autonomic Logistics Information System (ALIS) version 1.0.3, required to support the acceptance and flight operations of Block 1B and 2A aircraft at Eglin, Edwards, Yuma and Nellis AFBs, was conducted between September and October 2012. The test was conducted at Edwards using two of the mission systems test aircraft updated with software to be compatible with the new version of ALIS. The first version of ALIS software used in the test, version 1.0.3A3, was found to be deficient in response times at the beginning of the evaluation period, and an updated software version—1.0.3A3.1—was developed and fielded to permit the evaluation to proceed. Subsequent testing revealed numerous significant deficiencies in ALIS, such as inaccurate recording of component life—a key component of the prognostic health function— as well as the health management component of the system requiring unneeded, excessive grounding of aircraft. Post-flight delays in data transfer lengthened aircraft turnaround time. Overall, 58 deficiency reports were submitted from the evaluation, 4 of which were critical (designated as Category 1) and the test team recommended not fielding ALIS 1.0.3A3.1. The program developed and released another version of the ALIS 1.0.3 software, version 1.0.3A3.2, to address some of the deficiencies and more testing was accomplished in December 2012. The software update allowed for manual data entries, vice relying on automated processes embedded in the aircraft, to transfer data to ALIS. Although the test team considered the software to be adequate for fielding—and the 1.0.3A3.2 version is in use at Yuma, Nellis, and Edwards AFBs (for the operational test aircraft)—the reliance on manual data entry is laborious, prone to error, and not consistent with the lean design of maintenance support expected for fielded operations.

The most recent reliability data for the F-35 fleet indicate that all variants are currently below planned reliability performance for failures directly chargeable to the primary contractors as well as for flying hours between critical failures. The F-35A's demonstrated flying time between critical failures is below 50 percent of the planned level, while the F-35B and F-35C are just over 70 percent of the planned level. The following subsystems have been problematic:

- Upper lift fan door actuator (F-35B only)
- Thermal management system fan

- Nose landing gear brake assembly (F-35A/B only)
- 270 volt DC battery
- 80 kW inverter/converter/controller
- Augmentor fuel pump
- Open-loop compressor isolation valve
- Sensor for display processor, thermal management system
- Ventilation nacelle fan
- Display management computer/helmet

The direct time maintainers currently spend working on each aircraft per flying hour is less than required for the full operational system. However, fielded aircraft currently have very few functional mission systems and no weapons capabilities, which resulted in fewer failure modes and less demands on maintainer time. Additionally, direct maintenance time does not include time spent on Action Requests maintainers submit to Lockheed Martin when they cannot find a solution to a maintenance problem in the aircraft technical data, or if they do not trust results from the prognostic health management system. Maintainers cannot proceed without a response to an Action Request. As both the technical data and prognostic health management system are immature, maintainers required a great deal of unreported time to deal with Action Requests. As the program matures, the time needed to fulfill Action Requests should decrease.

Electronic Warfare

Early in 2012, I identified several critical shortfalls in test resources needed to faithfully replicate current threats to JSF and other weapon systems. These deficiencies in test capability prevent adequate developmental and operational testing of the F-35. The Department's budget now includes resources for improvements to open-air range capabilities, an anechoic chamber, and the JSF electronic warfare-reprogramming laboratory. We need to maintain a high degree of urgency within the offices that have been made responsible for delivering these resources to assure they will be available in time to support JSF Block 3F operational testing in 2018; otherwise, that testing will be delayed.