STATEMENT

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BEFORE THE

SENATE ARMED SERVICES COMMITTEE

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Good morning Mr. Chairman, Senator McCain, and Members of the Committee. Thank you for the opportunity to appear before you today to discuss the Joint Strike Fighter (JSF) program.

Technical Baseline Review (TBR) and Re-planning Flight Test

The TBR, which began approximately a year ago, recommended changes to mission systems development, as well as to developmental flight test plans and resources that yield a realistic and credible program for completion of the system design and development (SDD) phase of the program. The schedule developed during the TBR extends the SDD phase about 16 months beyond the end-date used during the Nunn-McCurdy certification of JSF. Three reasons underlie this extension:

- More flight test sorties, including re-fly and regression sorties, were needed; the current number of sorties is consistent with historical experience.
- The short take-off vertical landing (STOVL) aircraft had proven to be more complex than assumed previously and its performance was different than pre-test predictions.
- Progress in developing and integrating mission systems software was less than previously understood, requiring more time and effort.

A final flight test schedule that incorporates the TBR recommendations is being developed; I expect it to be completed by late July. I will be working with the operational test agencies and the program office to adjust plans for conducting operational testing accordingly. Currently, I expect an operational assessment of aircraft with Block 2 mission systems capabilities to begin early in 2015, and initial operational test and evaluation of aircraft with Block 3 mission systems capabilities to begin in the Spring of 2017.

Flight Sciences Progress

Over the last six months, four more flight test aircraft have been ferried to the test centers and flight rates have improved for the STOVL and Conventional Takeoff and Landing (CTOL) aircraft. An additional three flight test aircraft, expected to be delivered by the end of last month, had not been delivered as of 11 May, but are expected to arrive at the flight test centers soon.

STOVL Flight Test. The STOVL variant flight rate has improved from an average of approximately 4 sorties per aircraft per month to approximately 8 sorties per aircraft per month against a plan of 5 sorties per aircraft per month. The test team has accomplished STOVL mode testing on four test aircraft, an improvement over the single aircraft available for this testing last year. This has resulted in a significant increase in the amount of STOVL mode flight testing. Completing needed modifications to test aircraft (e.g., stronger STOVL auxiliary air inlet doors), adding test aircraft, increased staffing at the flight test center, an increase in the envelope available for flight test, and improvements to parts supply and maintainability have contributed to this improvement in the pace of flight testing. The test team has accomplished nearly all of the vertical landings and short takeoffs needed in preparation for amphibious ship integration trials planned later this year, as well as for the start of STOVL pilot training at the training center early next year.

CTOL Flight Test. The flight rate of CTOL test aircraft continues ahead of the post-TBR planned rate. In the last two months, the three flight sciences test aircraft have averaged approximately 11 sorties per month against a plan of 9 sorties per aircraft per month. This is also between the flight rates planned to be achieved later this year and next year, 10 and 11 per aircraft per month, respectively. Increased staffing and logistics support have enabled this higher flight rate to be achieved.

Carrier Variant (CV) Flight Test. The single Carrier Variant (CV) aircraft at the flight test center continues to fly at about the planned pace. A second CV flight sciences aircraft, which is the final remaining SDD flight sciences test asset, has completed its first flight at the contractor facility in Ft Worth, Texas. Flight sciences testing of the CV aircraft is in the very early stages of flight envelope expansion.

Constraints on available flight sciences test points have, however, begun to challenge the program. The ability to open the available flight envelope and make productive use of the achievable pace of flight testing is dependent on completing analysis and/or modifications required to relieve aircraft operating limitations (e.g., clearance to fly in conditions causing greater structural loads and at higher maximum speed), incorporating additional instrumentation, incorporating design changes, and making changes to control laws.

Progress on Discoveries in Flight Sciences and Durability Testing

The program continues to address previous flight sciences test discoveries of undesirable handling characteristics and higher than predicted structural loads in the CTOL and STOVL aircraft. Flight test results during transonic flight and maneuvers with elevated g-forces have resulted in the need to change control laws in the vehicle systems software to address undesirable roll-off, side-slip, and yawing. Flying qualities in the CTOL aircraft at medium altitudes have improved with these changes. More flight test and analyses are needed to characterize and resolve these problems in the STOVL aircraft, which experiences more severe undesirable handling qualities in a greater area of the transonic envelope than the CTOL aircraft. A risk exists that software modifications to control laws may be insufficient to improve the handling characteristics of the STOVL aircraft, in which case mechanical fixes (e.g., a spoiler system) could be needed. The program is working to develop operationally relevant criteria with which to make final assessments of the efficacy of the software changes to control laws that are possible before examining hardware modifications to the aircraft. The structural loads on the vertical tail fins of both the CTOL and STOVL aircraft, which stem from the side-slip control problem, are higher than predicted and require further analysis. Testing in lower altitude flight operations, of weapons integration, and in high angle of attack environments has yet to be done for any variant and may result in new discoveries.

The program also continues to make progress in addressing problems with STOVL aircraft components that enable vertical lift operations. The roll post nozzle actuator, lift fan clutch and clutch housing, and lift fan driveshaft are being re-designed. The current designs meet the original design specifications, which have proven to be insufficient and can impose limitations on flight operations. The test team is able to safely conduct flight test and STOVL mode operations using flight monitoring systems in SDD test aircraft. The program is adding thermal blankets and better potting material in early LRIP aircraft to the roll post nozzle actuator components to handle greater than anticipated heat experienced inside the roll post nozzle bay below 60 knots; and has started a nozzle actuator component redesign effort to enable the nozzle to withstand higher temperatures. The program is adding driveshaft spacers in early LRIP aircraft to compensate for the unanticipated expansion and contraction of the shaft during flight while a new shaft design is being developed for cut-in to later production. Higher than expected drag on the lift fan clutch during CTOL mode flight heats the clutch to unacceptable levels, which that affect the ability to transition to STOVL modes for landing. The program is adding a temperature sensor to the clutch housing so that the pilot can monitor and be aware of increasing temperature inside the clutch housing. Pilot procedures in response to high clutch temperatures are being developed for flight test, training, and operational scenarios. The clutch may be cooled by changing flight regimes (e.g. lowering the landing gear, changing altitude and airspeed), before engaging STOVL modes, fuel and operational conditions permitting. Modifications to the STOVL aircraft Auxiliary Air Inlet doors to address higher than predicted loads and dynamic conditions in SDD test aircraft enabled the pace of vertical lift operations in flight test to be increased. Retrofit and redesign changes are planned to Auxiliary Air Inlet doors on production aircraft.

As mentioned above, the test team is able to safely conduct flight test and vertical lift operations using flight monitoring systems installed in the STOVL SDD test aircraft. However, these problems must be corrected in aircraft that are to be used for training and operational testing because those aircraft will not be monitored in-flight. The schedule for implementing these corrections is driven by the planned dates for initiating CTOL-only mode training operations in early 2012, as well as unmonitored STOVL mode operations, which may be needed as soon as late 2012 if the ability to conduct such operations is desired commensurate with the delivery to the Marine Corps of the first operational low-rate initial production (LRIP) STOVL aircraft. If testing of the changes is not complete by late 2012, the initial operational STOVL aircraft will fly in CTOL mode only.

Late last year, fatigue cracks occurred in a wing carry-through bulkhead on the STOVL durability test article after approximately 1,500 hours of test. Root cause analysis showed that high stress concentrations occurred at the location of the cracks; those concentrations were not predicted by the finite element modeling that had been conducted. The CTOL and STOVL durability test articles, SDD flight test aircraft, and early production aircraft will be modified according to a retrofit plan that includes blending edges in the areas where the stresses are concentrated and adding structural "straps" to strengthen the bulkhead. A redesigned bulkhead will be incorporated in later production aircraft. The STOVL durability test article will be modified with both the retrofit and the redesigned parts and is expected to resume durability testing late this year or early in 2012. The CTOL durability test article may re-enter testing as early as next month. However, the bulkhead problem generated a thorough review by the program office of the durability of the design for all three variants. This effort identified additional candidates for modifications to assure aircraft are durable through at least two structural fatigue lives (16,000 hours). For example, a wing root rib in the CTOL variant was identified as needing a re-design. Early LRIP CTOL aircraft will require retrofit of modifications of this structure and a re-designed component will be incorporated into later production aircraft.

Mission Systems

Mission systems development and flight test plans were restructured as a result of the TBR. Block 0.5, the first mission systems software version, began flight test in mid-2010. Though more stable than initial versions of the mission systems software released in the F-22 program, Block 0.5 experienced too many problems to complete its assigned flight test objectives. Fixes for the problems discovered with Block 0.5 were subsequently incorporated into an initial Block 1 software version which began flight testing early this year. Block 1 flight test execution and integration of final software elements is slightly behind the current post-TBR plan. Efforts in the last six months have focused on completing the regression testing generated last year by problems discovered with Block 0.5 and supporting the fielding of a portion of the Block 1 capability needed to begin initial pilot training later this year. Approximately 40 percent of original Block

1 test points have been deferred to the next block, Block 2, because of aircraft limitations in the Block 1 configuration. I estimate there is likely to be at least a 1-month to 2-month delay in completing flight testing of the remaining available Block 1 capability, which is currently planned to conclude in October of this year. The potential exists for a further delay because in order to meet this year's goals, flight test productivity must be significantly greater in terms of mission systems flight rate and test point completion than has been the case during the last year of mission systems flight testing. The addition of the first two LRIP production aircraft, AF-6 and AF-7, to the SDD test fleet will be helpful, but before these aircraft can contribute to missions systems flight testing, they must be loaded with the latest Block 1 software and then participate in a maturity demonstration needed to support the beginning of pilot training later this year. The maturity demonstration is required to assure CTOL production aircraft can be flown safely without control room monitoring, as will be the case during training and operational testing.

The development and integration teams are essentially on the TBR-adjusted timeline for releasing the first Block 2 capability to flight test in November of this year. Testing will be done initially of software incorporating about one-half of the full set of capabilities planned for Block 2. The deferred Block 1 test points will also have to be flown. Block 2 integration and flight test is planned to complete in late 2013. Block 3 development and integration is in an early stage; it is slightly lagging planned levels of completion by 10-15 percent, and is planned to continue until mid-2015. Producing and integrating the software that provides the complex capabilities in these later blocks of mission systems will be a substantial challenge.

Successful development of the Helmet Mounted Display System (HMDS) presents one of the more significant challenges to providing combat capability. It is integral to the F-35 mission systems architecture and the concept of operations---it displays key aircraft handling/performance information as well as tactical situational awareness and weapons employment information on the pilot's helmet visor. In the F-35, the HMDS replaces the conventional heads-up display (HUD) found in other fighter aircraft. Problems include integration of the night vision capability, symbology jitter, and latency. These stem in turn from problems with camera hardware, insufficient computer processing power, inaccurate head position tracking, and poor helmet fit, complicated by vibration-inducing airframe buffet experienced at high angles-of-attack in some dynamic maneuvering regimes. The program is pursuing a dual path to resolve the technical issues and provide a system that will enable flight test to proceed and meet operational mission needs. One path is to complete development of the original HMDS system by the end of SDD Block 3. The alternate path is to integrate a technically mature, existing helmet mounted display system that addresses the symbology stability issues that have been discovered, but requires an additional night vision system (such as existing night vision goggles) to provide night combat capability. As a further risk reduction strategy, the program continues to investigate the possible incorporation of a conventional HUD, should some of the current problems prove to be unsolvable with either the origiinal HMDS or an alternate helmet. If a HUD is, in fact, required, this would involve significant modifications to the current cockpit design.

<u>Modeling and Simulation--*Verification Simulation (VSIM)*</u>

The program has continued planning of validation efforts for F-35 modeling, development of the virtual battlespace environment, and integration of the two into one simulation intended for integrated test and evaluation. Several staff members were added over the last several months to the VSIM verification, validation, and accreditation (VV&A) management team. More work is needed to determine the adequacy of the current VSIM VV&A effort, with regard to manpower, integration with the lab and flight testing programs, and timing of verification and validation efforts with respect to the points in the program where the different components of VSIM need to be accredited for use. Although the VSIM VV&A management team may now be adequately manned, the detailed analytical work of model validation will have to be performed by experts in the individual subsystems and subsystem models, and the program has yet to clearly identify the manpower and other resources required to perform this detailed analysis. Furthermore, robust model validation is based on comparison of model performance with lab and flight test results. The program has only begun the process of matching validation data requirements to test events that can provide the required data. The upcoming integrated master schedule needs to assure that adequate time is allotted for the correction of model deficiencies identified in the validation process, including the required turnaround time for deficiency identification and correction, between the collection of data to analyze given models and dates at which fully validated versions models are required for use.

Modeling and Simulation--*Other Models and Corporate Labs*

The program's latest modeling and simulation accreditation planning indicates a total of 34 models and virtual laboratories (including VSIM) for use as test venues in developmental testing need to be accredited. The program had originally planned to accredit 11 models by the end of FY 10, but delays and the current re-plan are moving most of those accreditations to completion at later times, with a new schedule awaiting the re-plan results. Three accreditations have been completed so far. The need dates for model accreditation are, in many cases, tied to delivery dates for capabilities in the jet. That is, as mission capabilities shift from one configuration block to another, the dates at which the capabilities will be verified move accordingly; likewise the dates at which the models used in verifying those capabilities need to be accredited. In other words, the schedule for modeling and simulation accreditation is currently dynamic, and will remain so until the schedules for delivering capability to which accreditation is tied have stabilized.

Propulsion Testing

Ground testing for production qualification is completed for the F135 STOVL propulsion system, and CTOL ground testing is planned to complete in July. Flight test of the production-representative F135 initial service release (ISR) engine has continued in all three variants: STOVL ISR flight test has accomplished approximately 25 percent of the total SDD test points required; CTOL flight test has completed approximately 33 percent of the total test points required; and CV flight test has completed approximately 27 percent of ISR test points. Two CTOL flight sciences test aircraft engines have been modified to correct the engine afterburner "screech" problem that was reported last year. Engine afterburner screech did not slow flight test. A small number of test points were attempted last year and could not be achieved due to the screech-driven limitation. Flight test planners deferred testing in the regimes where screech limits operations, and have instead been conducting other testing--essentially re-sequencing test events. One of the recently modified CTOL test aircraft has flown test points in the regime that could not be sustained last year due to screech and was able to achieve the desired test conditions. Continued flight test will determine the efficacy of the modifications to the engine made to correct screech.