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JOINT STRIKE FIGHTER

Restructuring Places Program on Firmer Footing, but Progress Still Lags

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Highlights

Highlights of GAO-11-325, a report to congressional committees

April 2011

JOINT STRIKE FIGHTER

Restructuring Places Program on Firmer Footing, but Progress Still Lags

Why GAO Did This Study

The F-35 Lightning II, also known as the Joint Strike Fighter (JSF), is the Department of Defense's (DOD) most costly and ambitious aircraft acquisition, seeking to simultaneously develop and field three aircraft variants for the Air Force, Navy, Marine Corps, and eight international partners. The JSF is critical for recapitalizing tactical air forces and will require a long-term commitment to very large annual funding outlays. The current estimated investment is $382 billion to develop and procure 2,457 aircraft.

This report, prepared in response to a congressional mandate in the National Defense Authorization Act for Fiscal Year 2010, discusses (1) program cost and schedule changes and their implications on affordability; (2) progress made during 2010; (3) design and manufacturing maturity; and (4) test plans and progress. GAO's work included analyses of a wide range of program documents and interviews with defense and contractor officials.

What GAO Recommends

To sustain a focus on accountability and facilitate tradeoffs within the JSF program, GAO recommends that DOD (1) maintain annual funding levels at current budgeted amounts; (2) establish criteria for evaluating the STOVL's progress and make independent reviews, allowing each variant to proceed at its own pace; and (3) conduct an independent review of the software development and lab accreditation processes. DOD concurred.

View GAO-11-325 or key components.
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What GAO Found

DOD continues to substantially restructure the JSF program, taking positive actions that should lead to more achievable and predictable outcomes. Restructuring has consequences—higher up-front development costs, fewer aircraft in the near term, training delays, and extended times for testing and delivering capabilities to warfighters. Total development funding is now $56.4 billion to complete in 2018, a 26 percent increase in cost and a 5-year slip in schedule compared to the current baseline. DOD also reduced procurement quantities by 246 aircraft through 2016, but has not calculated the net effects of restructuring on total procurement costs nor approved a new baseline. Affordability for the U.S. and partners is challenged by a near doubling in average unit prices since program start and higher estimated life-cycle costs. Going forward, the JSF requires unprecedented funding levels in a period of more austere defense budgets.

The program had mixed success in 2010, achieving 6 of 12 major goals it established and making varying degrees of progress on the others. Successes included the first flight of the carrier variant, award of a fixed-price aircraft procurement contract, and an accelerated pace in development flight tests that accomplished three times as many flights in 2010 as the previous 3 years combined. However, the program did not deliver as many aircraft to test and training sites as planned and made only a partial release of software capabilities. The short take off and landing variant (STOVL) experienced significant technical problems and did not meet flight test expectations. The Secretary of Defense directed a 2-year period to evaluate and engineer STOVL solutions.

After more than 9 years in development and 4 in production, the JSF program has not fully demonstrated that the aircraft design is stable, manufacturing processes are mature, and the system is reliable. Engineering drawings are still being released to the manufacturing floor and design changes continue at higher rates than desired. More changes are expected as testing accelerates. Test and production aircraft cost more and are taking longer to deliver than expected. Manufacturers are improving operations and implemented 8 of 20 recommendations from an expert panel, but have not yet demonstrated a capacity to efficiently produce at higher production rates. Substantial improvements in factory throughput and the global supply chain are needed.

Development testing is still early in demonstrating that aircraft will work as intended and meet warfighter requirements. Only about 4 percent of JSF capabilities have been completely verified by flight tests, lab results, or both. Only 3 of the extensive network of 32 ground test labs and simulation models are fully accredited to ensure the fidelity of results. Software development—essential for achieving about 80 percent of the JSF functionality—is significantly behind schedule as it enters its most challenging phase.

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Abbreviations

CAPE	Cost Assessment and Program Evaluation
CTOL	conventional takeoff and landing
CV	carrier variant
DCMA	Defense Contract Management Agency
DOD	Department of Defense
IMRT	Independent Manufacturing Review Team
JAT	Joint Assessment Team
JET	Joint Estimating Team
JSF	Joint Strike Fighter
OSD	Office of the Secretary of Defense
STOVL	short takeoff and vertical landing

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United States Government Accountability Office
Washington, DC 20548

April 7, 2011

Congressional Committees

The F-35 Lightning II, also known as the Joint Strike Fighter (JSF) is the Department of Defense's (DOD) most costly and ambitious aircraft acquisition, seeking to simultaneously develop and field three aircraft variants for the Air Force, Navy, Marine Corps, and eight international partners. The JSF is the core of DOD's long term tactical aircraft recapitalization plans as it is intended to replace hundreds of legacy aircraft. Total U.S. planned investment in the JSF is about $385 billion to develop and acquire 2,457 aircraft through 2035. With that many dollars at stake amidst pressing warfighter requirements for this new 5th generation capability, the Department has lately recognized numerous technical, financial, and management shortcomings and continues to significantly restructure the program, adding more time and money and making other changes that we support.

GAO has reported on JSF issues for a number of years. Appendix 2 summarizes key findings and recommendations from that body of work. One recurring theme has been the "single step," or revolutionary, acquisition strategy the JSF program adopted to develop and acquire full combat capabilities on a very aggressive, risky schedule with substantial concurrency, or overlap among development, testing, and production activities.[1] That strategy, coupled with a management environment that was slow to acknowledge and address problems with needed changes, are prime contributors to the relatively poor cost, schedule, and performance outcomes experienced to date. Our March 2010 report[2] discussed additional cost and schedule pressures, unsatisfactory performance in manufacturing and delivering aircraft, and concerns about not meeting warfighter requirements on time and in quantity. We recommended that (1) DOD complete an independent, comprehensive cost and schedule estimate and establish it as the official program of record for planning,

[1]Rather than a single step approach, best practices and current DOD acquisition guidance recommend that complex weapon system programs instead adopt a more evolutionary acquisition strategy, developing and procuring new systems incrementally to help achieve better program outcomes and deliver new capabilities to the warfighters sooner.

[2]GAO, *Joint Strike Fighter: Additional Costs and Delays Risk Not Meeting Warfighter Requirements on Time*, GAO-10-382 (Washington, D.C.: Mar. 19, 2010). Refer to the related products section for a list of prior GAO reports and testimonies.

budgeting, and congressional reporting purposes and (2) reassess warfighter requirements to determine the minimum needs (both capabilities and capacity) that can be achieved within realistic and reasonable timeframes and, if necessary, defer some capabilities to future increments. In addition, we suggested that Congress consider requiring DOD to establish a "system maturity matrix," a management tool to better measure the program's annual progress toward key objectives to improve oversight and better inform future budget decisions.

This is our second report required by law[3] in which we (1) evaluate program cost and schedule changes and their implications on affordability; (2) identify progress made in 2010 against established goals; (3) assess elements of design stability and manufacturing maturity and review production results; and (4) report status of development testing and technical challenges facing the program. To conduct this work, we evaluated DOD's restructuring actions and impacts on the program, tracked cost and schedule changes, and determined factors driving the changes. We reviewed program status reports, manufacturing data, test plans, and internal DOD analyses. We discussed results to date and future plans to complete JSF development and move further into procurement with DOD, JSF, and contractor officials including members of the independent review teams. We toured aircraft and engine manufacturing plants, obtained production and supply performance indicators, and discussed improvements underway with contractors. We conducted this performance audit from May 2010 to March 2011 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The F-35 program is a joint, multinational acquisition to develop and field an affordable, highly common family of stealthy, next-generation strike fighter aircraft for the United States Air Force, Marine Corps, Navy, and eight international partners. The JSF is a single-seat, single-engine aircraft incorporating low-observable (stealth) technologies, defensive avionics,

[3]National Defense Authorization Act for Fiscal Year 2010, Pub. L. No. 111-84 § 244 (2009).

advanced sensor fusion,[4] internal and external weapons, and advanced prognostic maintenance capability. There are three variants. The F-35A conventional takeoff and landing (CTOL) variant will provide air-to-ground attack capabilities to replace the Air Force's F-16 Fighting Falcon and the A-10 Thunderbolt II aircraft, and will complement the F-22A Raptor. The F-35B short takeoff and vertical landing (STOVL) aircraft will be a multi-role strike fighter to replace the Marine Corps' F/A-18C/D Hornet and AV-8B Harrier aircraft. The F-35C carrier-suitable variant (CV) will provide the Navy and Marine Corps a multi-role, stealthy strike aircraft to complement the F/A-18E/F Super Hornet. The JSF is DOD's largest cooperative program.[5] Our international partners are providing about $5.1 billion toward development, and foreign firms are part of the industrial base producing aircraft. DOD's funding requirements for the JSF assume economic benefits from partner purchases in reducing unit costs for U.S. aircraft.

JSF concept development began in November 1996 with a 5-year competition between contractors to determine the most capable and affordable preliminary aircraft design. Lockheed Martin won the competition and the JSF program entered system development and demonstration in October 2001. Pratt and Whitney is the primary engine manufacturer, while General Electric has been developing a potential second source for the engine. System integration efforts and a preliminary design review then revealed significant airframe weight problems impacting key performance requirements. In March 2004, DOD rebaselined the program, adding time and money for development and delaying key milestones. The Navy and Marine Corps also reduced their planned procurement by 409 jets, reducing the total U.S. buy to the current 2,457 quantity. The program was again rebaselined in March 2007 to reflect additional cost increases and schedule slips and the procurement period was extended by 7 years to 2034 with reduction in annual quantities.

Because of continuing problems and poor outcomes, the Secretary of Defense announced another comprehensive restructuring of the JSF program in February 2010. The restructuring followed an extensive

[4] Sensor fusion is the ability to take information from both multiple onboard and off board aircraft sensors and display the information in an easy-to-use format for the single pilot.

[5] The international partners are the United Kingdom, Italy, the Netherlands, Turkey, Canada, Australia, Denmark, and Norway. These nations are contributing funds for system development and plan to procure more than 700 aircraft.

Department-wide review initiated in 2009 and considered the findings and recommendations from three independent groups chartered to assess the program: the Joint Estimating Team (JET) evaluated program execution and resource requirements; the Independent Manufacturing Review Team (IMRT) assessed contractor capabilities and plans for ramping-up and sustaining production at maximum rates; and the Joint Assessment Team (JAT) reviewed engine costs and affordability initiatives. Key restructuring actions included adding $2.8 billion for development, extending flight testing by 13 months, adding flight test resources (one new test jet and use of 3 production jets), reduced near-term procurement by 122 aircraft, and review of the military services' capability need dates. The Under Secretary of Defense for Acquisition, Technology and Logistics stated that the department-wide review would continue under new program management and cited 2010 as a critical year for assessing progress against the new plans and the expected delivery of all test aircraft, completion of hundreds of test flights, and meeting other key milestones. We supported these actions in our March 2010 report and subsequent testimonies.[6] We noted the likelihood of additional cost growth and schedule extensions as the restructuring continues.

In March 2010, the Department declared that the program experienced a breach of the critical cost growth statutory thresholds.[7] The Department subsequently certified to Congress in June 2010 that the JSF program should continue.[8] Table 1 summarizes the evolution of JSF cost and

[6] GAO-10-382. Also GAO, *Joint Strike Fighter: Significant Challenges and Decision Ahead*, GAO-10-478T (Washington, D.C.: Mar. 24, 2010) and GAO, *Joint Strike Fighter: Significant Challenges Ahead as DOD Restructures Program*, GAO-10-520T (Washington, D.C.: Mar. 11, 2010).

[7] Commonly referred to as Nunn-McCurdy, 10 U.S.C. § 2433 establishes the requirement for DOD to submit unit cost reports on major defense acquisition programs or designated major subprograms. Two measures are tracked against the current and original baseline estimates for a program: procurement unit cost (total procurement funds divided by the quantity of systems procured) and program acquisition unit cost (total funds for development, procurement, and system-specific military construction divided by the quantity of systems procured). If a program's procurement unit cost or acquisition unit cost increases by at least 25 percent over the current baseline estimate or at least 50 percent over the original baseline estimate, it constitutes a breach of the critical cost growth threshold. Programs are required to notify Congress if a Nunn-McCurdy breach is experienced.

[8] When a program experiences a Nunn-McCurdy breach of the critical cost growth threshold, DOD is required to take a number of steps including reassessing the program and submitting a certification to Congress in order to continue the program, in accordance with 10 U.S.C. § 2433a.

schedule estimates at key junctures in its acquisition history through the current Nunn-McCurdy certification. Since then, in January 2011, the Secretary of Defense announced additional development cost increases and further changes consequent to the ongoing restructure, but has not yet established a new approved acquisition program baseline.

Table 1: Changes in Reported JSF Program Cost, Quantities, and Deliveries

	October 2001 (system development start)	December 2003 (2004 replan)	March 2007 (approved baseline)	April 2010 (initial program restructure)	June 2010 (Nunn-McCurdy)
Expected quantities					
Development quantities	14	14	15	14	14
Procurement quantities (U.S. only)	2,852	2,443	2,443	2,443	2,443
Total quantities	**2,866**	**2,457**	**2,458**	**2,457**	**2,457**
Cost estimates (then-year dollars in billions)					
Development	$34.4	$44.8	$44.8	$50.2	$51.8
Procurement	196.6	199.8	231.7	277.5	325.1
Military construction	2.0	0.2	2.0	0.6	5.6
Total program acquisition	**$233.0**	**$244.8**	**$278.5**	**$328.3**	**$382.5**
Unit cost estimates (then-year dollars in millions)					
Program acquisition	$81	$100	$113	$134	$156
Average procurement	69	82	95	114	133
Estimated delivery and production dates					
First operational aircraft delivery	2008	2009	2010	2010	2010
Initial operational capability	2010-2012	2012-2013	2012-2015	2012-2016	TBD
Full-rate production	2012	2013	2013	2016	2016

Source: GAO analysis and DOD data.

Note: Does not reflect cost and schedule effects from additional restructuring actions announced after June 2010.

Affordability Expectations Are Challenged as JSF Acquisition Costs Rise and Schedules Slip

Ongoing JSF restructuring continues to add more cost and time for developing, testing, and delivering aircraft to the warfighter. These actions, effectively implemented, should result in more predictable and achievable program outcomes, but restructuring comes with consequences—higher upfront development costs, fewer aircraft received in the near term, training delays, and extended times for testing and delivering the capabilities required by the warfighter. Affordability for the U.S. and our allies is challenged because unit prices are about double what they were at program start and with new forecasts that the aircraft may cost substantially more to operate and maintain over the life cycle than the legacy aircraft they replace. Going forward, the program requires unprecedented levels of funding in a period of more austere defense funding. Defense leaders stated that the JSF program lost its focus on affordability and that restoring the focus is paramount to improving program outcomes.

Additional Cost Increases and Schedule Delays Are Expected as Program Restructuring Continues

Defense leadership continued to restructure the JSF program following the Nunn-McCurdy certification. In January 2011, the Secretary of Defense directed additional changes, stemming in large part from the results of a comprehensive technical baseline review under new government and contractor management. Key program changes (1) added $4.6 billion to the development program through completion for a total development program estimate of $56.4 billion (an increase of 26 percent against the current baseline and 64 percent from the original baseline at program start); (2) extended the development test period to 2016 (a 4-year slip from the current baseline); and (3) reduced near-term procurement quantities by 124 aircraft in addition to the 122 aircraft cut announced in February 2010; and (4) lowered the annual rate of increase for boosting future production.

Because of the lingering technical issues on the STOVL, the most complex variant, the Secretary decoupled STOVL flight tests from the combined test plan and scaled back STOVL production to only 3 in fiscal year 2011 and to 6 per year for fiscal years 2012 and 2013. This represents a total cut of 37 STOVL aircraft during this 3-year period compared to the fiscal year 2011 budget plans. In announcing these changes, the Secretary also noted the STOVL's significant testing problems which include lift fan engine deficiencies, and poor durability test results, which could require redesigns and add weight to aircraft's structure and propulsion system. While the Secretary decoupled STOVL from the flight test program, STOVL was not further separated from the rest of the JSF program for management and reporting activities. It remains a part of the combined

JSF program for milestone decisions and cost, schedule, and performance reporting. Resolving STOVL problems and moving forward at an affordable cost is essential to the Marine Corps' future plans, which depend upon acquiring the STOVL in quantity to directly accompany, protect, and provide firepower to its ground expeditionary forces.

The recently submitted fiscal year 2012 Defense Budget reflects the financial impacts from restructuring actions through 2016. Compared to estimates in the fiscal year 2010 future years defense program for the same 5-year period, the Department increased development funding by $7.7 billion and decreased procurement funding by $8.4 billion reflecting plans to buy fewer aircraft. Table 2 summarizes the revised development and procurement funding requirements and annual quantities following the Secretary's reductions. Even after decreasing near-term quantities and lowering the ramp rate, JSF procurement still rapidly increases. Annual funding levels more than double and quantities more than triple during this period. These numbers do not include the additional orders expected from the international partners.

Table 2: Budgeted Development and Procurement Funding and Quantities for Fiscal Years 2012-2016

(Dollars in billions)						
Development Funding	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Air Force (CTOL)	$1.4	$1.2	$0.9	$0.6	$0.4	$4.5
Navy (CV)	0.7	0.7	0.7	0.6	0.5	3.2
Marine Corps (STOVL)	0.7	0.7	0.7	0.6	0.5	3.2
U.S. total development	**$2.7**	**$2.7**	**$2.3**	**$1.8**	**$1.3**	**$10.8**
Procurement Funding	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Air Force (CTOL)	$3.8	$4.1	$5.6	$6.5	$8.5	$28.5
Navy (CV)	1.8	2.5	2.8	3.3	2.9	13.2
Marine Corps (STOVL)	1.3	1.3	1.4	2.0	2.9	9.0
U.S. total procurement	**$6.9**	**$7.9**	**$9.8**	**$11.8**	**$14.3**	**$50.7**
Procurement Quantities	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Air Force (CTOL)	19	24	40	50	70	203
Navy (CV)	7	12	14	19	20	72
Marine Corps (STOVL)	6	6	8	12	18	50
U.S. total quantity	**32**	**42**	**62**	**81**	**108**	**325**

Source: GAO analysis of fiscal year 2012 President's Budget.

Note: Numbers may not add due to rounding.

Additional changes to cost and schedule are likely as restructuring continues. At the time of this report, the Secretary had not yet granted new milestone B approval nor approved a new acquisition program baseline. Originally planned for November 2010, program officials now expect the new acquisition program baseline in late 2011. Also, cost analysts are still revising procurement funding requirements for the period fiscal year 2017 through completion of procurement in 2035. Accordingly, the net effect of reducing near-term procurement quantities and deferring these aircraft to future years is uncertain and depends upon the assumptions made about future unit prices, annual quantities, and inflation. We expect total procurement costs will be somewhat higher than the estimate submitted in the Nunn-McCurdy certification (refer to table 1). Reduced quantities and use of production aircraft in testing will also limit training activities for the near-term and delay deliveries of new capabilities to the warfighters. Officials now forecast that the completion of system development, completion of initial operational testing, and the full rate production decision will extend into 2018. This represents slips of about 5 years in these important milestones against the current program baseline approved in 2007.

The military services are evaluating the impacts from restructuring on their initial operational capability (IOC) milestones, the critical need dates when the warfighter must have in place the first increment of operational forces available for combat. In response to the initial set of restructuring actions, the Air Force and Navy tentatively extended these milestones to 2016, but the Marine Corps slightly adjusted its IOC date by 9 months to December 2012. It is all but certain that the Marine Corps will be delaying its IOC date in the wake of the Secretary's STOVL actions. Air Force and Navy dates may also be adjusted to reflect the newest developments.

Program Requires Unprecedented Funding Levels Well into the Future

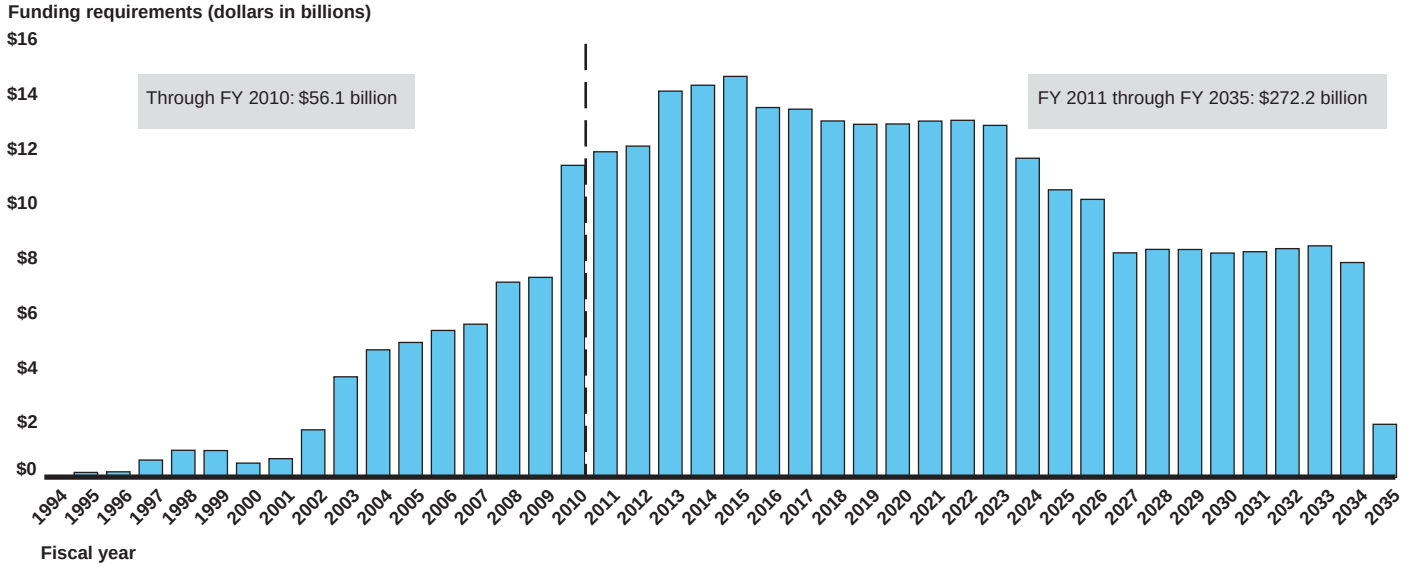
Affordability—both in terms of the investment costs to acquire the JSF and the continuing costs to operate and maintain it over the life-cycle—is at risk. A key tenet of the JSF program from its inception has been to deliver an affordable, highly common fifth generation[9] aircraft that could be acquired by the warfighters in large numbers. Rising aircraft prices erode buying power and make it difficult for the U.S. and its allies to buy as many aircraft as planned. Quantity reductions could drive additional

[9] Fifth generation aircraft include the F-22A and JSF and incorporate stealth characteristics, fused sensor data, and advanced radars.

price increases for future aircraft. Further, while the Department is still refining cost projections for operating and supporting future JSF fleets, cost forecasts have increased as the program matures and more data becomes available. Current JSF life-cycle cost estimates are considerably higher than the legacy aircraft it will replace; this has major implications for future demands on military operating and support budgets and plans for recapitalizing fighter forces. Defense leadership stated that the JSF program lost focus on affordability and that restoring and maintaining that focus is paramount to improving program outcomes.

In light of continued cost growth, the program places unprecedented demands for funding in the defense budget—an annual average of almost $11 billion for the next two decades. (This and other data in this paragraph reflect the fiscal year 2011 budget submission.) During the peak years of production, the average annual requirement is about $13 billion. The JSF will have to annually compete with other defense and nondefense priorities for the shrinking discretionary federal dollar amid continued concerns about the national debt and long term fiscal pressures. The JSF program has received more than $56 billion through fiscal year 2010. To complete the acquisition program as currently planned, another $272 billion will be required from 2011 through 2035. Figure 1 illustrates the annual funding requirements outlined in the program's Selected Acquisition Report released in April 2010. These funding levels do not reflect the additional funding increases in the Nunn-McCurdy certification and the Secretary's recent actions. DOD is in the process of establishing a new acquisition program baseline which will likely project even higher funding requirements.

Figure 1: JSF Annual Development and Procurement Funding Requirements (April 2010 Estimate)



Source: GAO analysis of DOD data.

The JSF is the linchpin in DOD's tactical aircraft recapitalization plans, replacing hundreds of legacy aircraft. Because of its sheer size and high priority within the Department, even relatively modest cost growth on the JSF can require the sourcing of billions of additional funds, largely from other programs in DOD's acquisition portfolio. On the other hand, slips in JSF schedules, cuts in annual procurement quantities, and deferred delivery of operational aircraft can require additional monies be spent on legacy aircraft, postponing planned retirements and sustaining fleets for longer periods of time. To mitigate projected shortfalls in tactical aircraft inventories due to JSF perturbations, the Navy recently procured additional F/A-18E/F Super Hornets and both the Navy and Air Force are funding service life extension programs and adding new capabilities to legacy aircraft.

Furthermore, international partners' participation in the JSF program is very important to maintaining affordability for all buyers. DOD budget plans expect the partners to buy 223 aircraft costing $24.1 billion during the fiscal year 2011-2016 period. However, JSF cost increases, schedule delays, and internal issues may result in reduced or deferred foreign buys. Some partners have already signaled plans to buy fewer aircraft, a different mix of aircraft, or defer purchases to later years. On the positive side, other countries have expressed interest in acquiring the JSF.

Decisions made by the international community and its impact on JSF affordability are largely beyond the program's direct control. However, improving JSF program outcomes to lower costs and reassure buyers is within DOD's and the contractors' control.

The eight international partners have important stakes in the JSF program, having provided about $5 billion in development funding, being counted upon to procure hundreds of aircraft, and expecting their industries to receive a significant portion of JSF manufacturing and supply business. DOD's procurement cost estimates provided to the Congress have long assumed that the eight partners will buy at least 730 JSF aircraft. Unit prices for U.S. quantities assume the economic benefit of these purchases. If fewer are sold overseas, the Air Force, Navy and Marine Corps (and the American taxpayer) may have to pay more. Unit costs can be expected to increase with smaller purchases due to diminished manufacturing economies of scale and because fixed costs have to be spread over fewer aircraft.

Maintaining a strong focus on affordability necessitates having reliable and complete cost data that provides accurate accounting reports, identifies potential cost and schedule problems early, and produces sound estimates of the cost to complete work. The JSF program has been hampered in this regard because, for at least the past three years, the prime contractor has not had an adequate and disciplined earned value management (EVM) system in place to effectively track costs and control schedule. The prime contractor was found deficient in meeting 19 of 32 required guidelines, calling into question its ability to manage the escalating costs and complex scheduling of the JSF program. In October 2010, the Defense Contract Management Agency (DCMA) withdrew the determination of compliance for the prime contractor's EVM system due to longstanding non-compliance issues with specific guidelines that underpin a sound system.[10] To address these shortcomings, the contractor is developing new processes, tools, training, and enforcement in order to achieve a fully integrated and automated EVM system. Officials will reassess the earned

[10] American National Standards Institute/Electronics Industries Alliance-748 is a collection of 32 earned value management system guidelines that incorporate business best practices for program management systems proven to provide strong benefits for program or enterprise planning and control. The processes include integration of program scope, schedule, and cost objectives, establishment of a baseline plan for accomplishment of program objectives, and use of earned value techniques for performance measurement during the execution of a program. The system provides a sound basis for problem identification, corrective actions, and management replanning as required.

value system by March 2012—more than four years after these problems were first discovered to see if modifications needed have been made.

EVM is an important, established tool that can provide objective product status reports. DOD requires its use by major defense suppliers to facilitate good insight and oversight of the expenditure of government dollars, thereby improving both affordability and accountability. JSF is DOD's largest acquisition ever, so it is particularly critical to improve and certify the contractor's EVM system as expeditiously as possible. If not improved, inaccurate performance reports and late notice of cost overruns will likely continue to hinder timely decision making and corrective actions. Strong leadership and a shared vision among stakeholders are critical to implementing EVM effectively.

Progress in Achieving the JSF Program's 2010 Goals Was Mixed

The JSF program established 12 clearly-stated goals in testing, contracting, and manufacturing for completion in calendar year 2010. It had mixed success, achieving 6 goals and making varying degrees of progress on the other 6. For example, the program exceeded its goal for the number of development flight tests but did not deliver as many test and production aircraft as planned. Also, the program awarded its first fixed-price contract on its fourth lot of aircraft production, but did not award the fixed-price engine contract in 2010 as planned. Table 3 summarizes JSF goals and accomplishments for 2010.

Table 3: JSF Progress on Stated Goals for 2010

Key event	Achieved in 2010	Status
Complete 400 development flight tests	Yes	Completed 410 test flights
First vertical landing of STOVL variant	Yes	Achieved March 2010
Carrier variant first flight	Yes	Achieved June 2010
Autonomic logistic information system is operational	Yes	Began limited operations July 2010
Training for 125 maintenance personnel completed	Yes	Trained 138 maintenance personnel
Award contract for fourth aircraft production lot	Yes	Awarded contract November 2010
Eleven test aircraft delivered to test sites	No	Delivered eight aircraft
Flight test rate of 12 flights per aircraft per month demonstrated	No	Achieved flight test rate of 2 to 8 per month
At least 3 aircraft delivered to Eglin Air Force Base	No	None delivered, expected mid-2011
Begin flight training operations at Eglin Air Force Base	No	Expected September 2011
Block 1.0 software delivered to flight test	No	Delivered limited capability November 2010 with full capability expected June 2011
Award contract for fourth engine production lot	No	Expected May 2011

Source: GAO analysis of DOD data.

The development flight test program significantly ramped up operations in 2010, accomplishing three times as many test flights as the previous 3 years combined. Table 4 summarizes actual flights, hours, and test points[11] flown by each variant compared to the 2010 plan.

[11]Flight test points are specific, quantifiable objectives in flight plans that are needed to verify aircraft design and performance.

Table 4: Flight Test Performance in 2010

	Conventional takeoff and landing variant	Short takeoff and vertical landing variant	Carrier variant	Total
Flight tests				
Actual	171	212	27	410
Planned	112	251	31	394
Difference	59	(39)	(4)	16
Flight test hours				
Actual	290	286	41	617
Planned	202	409	56	667
Difference	88	(123)	(15)	(50)
Flight test points flown				
Actual	1373	1924	496	3793
Planned	1064	2438	270	3772
Difference	309	(514)	226	21

Source: GAO analysis of DOD data.

Although still hampered as in prior years by the late delivery of test aircraft, flight tests substantially increased in volume and pace at the two main government test sites—Edwards Air Force Base, California, for CTOL tests and Patuxent River Naval Air Station for STOVL and CV testing. The CTOL variant significantly exceeded plans while initial testing of the carrier variant was judged satisfactory, below plans for the number and hours of flight but ahead on test points flown. The STOVL, however, substantially under-performed in flight tests and experienced significant technical issues unique to this variant that could add to its weight and cost. The STOVL's test problems were a major factor in the heightened scrutiny and two-year probation period directed by the Secretary to engineer solutions, assess impacts, and inform a future decision as to whether and how to proceed with this variant.

Evaluating annual performance against stated goals can be an effective tool that facilitates oversight by the Congress and defense leadership and useful for informing future budget decisions. In our 2010 report, we suggested that Congress consider requiring DOD to establish a system maturity matrix to better measure the program's progress in maturing the weapon system and providing evidence to support budget decisions.[12] The

[12] GAO-10-382.

Ike Skelton National Defense Authorization Act for Fiscal Year 2011[13] established this requirement and we understand the Department is working on its implementation. We believe this tool and process will improve oversight and budgeting, holding people accountable for meeting interim objectives and, for objectives not met, providing criteria and a forum for evaluating reasons why and what should be done.

Program Has Still Not Fully Demonstrated a Stable Design and Mature Manufacturing Processes as It Enters Its Fifth Year of Production

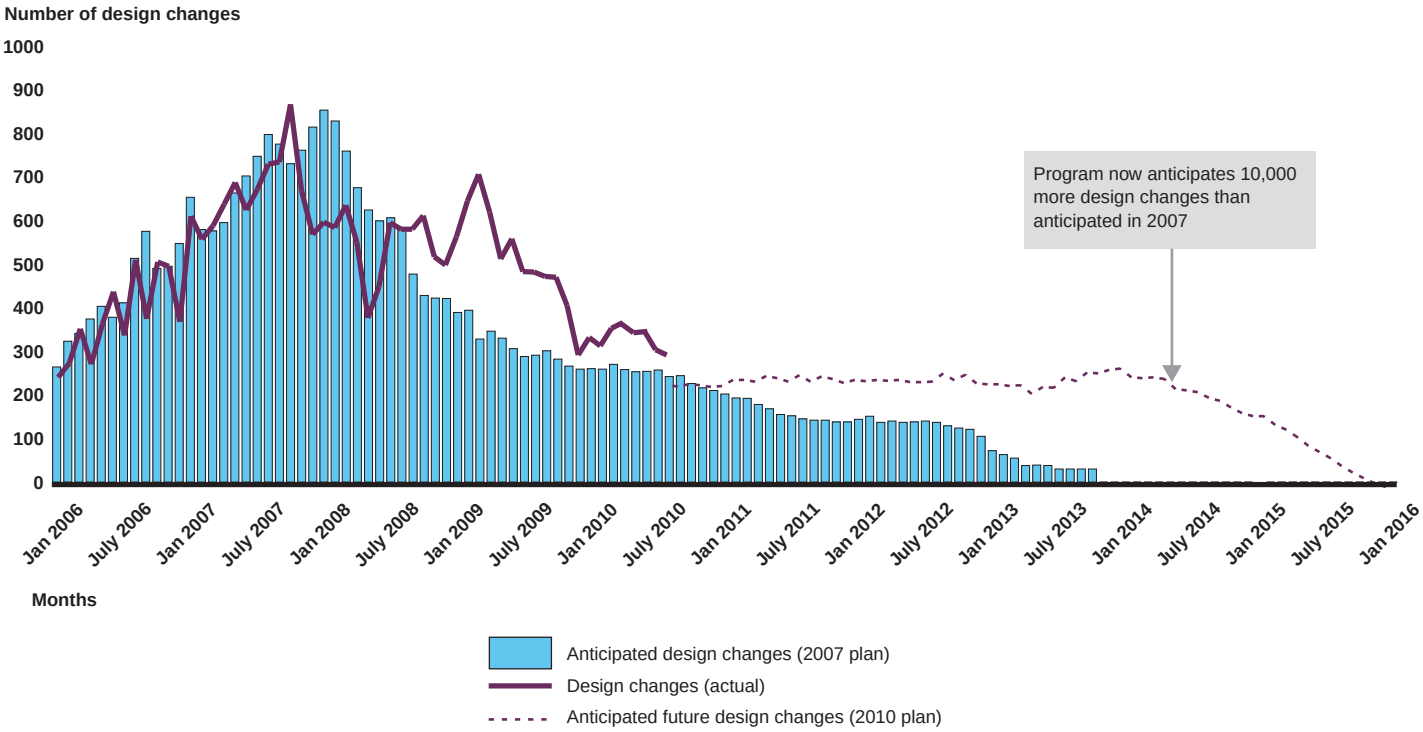
After completing 9 years of system development and 4 years of overlapping production activities, the JSF program has been slow to gain adequate knowledge that its design and manufacturing process are fully mature and ready for greater levels of annual production. The JSF program still lags in achieving critical indicators of success expected from well-performing acquisition programs. Specifically, the program has not yet stabilized aircraft designs—engineering changes continue at higher than expected rates long after critical design reviews and well into procurement, and more changes are expected as testing accelerates. Also, the aircraft and engine manufacturing processes are not yet mature enough to support efficient production at higher annual rates and substantial improvements in the global supply network are needed. Further, the growth in aircraft reliability—crucial for managing life-cycle costs—has not been demonstrated to the extent planned by this time.

The Program Has Not Yet Stabilized Aircraft Designs

Engineering drawings released since design reviews and the number and rate of design changes are excessive compared to plans and best practices. Critical design reviews were completed on the three aircraft variants in 2006 and 2007 and the designs declared mature, but the program continues to experience numerous changes. Since 2007, the program has produced 20,000 more engineering drawings, a 50-percent increase in total drawings and about 5 times more than best practices suggest. In addition, changes to drawings have not decreased and leveled off as planned. Figure 2 tracks and compares monthly design changes and future forecasts against contractor plans in 2007. The monthly rate in 2009 and 2010 was higher than expected and the program now anticipates more changes over a longer period of time—about 10,000 more changes through January 2016. We expect this number to go up given new forecasts for additional testing and extension of system development until 2018.

[13] Pub. L. No. 111-383, § 122.

Figure 2: Monthly Design Changes for JSF Aircraft



Source: GAO analysis of DOD data.

A key indicator of a product's maturity is the stability of its design. The number of engineering drawings released and subsequent changes provide indicators of the maturity of the design. Engineering drawings are critical because they communicate to the manufacturer and suppliers how the part functions, what it looks like, and what materials and critical processes are used to build the product. Best practices suggest 90 percent of a product's engineering drawings be released by the critical design review. Late engineering drawings and high levels of changes often indicate a lack of understanding about the design, and can cause part shortages and inefficient manufacturing processes as work is performed out of sequence. Some level of design change is expected during the production cycle of any new and highly technical product, but excessive changes raise questions about the JSF's design maturity and its readiness for higher rates of production.

With most of development testing still ahead for the JSF, the risk and impact from required design changes are significant. Acquisition programs

typically encounter higher and more substantive changes as a result of discovery and rework during development flight and ground testing. Future changes may require alterations to the manufacturing process, changes to the supply base, and costly retrofitting of aircraft already produced and fielded. A key cost driver for the program has been the higher than expected effort needed to address design related issues. The contractor has not been able to reduce engineering staff as fast as expected. DOD's restructuring actions recognize these issues and added time to development, more flight testing, and reduced procurement. Additional changes are likely as development flight testing continues.

Some emerging concerns may drive additional and substantive design changes:

- **JSF Lift System Development and Integration.** Essential to STOVL operations, the lift fan continues to be a prime risk area. The program is working to mature lift fan and drive shaft technologies and a required redesign expected in spring 2011.

- **Fatigue Cracks in STOVL Test Article.** During a recent durability ground test, fatigue cracks were discovered in a major bulkhead of the STOVL test article. Cracks were discovered after 1,500 hours of durability testing, less than one-tenth of the hours planned for fatigue tests to certify that the STOVL airframe meets its design life requirement. Officials reported that stress data had been under-estimated during initial design. Inspections of aircraft and other test articles did not identify cracks at the same site. Decisions about potential redesign and re-manufacture are still to be determined.

- **Wing Tip Vortex.** Prime contractor officials identified wing tip vortices as a potential risk to the program. Wing tip vortices are tubes of circulating air which are left behind the aircraft's wing as it generates lift. The cores of the vortices are sometimes visible because of water condensation. If these are visible during daytime flights they could negatively impact the aircraft's stealth capabilities.

- **Outer Mold Lines.** Defense Contract Management Agency officials noted difficulties in manufacturing outer mold lines, resulting from tight tolerance specifications and multiple manufacturing methodologies among the different JSF parts suppliers. The manufacturing processes are new and different from legacy practices. Inability to meet the outer mold line requirements could have major impacts on cost as well as stealth requirements and capabilities. This problem is not expected to be resolved until the June 2015 time frame

after which a large number of aircraft will have been built and would need to be retrofitted for any design changes. Program officials stated some redesign activities have begun and will take into the 2013 timeframe to begin developing the changes, their costs, and implementation. The effects of these changes could extend out into 2015, but will be prioritized to reduce performance and cost impacts.

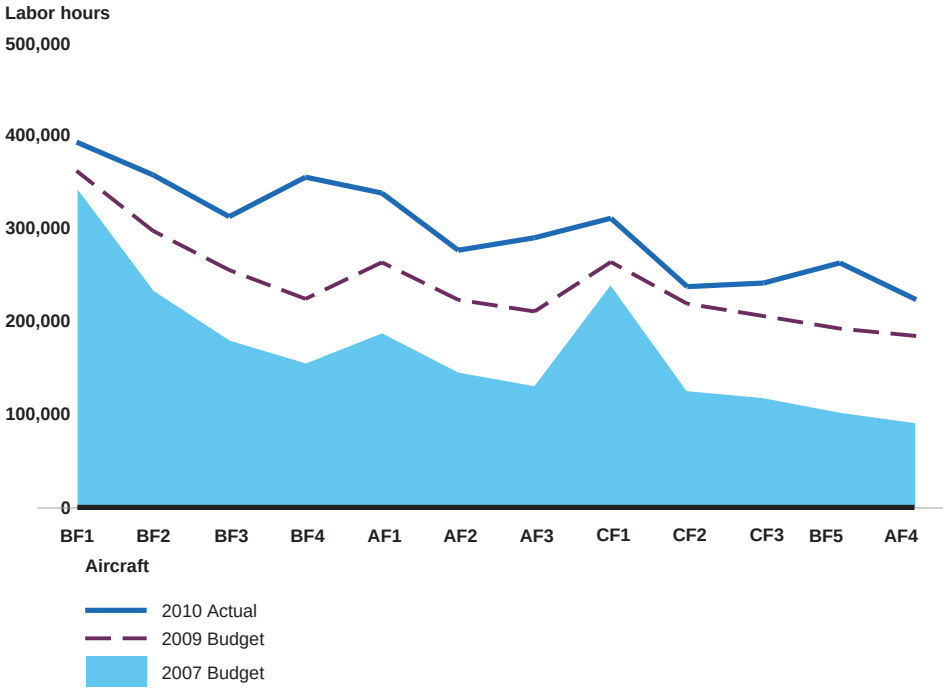
Manufacturing Processes are Not Yet Mature Enough for Efficient Production at Increased Rates

Manufacturing and delivering test jets took much more time and money than planned and the full contingent of test aircraft is still not available at military testing sites, years later than promised. Projected costs to complete the first three production lots for aircraft and engines also exceed the negotiated amounts at contract award and aircraft will be delivered late. The production impacts of restructuring actions that reduced quantities, lowered the ramp rate, and delayed the full-rate production decision have not been fully determined. We found that the aircraft and engine manufacturers are making good faith efforts to implement the IMRT and JAT recommendations and to make other improvements with performance measures indicating some success.

As in prior years, lingering management inefficiencies, including substantial out-of-station work[14] and part shortages, continued to increase the labor needed to manufacture test aircraft. Figure 3 depicts forecasted and actual labor hour requirements for building 12 production-representative test jets. Total labor hours required to produce the test aircraft increased over time. The 2010 actual labor hours exceeded the 2007 budgeted hours by more than 1.5 million hours, a 75 percent increase.

[14] Out of station work occurs when manufacturing steps are not completed at its designated work station and must be finished elsewhere later in production. This is highly inefficient, increasing labor hours, causing delays, and sometimes quality problems.

Figure 3: JSF Labor Hours for Manufacturing Test Aircraft



Source: GAO analysis of DOD data.

Manufacturing production aircraft is different from building test aircraft, and some gains in learning as more aircraft are built can be expected to, over time, reduce labor hour costs. However, the experience to date on the test aircraft and initial production aircraft suggests that future costs for building production aircraft may be higher than currently budgeted. The costs on the first three low-rate production contracts have increased from amounts negotiated at contract award and the completion dates for delivering aircraft have been extended over nine months on average. We are encouraged by DOD's award of a fixed price incentive fee contract for lot 4 production and the prospects for the cost study to inform lot 5 negotiations, but we have not examined contract specifications.

DOD began procuring production jets in 2007 and has now ordered 58 aircraft on the first four low-rate initial production lots. JSF contracts anticipated the delivery of 14 production jets through 2010, but none have been delivered. Delivery of the first two production jets (both CTOLs) has been delayed several times since the contract was signed and is now expected in April 2011. In addition, DOD expects to procure 32 more aircraft in fiscal year 2011. Building a large backlog of jets on order but

undelivered is not an efficient use of federal funds, tying up millions of dollars in obligations ahead of the ability of the manufacturing process to produce. We note that the Secretary used a similar line of reasoning to reduce STOVL production.

DOD does not yet know the full effect that restructuring actions will have on future annual procurement funding requirements. Cost analysts are still calculating the impacts from deferring procurement of 246 aircraft from the near-term to future years, lowering the ramp rate, and extending the full-rate production decision. Future funding requirements could be even higher than projected and the quantities considered affordable by the U.S. and allies could be reduced, further driving up unit costs.

The Secretary's decisions to reduce near-term procurement quantities and adopt a less-steep ramp up in future production were based on IMRT findings. The Secretary chartered the IMRT to comprehensively review JSF manufacturing capacity to assess the contractor's ability to achieve planned production ramp-up and to sustain the predicted maximum production rates. The IMRT's October 2009 report made 20 specific recommendations for corrective actions. As of September 2010, officials considered eight of the recommendations complete and three others on track. Implementation of the remaining nine recommendations was incomplete or behind schedule.

The most significant incomplete recommendation is improving global supply chain management. The JSF already has an extensive number of suppliers worldwide and those numbers will increase with future workload shared among numerous domestic and foreign firms. The IMRT cites the global supply chain as the critical manufacturing challenge facing the program, requiring significant improvement in delivery performance and responsiveness in order to achieve the program's eventual production rate goal of 20 aircraft per month. According to the prime contractor, the global supply chain remains on the critical path and progress has been made, but the global transportation plan and supply chain risk management plan are incomplete. Another IMRT recommendation that still needs to be addressed is the performance of a comprehensive schedule risk assessment, now expected to begin in spring 2011. We recommended this in our March 2009 report.[15] Schedule risk assessments

[15] GAO, *Joint Strike Fighter: Accelerating Procurement before Completing Development Increases the Government's Financial Risk*, GAO-09-303 (Washington D.C.: Mar. 12, 2009).

can provide keen insight into critical path activities, cost and schedule interrelationships, and emerging risks.

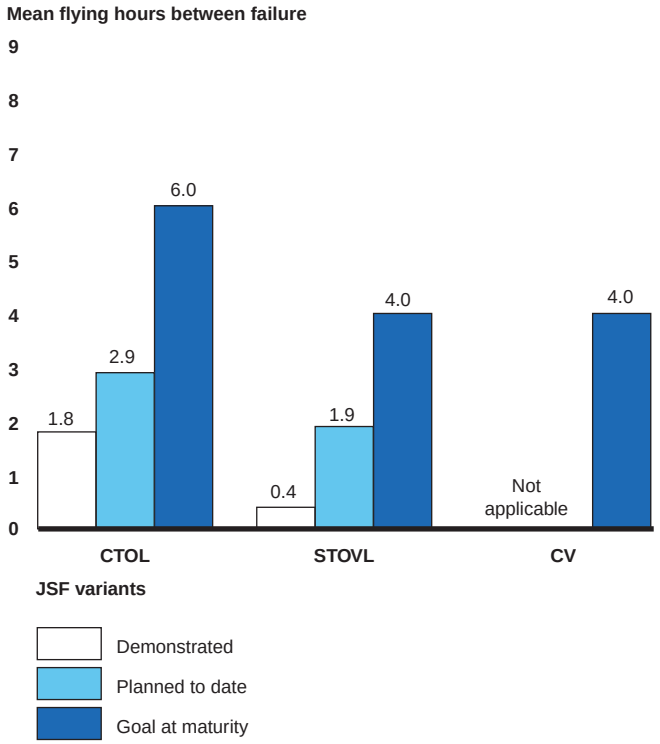
The primary F135 engine contractor faces similar challenges as it moves deeper into production. All development engines and initial production units have been delivered, but the costs to complete each of the first three engine production contracts increased and deliveries slipped since contract awards. Officials said these delays have not been especially troublesome to date because aircraft deliveries were even later. The contractor achieved the initial service release for the CTOL and CV engine, meaning the engine configuration is qualified and ready to go into production, but the STOVL's initial release was delayed until December 2010 due to qualification testing. The JAT reviewed F135 program performance, identified cost drivers, and made affordability projections. JAT officials said the contractor's cost reduction efforts were credible but largely dependent on receiving more government funding for affordability initiatives and alternative sourcing arrangements.

Our past work in best practices found that successful product development programs reach a point at which they know that manufacturing processes will efficiently produce a new product conforming to cost, quality, and schedule targets before they begin producing a system. Reaching this point means more than knowing that the product can be built; it means that critical manufacturing processes are under control, such that the quality, volume, and cost are proven acceptable. By these criteria, the JSF contractors' abilities to ramp-up to greater rates of production have not yet been demonstrated. The aircraft and engine manufacturers now have significantly more items in production flow compared to prior years, but throughput capacity to complete all work and deliver end items is constrained. We determined that the aircraft and engine contractors are making good faith efforts to implement the recommendations of the IMRT and JAT and to make other improvements to production capacity and flow. The aircraft manufacturer is reporting a decrease in out of station work, more efficient work stations, improved quality, increased parts availability, and reduced span times. Until improvements are fully implemented and demonstrated, the restructuring actions to reduce near term procurement quantities and establish a more achievable ramp rate was appropriate and will provide more time to fully mature manufacturing and supply processes and catch up with aircraft backlogs. Improving factory throughput and controlling costs—driving down unit costs and delivering on time— are essential for efficient manufacturing and timely delivery to the warfighter at the increased production rates planned for the future.

Aircraft Are Not Meeting Early Reliability Growth Plans

STOVL and CTOL aircraft are behind reliability growth plans aimed at demonstrating that the aircraft will meet warfighter support and availability requirements. The carrier variant is in early stages of flight testing and sufficient reliability data was not available. Reliability is a function of the specific elements of a product's design; a system is reliable when it can perform over a specified period of time without failure, degradation, or need of repair. Improvements over time occur through design changes or manufacturing process improvements. A key reliability metric is mean flying hours between failure, defined as the number of flying hours achieved divided by the number of failures incurred. Reliability growth plans called for the STOVL to have achieved at least 1.9 flying hours between failures and for the CTOL 2.9 flying hours between failures by this point in the test program. However, the STOVL aircraft is significantly behind plans, achieving about 0.4 hours between failures, or about 20 percent of what was expected by this time. The CTOL variant was also behind plans achieving 1.8 hours between failures, approximately 60 percent of what was expected. Figure 4 depicts progress of each variant in demonstrating mean flying hours between failures, as of September 2010.

Figure 4: JSF Mean Times between Failure Demonstrated to Date



Source: GAO analysis of DoD data.

Improving reliability rates are essential to control future operating costs and ensure aircraft are available as needed by the warfighter. Compared to the up-front costs of acquiring aircraft, the long-term costs for operating, maintaining, and sustaining JSF fleets over an aircraft's useful life represent the much larger portion of total ownership costs. We have reported in the past that it is important to demonstrate that system reliability is on track to meet goals before production begins as changes after production commences can be inefficient and costly.[16]

[16] GAO, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: July 15, 2002).

Testing Has Been Slow and Has Not Demonstrated That the Aircraft Will Work in Its Intended Environment

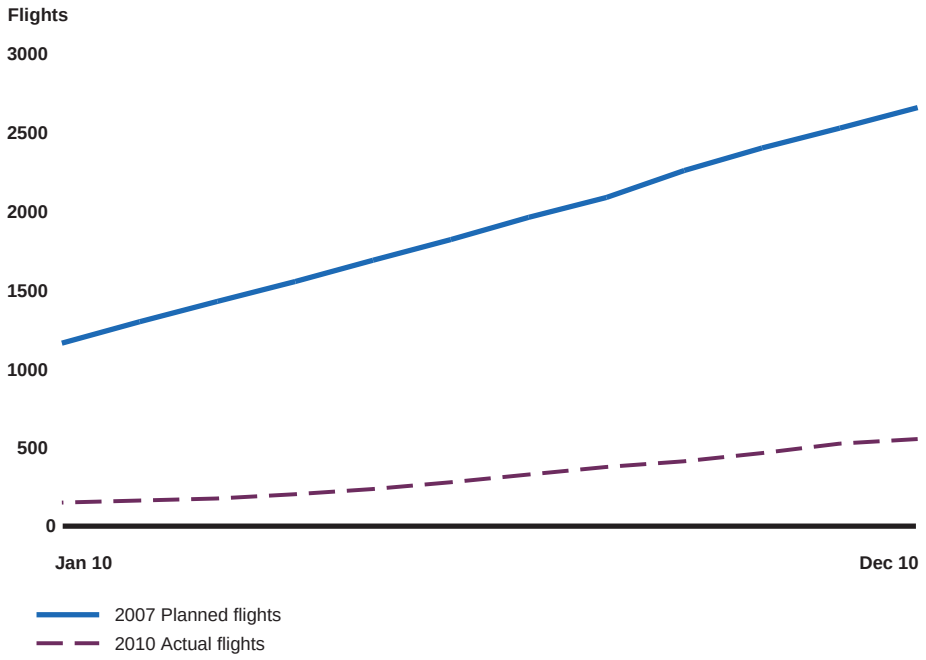
The JSF program is still very early in demonstrating aircraft design and testing to verify it works as intended. As of December 2010, about four percent of JSF capabilities have been completely verified by flight tests, lab results, or both. Initial tests of a fully integrated aircraft to demonstrate full mission systems capabilities and weapons delivery is now not expected until 2015, three years later than planned. The program demonstrated measurable progress in development flight testing during 2010, but still lags earlier expectations, and the STOVL problems have constrained overall progress. Only 3 of 32 ground test labs and simulation models critical to complement and, in some cases, substitute for flight tests, are accredited to verify and ensure the fidelity of results. Software development—essential for achieving about 80 percent of the JSF functionality—is significantly behind schedule as it enters its most challenging phase. Software delivery to the test program that is essential to demonstrating full system capability is now expected in late 2014, a 3-year delay.

Our work in best practices suggests that a key indicator of a product's maturity and readiness for production is when a fully integrated, capable system has been demonstrated to work in its intended environment. A fully integrated, capable system would include the integration of all the hardware, including mission avionics systems, and software needed to provide the system its full mission capabilities. Many past DOD weapons programs have failed to demonstrate that the system works as intended before entering production, discovering costly design problems late in development when the more complex software and advanced capabilities are integrated and tested.

Development Flight Testing Is Progressing but Behind Plans

Development flight testing was much more active in 2010 than prior years and had some notable successes, but overall still lagged behind expectations. The continuing effects from late delivery of test aircraft and an inability to achieve the planned flying rates per aircraft substantially reduced the amount and pace of testing planned previously. Consequently, even though the flight test program accelerated its pace last year, the total number of flights accomplished during the first four years of the test program significantly lagged expectations when the program's 2007 baseline was established. Figure 5 shows that the cumulative number of flights accomplished by the end of 2010 was only about one-fifth the number forecast by this time in the 2007 test plan.

Figure 5: Actual JSF Flight Tests Completed through 2010 Compared to the 2007 Plan



Source: GAO analysis of DOD data.

Program officials reported that 13 test aircraft are now out of production.[17] Ten test aircraft have been ferried to test sites and others are in varying stages of final check-out. The program has accomplished first flights for all three variants. Officials had hoped aircraft could achieve a rate of 12 flights per month. However, the average flight rate for 2010 ranged from over 2 to almost 8 per month.

By the end of 2010, about 10 percent of more than fifty thousand planned test points have been completed. According to program officials, completion of a test point means that the test point has been flown and that flight engineers ruled that the point has met the need. Further analysis may be necessary for the test point to be closed out. The majority of the points were earned on airworthiness tests (basic airframe handling

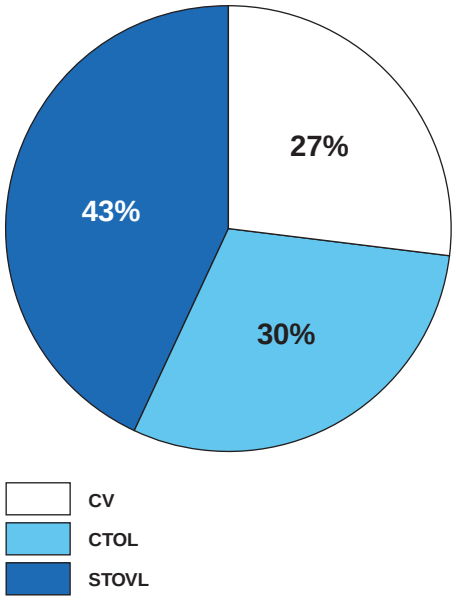
[17] This includes 12 test aircraft and the non-production representative model that achieved much of the test flights prior to 2010. A 14th test aircraft, the test carrier variant added in the recent restructuring is expected to be delivered in 2012.

characteristics) and in ferrying the planes to test sites. According to a senior level DOD test official, airworthiness and ferry test points should be relatively easy to accomplish. Remaining test points include more complex and stringent requirements, such as mission systems, ship suitability, and weapons integration that have yet to be demonstrated.

As discussed earlier, STOVL flight performance lagged plans during 2010, while the CTOL variant exceeded and the CV variant generally met plans. Officials reported that design and manufacturing defects and excessive component failures caused prolonged maintenance periods that drove the low fly rates. For instance, in the July to August 2010 period, STOVL test aircraft were down for unscheduled maintenance more than half the time. Further test delays will likely cause the program to miss critical future milestones. STOVL initial at-sea testing will not start until October 2011 because of delays in clearing the vertical-landing envelope. STOVL-related delays are also causing Marine Corps leadership to reassess its requirements and will likely extend the date for achieving initial operational capabilities, currently set in December 2012.

Concerned that STOVL testing problems were negatively affecting the other variants, the Department moved to decouple the STOVL testing and placed the variant on a two-year probation period to work out problems and get back on track. The Secretary's actions will require a new test plan since current flight test plans rely substantially on the STOVL to fly and demonstrate test points in common with other variants. The current plan has the STOVL responsible for completing about 43 percent of the total test points.

Figure 6: Test Point Distribution by Variant (2010 Test Plan)



Source: GAO analysis of DoD data.

JSF restructuring actions are positive and support a more robust and achievable test plan. Officials added more resources for development testing, extended the flight test schedule, and reduced the overlap with initial operational testing. More recently, officials revised the test plan increasing the total number of test flights from 5,856 to 7,727, about one-third more. To increase capacity, the restructure added one carrier variant test aircraft, an additional software integration line, and allowed the program to utilize up to three production aircraft for development testing. Compared to the previous test plan, officials assumed more ground time for aircraft maintenance and planned modifications, as well as a more measured ramp-up in the rate of flights per test aircraft. The restructuring largely reverses the program's earlier Mid-Course Risk Reduction plan that reduced test resources. Our March 2008 report[18] criticized DOD's mid-course plan, particularly the cuts made in flight test assets and the number of flight tests, as well as the program's failure to address root causes of cost growth, the very reasons why officials felt the mid-course plan was

[18] GAO, *Joint Strike Fighter: Recent Decisions by DOD Add to Program Risks*, GAO-08-388 (Washington, D.C.: Mar. 11, 2008).

needed. Since that report was issued, JSF cost and schedule continued to deteriorate and officials recognized a need to increase test assets and add more flight testing.

Most Ground Test Labs and Simulation Models Are Not Accredited or Verified

The JSF test program relies much more heavily than previous weapon systems on its modeling and simulation labs to test and verify aircraft design and subsystem performance. However, only 3 of 32 labs and models have been fully accredited to date; the program had planned to accredit 11 labs and models by now. Accreditation is essential to ensure the fidelity of results validate that the models accurately reflect aircraft performance. Accreditation is a lengthy and involved technical evaluation using flight test data to verify lab results. Much work remains before the program can fully utilize the models and simulation capabilities needed to verify results and to demonstrate that ground testing can substitute for flight testing. However, the ability to substitute is unproven and progress in reducing program risk is difficult to assess. Contracting officials told us that early results are providing good correlation between ground and flight tests.

The Director of Operational Test and Evaluation reported that 50 percent of the models will be accredited during the final year of flight testing, a highly risky approach. Delays in accreditation add risks to not completing future software blocks on time and for discovering defects late. More flight testing may be needed to cover lab shortcomings, but is generally more expensive, and could lead to more delays in completing development and operational testing. It could also require more production aircraft for a longer period to supplement test assets, resulting in fewer systems at training sites and operational bases.

Contractor utilization of labs has increased markedly and the number and integration of labs is impressive, but capacity may be constrained. Because of development concurrency, there is overlap in scheduling the new blocks and resources must be shared between blocks when rework on an earlier block is required. If integration and test is delayed due to capacity or conflict with an earlier block, lab officials said that expected capabilities may not be delivered on time to meet flight test and training dates. Mitigating strategies include adding people, lab capacity, software test lines, and shifting capabilities to later blocks. The 2010 restructuring added $250 million to increase integration lab capacity. According to program officials, the greater number of labs allows engineers to work simultaneously on different development blocks, reducing bottlenecks that may occur in testing. Program and contractor officials believe that the

up-front investment of $5 billion in simulation labs will pay off in early risk reduction, reduce flights, control costs, and are essential to meet key milestones in JSF's aggressive test plan.

Software Development Is behind Schedule with Most Complex Work Still Ahead

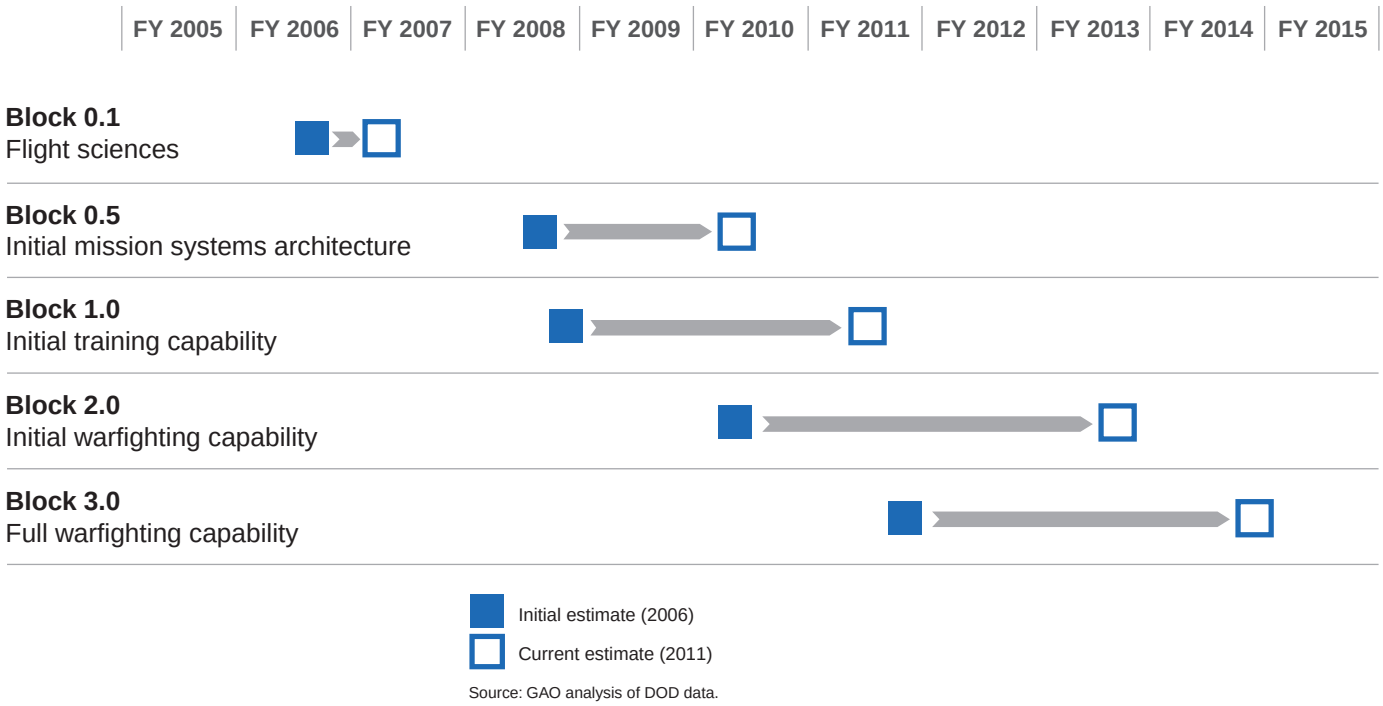
Software providing essential JSF capability is not mature and releases to the test program are behind schedule. Officials underestimated the time and effort needed to develop and integrate the software, substantially contributing to the program's overall cost and schedule problems and testing delays, while requiring the retention of engineers for longer periods. Significant learning and development work remains before the program can demonstrate the mature software capabilities needed to meet warfighter requirements. Good progress has been made in the writing of software code—about three-fourths of the software has been written and integrated, but testing is behind schedule and the most complex work is still ahead. Program restructuring added a second software integration line which should improve throughput.

The JSF software development effort is one of the largest and most complex in DOD history, providing 80 percent of JSF's functionality essential to capabilities such as sensor fusion, weapons and fire control, maintenance diagnostics, and propulsion. JSF has about 8 times more on-board software lines of code than the F/A-18E/F Super Hornet and 4 times more than the F-22A Raptor. Also, the amount of code needed will likely increase as integration and testing efforts intensify. In 2009, officials reported that about 40 percent of the software had completed integration and testing. They did not provide us a progress report through 2010. Integration and test is a lengthy effort and is typically the most challenging phase of software development requiring specialized skills and integration test lines. The program has experienced a growth of 40 percent in total software lines of code since preliminary design review and 13 percent growth since the critical design review. Other recent defense acquisitions have experienced 30 to 100 percent growth in software over time.

Software capabilities are developed, tested, and delivered in 5 blocks, or increments. Several blocks have grown in size and taken longer to complete than planned. Software defects, low productivity, and concurrent development of successive blocks created inefficiencies, taking longer to fix defects and delaying the demonstration of critical capabilities. In addition, program and prime contractor officials acknowledge they do not include integration as a key tracking metric and have been unable to agree on how to track it. This has made it hard for the program to analyze integration trends and take action to remedy the

situation. Instead the program office and prime contractor have made several adjustments to the software development schedule, each time lengthening the time needed to complete work, as shown in figure 7.

Figure 7: Slips in Delivering Software to Flight Test



Source: GAO analysis of DOD data.

Delays in developing, integrating, and releasing software to the test program have cascading effects hampering flight tests, training, and lab accreditation. While progress is being made, a substantial amount of software work remains before the program can demonstrate full warfighting capability. The program released block 0.5 for flight test nearly 2 years later than planned in the 2006 plan, largely due to integration problems. Each of the remaining three blocks—providing full mission systems and warfighting capabilities—are now projected to slip between 2 to 3 years compared to the 2006 plan. Defects and workload bottlenecks delayed the release of full block 1 capabilities; the initial limited release of block 1 software was flown for the first time in November 2010. Software defects increased throughout 2010, but fixing

defects did not keep pace. Some capabilities were moved to future blocks in attempts to meet schedule and mitigate risks. For example, full data fusion mission systems[19] were deferred from block 2 to 3. Further trades and deferrals may be needed. Rather than working all blocks concurrently, focusing efforts on a more measured evolutionary approach could result in more timely release of incremental capabilities to the testing, training, and warfighter communities. Development and integration of the most advanced capabilities could be deferred to future increments and delivered to the warfighter at a later date.

The recent technical baseline review identified software as a significant challenge, slowing system development and requiring more time and money. Although officials are confident that such risks can be addressed, the scale and complexity of what is involved remains a technically challenging and lengthy effort. Uncertainties pertaining to critical technologies, including the helmet-mounted display and advanced data links, add to challenges. Deficiencies in the helmet mounted display, especially latency in transmitting sensor data, are causing officials to develop a second helmet while trying to fix the first model. Resolution could result in a major redesign or changes in the JSF's concept of operations by placing limitations on the operational environment, according to program officials.

Conclusions

The JSF program is at a critical juncture—9 years in development and 4 years in limited production, but still early in testing and verifying aircraft performance. If effectively implemented and sustained, the Department's restructuring should place the JSF program on firmer footing and lead to more achievable and predictable outcomes. However, restructuring comes with a price tag—higher up-front development costs, fewer aircraft received in the near term, training delays, and prolonged times for testing and delivering the capabilities required by the warfighter. Reducing near-term procurement quantities lessens concurrency, but the overlap among development, testing, and production activities is still substantial and risky. Development and testing activities will now overlap 11 years of production based on the latest extension in key milestones. Flight testing

[19] Mission systems are critical to realizing increased warfighter capability in combat effectiveness through next generation sensors with fused information from on-board and off-board systems (i.e. electronic warfare, communication navigation identification, electro-optical target system, electro-optical distributed aperture system, radar, and data links).

and production activity are increasing and contractors are improving supply and manufacturing processes, but deliveries are still lagging. The challenge in front of the aircraft and engine contractors is improving the global supply chain and accelerating manufacturing throughput to produce quality products in economic quantities and on time. Slowed deliveries have built a growing backlog of jets on order but not delivered; this is not a good use of federal funds, tying up millions of obligated dollars much ahead of the ability of the manufacturing process to produce. The Secretary of Defense used similar reasoning in significantly reducing STOVL procurement until technical issues are resolved and the manufacturing process able to deliver efficiently and on time.

The JSF acquisition demands an unprecedented share of the Department's future investment funding. The program's size and priority is such that its cost overruns and extended schedules are either borne by funding cuts to other programs or else drive increases in the top line of defense spending, the latter not an attractive option in a period of more austere budgets. Up until now, JSF problems have been addressed either with more time and money or by deferring aircraft procurement to be borne by future years' budgets. It is past time to place some boundaries on the program such that future difficulties can be managed within a finite budget by facilitating trades within the JSF program and thereby minimizing impacts on other defense programs and priorities. Also, Department actions to limit STOVL procurement, decouple it from development testing, and concentrate efforts to resolve deficiencies are appropriate. Given its criticality to the Marine Corp's future tactical aviation plans, additional steps may be needed to set the framework and criteria for the "probation period" and to sustain management focus on STOVL in order to better ascertain its progress and inform future decisions. Focused individual attention on STOVL apart from the other two variants could allow each variant to proceed through development and testing at its own pace. Furthermore, development testing is hampered both by the late delivery of software increments and the lagging schedule for accrediting ground labs and simulation models. A comprehensive independent review of the software development process and lab accreditation issues could enhance management insight and identify opportunities for improvement in these critical areas. We note that the previous independent teams established by the Department significantly improved the manufacturing, engine, and cost estimating processes.

We agree with defense leadership that a renewed and sustained focus on affordability by contractors and the Government is critical to moving this important program forward and enabling our military services and our

allies to acquire and sustain JSF forces in needed quantities. Maintaining senior leadership's increased focus on program results, holding government and contractors accountable for improving performance, and bringing a more assertive, aggressive management approach for the JSF to "live within its means" could help effectively manage growth in the program and limit the consequences on other programs in the portfolio. Controlling JSF future cost growth would minimize funding disruption and help stabilize the defense acquisition portfolio by providing more certainty to financial projections and by facilitating the allocation of remaining budget authority to other defense modernization programs.

Recommendations for Executive Action

Given the other priorities that DOD must address in a finite budget, a renewed and sustained focus on affordability by contractors and the Government is critical for successfully moving the JSF program forward. DOD must plan ahead for a way to address and manage JSF challenges and risks in the future. To facilitate making tradeoff decisions with respect to the JSF program that limit impacts to other DOD programs and priorities and to improve key management processes, we recommend that the Secretary of Defense take the following actions to reinforce and strengthen program cost controls and oversight:

1. The JSF program should maintain total annual funding levels for development and procurement at the current budgeted amounts in the fiscal year 2012-2016 future years defense plan (modified, if warranted, by the new acquisition program baseline expected this year). It should facilitate trades among cost, schedule, requirements, and quantities to control cost growth. Having gone through the Technical Baseline Review (TBR) and budget approval process, it is reasonable to expect the program to execute against the future years defense plan going forward. Only in instances of major and unforeseen circumstances, should the Department consider spending more money on the program. Even then, we would expect changes to be few and adopted only after close scrutiny by defense leadership. Approved changes should be well supported, adequately documented, and reported to the congressional defense committees.

2. Establish criteria for the STOVL probation period and take additional steps to sustain individual attention on STOVL-specific issues, including independent F-35B/STOVL Progress Reviews with Senior Leadership to ensure cost and schedule milestones are achieved to deliver required warfighter capabilities. The intent is to allow each JSF

variant to proceed and demonstrate success at its own pace and could result in separate full-rate production decisions.

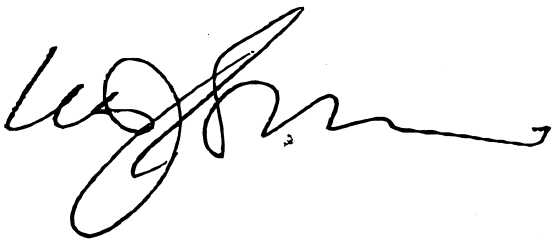
3. The Department should conduct an independent review of the contractor's software development, integration, and test processes—similar to its review of manufacturing operations—and look for opportunities to streamline software efforts. This review should include an evaluation of the ground lab and simulation model accreditation process to ensure it is properly structured and robustly resourced to support software test and verification requirements.

Agency Comments and Our Evaluation

DOD provided us with written comments on a draft of this report. The comments are reprinted in appendix III. We worked collaboratively with defense officials to hone our draft recommendations, making them more targeted. DOD concurred with the recommendations as amended. We also incorporated technical comments as appropriate.

We are sending copies of this report to the Secretary of Defense; the Secretaries of the Air Force and Navy; the Commandant of the Marine Corps; and the Director of the Office of Management and Budget. The report also is available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions concerning this report, please contact me at (202) 512-4841 or sullivanm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Staff members making key contributions to this report are listed in appendix IV.



Michael J. Sullivan
Director
Acquisition and Sourcing Management

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Appendix I: Scope and Methodology

To determine the Joint Strike Fighter (JSF) program's progress in meeting cost, schedule, and performance goals, we received briefings by program and contractor officials and reviewed financial management reports, budget documents, annual Selected Acquisition Reports, monthly status reports, performance indicators, and other data. We identified changes in cost and schedule, and obtained officials' reasons for these changes. We interviewed officials from the JSF program, contractors, and the Department of Defense (DOD) to obtain their views on progress, ongoing concerns and actions taken to address them, and future plans to complete JSF development and accelerate procurement. At the time of our review, the most recent Selected Acquisition Report available was dated December 31, 2009 and released in April 2010. At the time of our review, DOD was preparing a new acquisition program baseline for the program which would reflect updated cost and schedule projections.

In assessing program cost estimates, we compared the official program cost estimate in the 2009 Selected Acquisition Report and subsequent cost estimate developed after the Nunn-McCurdy breach to estimates developed by the JSF program and Defense Contract Management Agency (DCMA) reports. We interviewed program office officials and members of the DOD Cost Analysis and Program Evaluation Office (CAPE), and DCMA to understand their methodology, data, and approach in developing cost estimates. To assess the validity and reliability of contractors' cost estimates, we reviewed audit reports prepared by DCMA and cost performance reports prepared by the contractor.

To access the program's plans and risk in manufacturing and its capacity to accelerate production, we analyzed manufacturing cost and work performance data to assess progress against plans. We compared budgeted program labor hours to actual labor hours and identified growth trends. We reviewed data and briefings provided by the program, DCMA, and CAPE to assess supplier performance and ability to support accelerated production in the near term. We also determined reasons for manufacturing delays, discussed program and contractor plans to improve, and projected the impact on development and operational tests. We interviewed Naval Air Systems Command and contractor officials to discuss Earned Value Management System issues but we did not conduct any analysis since the data was deemed unreliable by DCMA.

To assess plans, progress, and risks in test activities, we examined program documents and interviewed DOD, program office, and contractor officials about current test plans and progress. To assess progress towards test plans, we compared the number of flight tests conducted as

of December 2010 to the original test plan established in 2007. We also reviewed documents and interviewed prime contractors about flight testing, the integrated airborne test bed, and ground testing. To assess the ground labs and test bed, we interviewed officials and toured the testing labs at the Lockheed Martin facilities in Fort Worth, Texas. We also reviewed the independent assessments conducted by the JET and NAVAIR to obtain their perspective on the program's progress in test activities.

In performing our work, we obtained information and interviewed officials from the JSF Joint Program office, Arlington, Virginia; Naval Air Systems Command, Patuxent River, Maryland; Defense Contract Management Agency, Fort Worth, Texas; Lockheed Martin Aeronautics, Fort Worth, Texas; Defense Contract Management Agency, Middletown, Connecticut; and Pratt & Whitney, Middletown, Connecticut. We also met with and obtained data from the following offices of the Secretary of Defense in Washington, D.C.: Director, Operational Test and Evaluation; Cost Analysis and Program Evaluation Office; and Systems and Software Engineering. We assessed the reliability of DOD and JSF contractor data by (1) performing electronic testing of required data elements, (2) reviewing existing information about the data, and (3) interviewing agency officials knowledgeable about the data. We determined that the data were sufficiently reliable for the purposes of this report. We conducted this performance audit from May 2010 to February 2011 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Prior GAO Reports on JSF and DOD Responses and Subsequent Actions

GAO report	Est. dev. costs dev. length APUC[a]	Key program event	Primary GAO message	DOD response and actions
2001 GAO-02-39	$34.4 Billion 10 years $69 Million	Start of system development and demonstration approved.	Critical technologies needed for key aircraft performance elements are not mature. Program should delay start of system development until critical technologies are mature to acceptable levels.	DOD did not delay start of system development and demonstration stating technologies were at acceptable maturity levels and will manage risks in development.
2005 GAO-05-271	$44.8 Billion 12 years $82 Million	The program undergoes re-plan to address higher than expected design weight, which added $7 billion and 18 months to development schedule.	We recommend that the program reduce risks and establish executable business case that is knowledge-based with an evolutionary acquisition strategy.	DOD partially concurred but does not adjust strategy, believing that their approach is balanced between cost, schedule and technical risk.
2006 GAO-06-356	$45.7 Billion 12 years $86 Million	Program sets in motion plan to enter production in 2007 shortly after first flight of the non-production representative aircraft.	The program plans to enter production with less than 1 percent of testing complete. We recommend program delay investing in production until flight testing shows that JSF performs as expected.	DOD partially concurred but did not delay start of production because they believe the risk level was appropriate.
2007 GAO-07-360	$44.5 Billion 12 years $104 Million	Congress reduced funding for first two low-rate production buys thereby slowing the ramp up of production.	Progress is being made but concerns remain about undue overlap in testing and production. We recommend limits to annual production quantities to 24 a year until flying quantities are demonstrated.	DOD non-concurred and felt that the program had an acceptable level of concurrency and an appropriate acquisition strategy.
2008 GAO-08-388	$44.2 Billion 12 years $104 Million	DOD implemented a Mid-Course Risk Reduction Plan to replenish management reserves from about $400 million to about $1 billion by reducing test resources.	We believe new plan actually increases risks and that DOD should revise the plan to address concerns about testing, use of management reserves, and manufacturing. We determine that the cost estimate is not reliable and that a new cost estimate and schedule risk assessment is needed.	DOD did not revise risk plan nor restore testing resources, stating that they will monitor the new plan and adjust it if necessary. Consistent with a report recommendation, a new cost estimate was eventually prepared, but DOD refused to do a risk and uncertainty analysis that we felt was important to provide a range estimate of potential outcomes.

GAO report	Est. dev. costs dev. length APUC[a]	Key program event	Primary GAO message	DOD response and actions
2009 GAO-09-303	$44.4 Billion 13 years $104 Million	The program increased the cost estimate and adds a year to development but accelerated the production ramp up. Independent DOD cost estimate (JET I) projects even higher costs and further delays.	Because of development problems, we stated that moving forward with an accelerated procurement plan and use of cost reimbursement contracts is very risky. We recommended the program report on the risks and mitigation strategy for this approach.	DOD agreed to report its contracting strategy and plans to Congress. In response to our report recommendation, DOD subsequently agreed to do a schedule risk analysis, but still had not done so as of February 2011. In February 2010, the Department announced a major restructuring of the JSF program, including reduced procurement and a planned move to fixed-price contracts.
2010 GAO-10-382	$49.3 Billion 15 years $112 Million	The program was restructured to reflect findings of recent independent cost team (JET II) and independent manufacturing review team. As a result, development funds increased, test aircraft were added, the schedule was extended, and the early production rate decreased.	Because of additional costs and schedule delays, the program's ability to meet warfighter requirements on time is at risk. We recommend the program complete a full comprehensive cost estimate and assess warfighter and IOC requirements. We suggest that Congress require DOD to prepare a "system maturity matrix"–a tool for tying annual procurement requests to demonstrated progress.	DOD continued restructuring actions and announced plans to increase test resources and lower the production rate. Independent review teams evaluated aircraft and engine manufacturing processes. As we projected in this report, cost increases later resulted in a Nunn-McCurdy breach. Military services are currently reviewing capability requirements as we recommended. The Department and Congress are working on a "system maturity matrix" tool, which we suggested to Congress for consideration, to improve oversight and inform budget deliberations.

Source: DOD data and GAO analysis.

[a]Average procurement unit cost.

Appendix III: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

APR - 5 2011

Mr. Michael Sullivan
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Sullivan:

This is the Department of Defense (DoD) response to the GAO Draft Report, GAO-11-325, "JOINT STRIKE FIGHTER: Restructuring Places Program on Firmer Footing, but Progress is Still Lagging Overall," dated February 28, 2011 (GAO Code 120918). Detailed comments on the report recommendations are enclosed.

The DoD concurs with all three recommendations. The rationale and actions taken by DoD are included in the enclosure.

We appreciate the opportunity to comment on the draft report. My point of contact is Colonel Jason Denney, U.S. Air Force, Jason.Denney@osd.mil, 703-697-3619.

Sincerely,

David G. Ahern
Deputy Assistant Secretary of Defense
Portfolio Systems Acquisition

Enclosure:
As stated

GAO DRAFT REPORT DATED FEBRUARY 28, 2011
GAO-11-325 (GAO CODE 120918)

"JOINT STRIKE FIGHTER: RESTRUCTURING PLACES PROGRAM ON FIRMER FOOTING, BUT PROGRESS IS STILL LAGGING OVERALL"

The Department remains committed to the F-35 Joint Strike Fighter (JSF) program. The Fiscal Year (FY) 2012 President's Budget (PB) demonstrates this commitment to the F-35 as the backbone of the future tactical aircraft inventory for the Air Force, Navy, Marine Corps, as well as our International Partners.

The Department and the F-35 prime contractor are committed to delivering F-35 aircraft that meet the Services' requirements as specified in the Joint Operational Requirements Document (JORD) in addition to controlling and reducing costs wherever and whenever possible, with the goal of providing the Services' an affordable tactical aviation capability.

Following a Critical Nunn-McCurdy Breach, a rescission of the original October 26, 2001 Milestone B (MS B) decision, and program recertification in June 2010, the Department set out to establish a firmer foundation for the program. The F-35 Program Executive Officer (PEO) executed an extensive bottoms-up Technical Baseline Review (TBR) involving over 120 tactical aircraft experts from both the Services and the Department to evaluate every aspect of the System Development and Demonstration (SDD) phase of the program. In addition to the TBR, the PEO will execute a schedule risk assessment this summer and finalize the program's Integrated Master Schedule this fall following an Integrated Baseline Review.

The Department will hold a Defense Acquisition Board (DAB) in May 2011 to review the restructured SDD phase of the program and update the Acquisition Program Baseline.

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommends that the Secretary of Defense to maintain total annual funding levels for development and procurement at the current budgeted amounts in the fiscal year 2012-2016 future years defense plan (modified, if warranted, by the new acquisition program baseline expected this year). It should facilitate trades among cost, schedule, requirements, and quantities to control cost growth. Having gone through the Technical Baseline Review (TBR) review and budget approval process, it is reasonable to expect the program to execute against the FYDP budget going forward. Only in instances of major and unforeseen circumstances, should the Department consider spending more money on the program. Even then, we would expect changes to be few and adopted only after close scrutiny by defense leadership. Approved changes should be well supported, adequately documented, and reported to the congressional defense committees.

DOD RESPONSE: Concur The Department is confident that the F-35 budget request for FY 2012-2016 provides the appropriate level of funding for the restructured development program and revised procurement profile. The Department undertakes a very thorough and in-depth process to develop the annual Defense Budget. The goal is to prepare a budget that does not change significantly from year to year and provides acquisition programs and the Services a stable funding and procurement profile to plan against. In this instance, the JSF Program Office conducted an extensive TBR involving over 120 tactical aircraft experts from both the Services and the Department to evaluate every aspect of the SDD phase of the program. The resultant schedule and cost adjustments made following the TBR, and reflected in the FY2012 Budget, afforded the Department a more realistic basis to manage the program. The approval of a new MS B and APB will reflect these budget decisions. Any significant proposed changes to the F-35 budget in future years will be thoroughly reviewed as part of the annual Defense Acquisition Executive Program Reviews and approved as part of the budget review and submission process.

RECOMMENDATION 2: The GAO recommends that the Secretary of Defense to establish criteria for the short take off and landing variant (STOVL) probation period and take additional steps to sustain individual attention to STOVL-specific issues, including independent F-35B/STOVL Progress Reviews with Senior Leadership to ensure cost and schedule milestones are achieved to deliver required warfighter capabilities. The intent is to allow each JSF variant to proceed and demonstrate success at its own pace and could result in separate full-rate production decisions.

DOD RESPONSE: Concur. The Service Acquisition Executives (SAEs) for the Department of the Navy and Air Force have established a battle rhythm of monthly SAE reviews with the F-35 PEO to assess the overall F-35 program, with additional emphasis on F-35B Short Take Off and Vertical Landing (STOVL) variant. These monthly SAE Reviews examine the F-35 airframe and propulsion SDD, Production, and Sustainment programs with particular emphasis on Cost/Affordability, Risk, and Schedule. In addition, the Commandant of the Marine Corps has established a monthly F-35 review focused solely on the F-35B variant. This review is also led by Department of the Navy (DoN) Senior Acquisition Executives. The topics and metrics that are assessed include, but are not limited to, the following:

- Cost/Affordability/Earned Value Management (EVM): A review of Acquisition Procurement Unit Cost, Program Acquisition Unit Cost, Operations and Support costs, and EVM cost/schedule indices.
- Risk: Monthly assessment of 'Program Risk' with explanations about each risk item, their interactions, and risk burn-down plans. Assessments include a review of the assumptions and environment used to determine the risk evaluations.
- F-35B weight/weight growth: Weight assessments track each pound added to the airframe with an understanding of the underlying reasons for the growth. If there

are trades that need to be made to mitigate weight growth, DoN senior leadership/warfighters are to be consulted.

- Key Performance Parameters (KPPs): Review of F-35B KPPs with a tracking/ trending methodology and monthly discussions of CONOPS considerations that might help facilitate achievement of F-35 KPPs and program goals.
- Airframe Technical Performance Measurements: Assessments of reliability, maintainability, combat radius, and gross weight (with metrics that indicate the desired value(s), the current status, margin, and trends).
- F-35B Flight Test: Review of F-35B flight test data, to include, planned/scheduled test points to be flown versus achieved test points flown; scheduled test flights flown versus actual test flights flown (delineated by STOVL variant); and Clean-Wing Flight Envelope coverage (to assess the progress on the envelope cleared for flight as a result of Developmental Test and alignment with software delivery).

As these monthly reviews mature, the DoN will refine key F-35B metrics to ensure this essential capability is delivered to the Marine Corps Warfighters and to enable the Department to make a decision on the F-35B STOVL variant probation status.

RECOMMENDATION 3: The GAO recommends that the Secretary of Defense to conduct an independent review of the contractor's software development, integration, and test processes—similar to its review of manufacturing operations—and look for opportunities to streamline software efforts. This review should include an evaluation of the ground lab and simulation model accreditation process to ensure it is properly structured and robustly resourced to support software test and verification requirements.

DOD RESPONSE: Concur The Department believes that the newly structured program, which delivers a JORD-compliant Block 3 capable aircraft at the end of the SDD phase, provides the Warfighter capability needed. The Department acknowledges that delivery of that capability has taken longer and will cost more than planned, in part due to poor performance to date in software development. The recent TBR ensured that full Block 3 capability was adequately costed and scheduled with the appropriate amount of acceptable risk, to include the risk in the software development portion of the program. In order to maximize our developmental investment, it would be prudent to independently verify the contractor has appropriate processes to develop and field software and is diligently following them accordingly.

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

Michael Sullivan (202) 512 4841 or sullivanm@gao.gov

Acknowledgments

In addition to the contact name above, the following staff members made key contributions to this report: Bruce Fairbairn, Assistant Director; Charlie Shivers; Julie Hadley; Matt Lea; Jason Lee; Sean Merrill; LeAnna Parkey; Karen Richey; Dr. W. Kendal Roberts; and Robert Swierczek.

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