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Proposed Termination of Joint Strike Fighter (JSF) F136 Alternate Engine

April 13, 2006

Christopher Bolkcom
Specialist in National Defense
Foreign Affairs, Defense, and Trade

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 13 APR 2006		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Proposed Termination of Joint Strike Fighter (JSF) F136 Alternate Engine				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Congressional Research Service The Library of Congress 101 Independence Avenue, SE Washington, DC 20540-7500				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 19	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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Summary

The Department of Defense's (DOD) FY2007 budget proposes to cancel the F136 alternate engine for the F-35 Joint Strike Fighter (JSF), a program that was initiated by Congress in the FY1996 Defense Authorization Act, and which has received consistent congressional support since its inception.

In FY1996, defense authorization conferees (H.Rept. 104-450, Sec. 213) expressed their concern over a lack of engine competition in the JSF program and directed DOD to ensure that the program "provides for adequate engine competition." (p.706)¹ In FY1998, authorization conferees (H. Rept. 105-340, Sec. 213) directed DOD to certify that "the Joint Strike Fighter Program contains sufficient funding to carry out an alternate engine development program that includes flight qualification of an alternate engine in a joint strike fighter airframe." (p.33)

Some have criticized DOD as being "penny wise and pound foolish" in its proposal to terminate the F136. Critics argue that this decision appears driven more by immediate budget pressures on the department rather than long term pros and cons of the F136 program. Others applaud this decision, and say that single source engine production contracts are the norm, not the exception. Long-term engine affordability, they claim, is best achieved by procuring engines through multiyear contracts from a single source.

Cancelling the F-136 poses questions on operational risk and potential cost and savings. Additional issues include the potential impact this termination could have on the U.S. defense industrial base, and on U.S. relations with key allied countries. Finally, eliminating competitive market forces for DOD business worth billions of dollars may concern those who wish to reform DOD's acquisition system and conform to higher standards of accountability.

This report will be updated as events warrant.

¹ At that time, the JSF program was The Joint Advanced Strike Technology Program (called JAST).

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Proposed Termination of F136 Alternate Engine

Introduction

The Department of Defense's (DOD) FY2007 budget proposes to cancel the F136 alternate engine for the F-35 Joint Strike Fighter (JSF), a program initiated by Congress in the FY1996 Defense Authorization Act, and which has received consistent congressional support since its inception.² The reason cited for this proposed cancellation was that it would save \$1.8 billion over the Future Years Defense Plan (FYDP), yet entail little operational risk.

Some DOD leaders, however, have expressed mixed feelings about this decision. On February 16, 2006 Secretary of Defense Rumsfeld testified that the merits of terminating the F136 were "clearly debatable."³ On March 1, 2006, Air Force Secretary Michael Wynne testified that he was worried about the "downstream effects" of this decision.⁴ These statements may suggest that there is a lack of consensus within DOD regarding this course of action, or it may simply presage the congressional scrutiny to follow.

Background

In FY1996, defense authorization conferees (H.Rept. 104-450, Sec. 213) expressed their concern over a lack of engine competition in the JSF program and directed DOD to ensure that the program "provides for adequate engine competition." (p.706)⁵ In FY1998, authorization conferees (H.Rept. 105-340, Sec. 213) directed DOD to certify that "the Joint Strike Fighter Program contains sufficient funding to carry out an alternate engine development program that includes flight qualification of an alternate engine in a joint strike fighter airframe." (p.33)

² More information about the F-35 Joint Strike Fighter can be found in two CRS Reports: RL31360, *Joint Strike Fighter (JSF): Potential National Security Questions Pertaining to a Single Production Line* and RL30563, *F-35 Joint Strike Fighter (JSF) Program: Background, Status, and Issues*.

³ Michael Bruno. "House defense appropriators push back on JSF engine." *Aerospace Daily & Defense Report*. February 17, 2006.

⁴ CONGRESSIONAL TRANSCRIPTS. *Reuters*. Congressional Hearings. March 1, 2006. House Armed Services Committee Holds Hearing on FY2007 Budget: Air Force

⁵ At that time, the JSF program was The Joint Advanced Strike Technology Program (called JAST).

Congress's interest in establishing and funding an alternate engine to the JSF's primary engine — the Pratt & Whitney F135 — may have been informed by what has become known as “The Great Engine War” that ran from 1984 to 1994. The Great Engine War describes the competition between Pratt & Whitney (PW) and General Electric (GE) to produce engines (the F100 and F110 respectively) to power the Air Force's F-16 *Falcon* and F-15 *Eagle* fighter aircraft. This competition was held annually between 1984 and 1994 to produce and maintain these engines for the Air Force. After 1994, PW and GE continued to compete for engine business among foreign air forces that operated the F-16 and F-15. At the time, this acquisition strategy was unprecedented and controversial. Many extolled the advantages of competition and the benefits it conferred to DOD and the taxpayer.

The Great Engine War's roots extend well before 1984. Most observers credit Congress with initiating this competition by providing funds in FY1976 and FY1979 to develop a new engine that might serve to power the Navy's F-14 *Tomcat*, or the Air Force's F-15 and F-16. Ultimately, DOD spent over \$376 million to develop the F110 to compete with the F100, and \$600 million to improve the F100's durability and reliability to make it a stronger competitor. Proponents believe that the annual competition during the Great Engine War produced better engines, on better terms, for less money than would purchasing from a single company facing no competition. Recently, contrary opinions have emerged, and critics say that “There is no evidence that the F-16 engine competition saved money.”⁶

Some have criticized DOD as being “penny wise and pound foolish” in its proposal to terminate the F136. Critics argue that this decision appears driven more by immediate budget pressures on the department rather than long term pros and cons of the F136 program. For example, Secretary of the Air Force Michael Wynne reportedly said that the idea of cancelling the F136 “came up during the QDR, in the course of attempts to identify ways to save costs at the Pentagon.”⁷ Others applaud this decision, and say that single source engine production contracts are the norm, not the exception. Long-term engine affordability, they claim, is best achieved by procuring engines through multiyear contracts from a single source.

It is not clear if the decision to terminate F136 was based on its merits or if it was the result of tradeoffs in a budget-cutting process. However, the program is clearly handicapped in budget considerations by the fact that its benefits won't be realized for a decade, while its costs are immediate.

Initial congressional response to the proposed termination of the F136 has been both positive and negative. In early March 2006 the Senate Armed Services Committee held two hearings to explore and assess this proposed termination.

⁶ “Joint Strike Fighter - Engine Development,” (JSF Talk-3) *Talking Points*. Pratt & Whitney. February 23, 2006.

⁷ Richard Mullen. “Cutting JSF Engine Was Navy Idea: Wynne.” *Defense Today Instant Update*. March 2, 2006.

Issues

As DOD has noted, cancelling the F136 poses questions on operational risk and potential cost and savings. Additional issues include the potential impact this termination could have on the U.S. defense industrial base, and on U.S. relations with key allied countries. Finally, eliminating competitive market forces for DOD business worth billions of dollars may concern those who wish to reform DOD's acquisition system and conform to higher standards of accountability.

Relations with Key Allies

Potential foreign sales and allied participation in the JSF program have been actively pursued as a way to defray some of the cost of developing and producing the aircraft. Congress insisted from the outset that the JAST program include ongoing efforts by the Defense Advanced Research Projects Agency (DARPA) to develop more advanced short takeoff and vertical landing (STOVL) aircraft, opening the way for British participation.

Eight countries — Australia, Canada, Denmark, Italy, Netherlands, Norway, Turkey, United Kingdom — have pledged about \$4.5 billion to join in JSF development as partners.⁸ Israel and Singapore have both signed letters of intent to become partners in the JSF program and to contribute \$50 million. Poland is reportedly leaning toward a foreign military sales investment of \$75 to \$100 million in the JSF program.⁹

The United Kingdom is the biggest participant in the program. On December 20, 1995, the U.S. and British governments signed a memorandum of understanding (MOU) on British participation in the JSF program as a collaborative partner in the definition of requirements and aircraft design. This MOU committed the British government to contribute \$200 million towards the cost of the 1997-2001 concept demonstration phase.¹⁰ British Aerospace, Rolls-Royce, and other U.K. defense firms that have long been involved in major U.S. aircraft programs are expected to be subcontractor participants in the JSF program.¹¹

On January 17, 2001, the United States and the United Kingdom signed an MOU that committed the British government to spend \$2 billion supporting the JSF System Development and Demonstration (SDD) phase. Britain's investment equates to approximately 8% of the SDD program, and has been described by many analysts as a boon for the JSF program. Britain's — and other allies' — participation in the program makes it much more difficult for Congress or the Administration to cancel

⁸ Katie Fairbank, "Strike Fighter's Support Extends," *Dallas Morning News*. July 12, 2002.

⁹ Grzegorz Holdanowicz, "Poland Steps Up Interest in JSF," *Jane's Defense Weekly*. July 18, 2001.

¹⁰ U.S., U.K. Sign JAST Agreement. *Aerospace Daily*, December 21, 1995: 451.

¹¹ Since the 1970s many European and Japanese firms have been major participants in U.S. aircraft, avionics, and munitions programs as subcontractors or affiliates of U.S. firms; e.g., F-15, F-16, AV-8, F/A-18, and AWACS programs.

the program, according to analysts.¹² In his nomination hearing, former DOD acquisition chief Pete Aldridge testified that any decision on the fate of the JSF would have to weigh its “international implications.”¹³

Friction currently exists between DOD and many foreign partners in the JSF program. Denmark, Italy, the Netherlands, Norway, and Turkey have expressed dissatisfaction with the quality and quantity of the work their companies have been awarded on the F-35.¹⁴ These countries have threatened to reduce their participation in the program, or purchase the Eurofighter *Typhoon* instead of the F-35. The governments of Italy and the United Kingdom have both lobbied for F-35 assembly facilities to be established in their countries. Technology transfer has been a contentious issue, with foreign partners arguing that the United States is too cautious in sharing the JSF’s technical capabilities. Canceling the F136 would likely mean a considerable loss of revenue for GE’s UK-based partner, Rolls Royce. Although Rolls Royce has established business relations with Pratt & Whitney, this business appears to be far short of the 40% partnership Rolls enjoys with GE.

It is unclear how, or to what extent, terminating the F136 would harm the JSF program’s international participation. Early allied response has not been positive. The United Kingdom’s top defense procurement official reportedly stated that his country would cease participation in the JSF program if the F136 engine were cancelled and technology transfer issues were not resolved to its satisfaction.¹⁵

Operational Risk

DOD officials argue that terminating the F136 poses little operational risk. The decision to pursue an alternate engine for F-14s, F-15s, and F-16s, they say, came at a time when the Services were dissatisfied with the performance of existing engines (TF30 and F100). During the “Great Engine War,” DOD pursued alternate engines not only for cost savings, but to improve engine performance, reliability, and to reduce operational risk. DOD argues that these same conditions do not exist today.

¹² Greg Schneider. “Britain Backs Joint Strike Fighter Effort.” *Washington Post*. January 18, 2001. “British commitment seen as major boost to the Joint Strike Fighter.” *Inside the Air Force*. January 19, 2001.

¹³ Marc Selinger, “JSF decision should weigh ‘international implications,’ nominee for acquisition post says,” *Aerospace Daily*. April 27, 2001.

¹⁴ “Norway Signs Industrial Partnership with Eurofighter Consortium,” *Defense Daily*, Jan. 29, 2003. Joris Janssen Lok, “Frustration Mounts Among JSF Partners,” *Jane’s Defense Weekly*. Mar. 24, 2004. Thomas Dodd, “Danish Companies Consider Quitting JSF Programme,” *Jane’s Defence Weekly*, Jan. 9, 2004. Tom Kingston, “Unsatisfied Italy May Cut JSF Participation,” *Defense News*, May 10, 2004. Lale Sariibrahimoglu, “Turkey may withdraw from JSF program,” *Jane’s Defence Weekly*, Nov. 10, 2004.

¹⁵ Megan Scully. “British Demand Better Access To Fighter.” *NATIONAL JOURNAL’S CONGRESS DAILY AM*. March 15, 2006. George Cahlink. “U.K. Procurement Chief Warns Backup Engine Dispute Threatens JSF Deal.” *Defense Daily* March 15, 2006.

In a briefing provided to Congress¹⁶, the DOD Office of Program Analysis and Evaluation (PA&E) states that the F135 engine produced by Pratt & Whitney (PW) for the F-35 is performing well. The first F135 aircraft engine was delivered December 2005. Current F135 testing is “on track and successful,” PA&E notes, and is 33% complete as of February 2006. Further, PA&E states that the F119 engine that PW produced for the F-22A *Raptor*, which served as the basis of the F135, is also performing well. PA&E notes that the F119 has performed well after roughly 18,000 flight hours and will achieve 100,000 flight hours by 2009. This briefing also notes that the F-22 *Raptor* and the F/A-18E/F *Super Hornet* rely on a sole source engine supplier (the PW F119 and GE F414 respectively), implying that the F-35 can likewise rely on a single engine manufacturer.

DOD also argues that industry advances in engine design tools such as computational fluid design for airflow prediction, and advanced software for prognostic health monitoring, further reduce the risk of powering the F-35 with a single type of engine. Presumably, using these tools will result in better-made engines that would encounter fewer problems during their lives, and would also provide the means of predicting or detecting engine problems before they occur.

Others who support DOD’s decision to terminate the F136 argue that an alternate engine will not help mitigate risk. They say that there are no instances in the historical record of a fighter aircraft fleet being grounded by an engine defect. Engine problems, they say, are typically limited to a specific model, or engine series, or to a particular airfield or base.

A number of observations can be made regarding these arguments. First, the comparison between the F-22 and the F/A-18E/F and the F-35 may not be apt. Both the *Raptor* and the *Super Hornet* are equipped with two engines. The F-35 will have one engine. A single engine aircraft is inherently subject to higher risk than a two-engine aircraft, as the consequences of engine problems in the F-35 will be worse than for the F-22 or F/A-18E/F. As one simple datum to consider, between FY1990 and FY2004, the single-engine F-16 suffered 80 Class A engine-related mishaps for a rate of 1.31 per 100,000 flight hours. The twin-engine F-15 suffered 21 engine related Class A engine-related mishaps for a rate of .64 per 100,000 flight hours.¹⁷ Further, unlike the *Raptor* and *Super Hornet*, one of the F-35 variants will be powered by an engine capable of vertical and/or short takeoff and landings (VSTOL). The VSTOL engine will be more complex than the conventional engines and will be subject to different operational stresses and conditions. The AV-8B Harrier, the Marine Corps short take off and vertical landing (STOVL) fighter aircraft has one of the highest mishap rates of all military aircraft. Importantly, unlike most aircraft types that are subject to mishaps most frequently through human error, two-thirds of AV-8B’s mishaps are related to the aircraft failures.¹⁸ Further, the four primary material

¹⁶ “JSF Alternate Engine Decision” Briefing. OSD/PA&E. February 27, 2006.

¹⁷ Fighter/Attack Aircraft. Engine-Related Class A Mishaps. USAF Safety Center. [http://afsafety.af.mil/stats/e_stats_2.asp]

¹⁸ Sandra Ervin. “Navy Aims to Curtail Aviation Mishaps Caused by Crew Error.” *National Defense*. October 2000. *First annual report of the Harrier Review Panel (HaRP)*. USMC. (continued...)

problems related to AV-8B mishaps reportedly are Engine, Flaps Controller, Nose Wheel Steering, and Ejection System.¹⁹ It is to be hoped that the VSTOL JSF will improve upon the AV-8B's safety record and engine problems. However, it appears optimistic to contend that engines generally, and VSTOL engine in particular, do not contribute to safety concerns.

A second point that might be made regarding DOD's risk assessment is that the experience with the F119 and F135 engines is still relatively modest. By the time the decision was made to divide engine production contracts between GE and PW in 1984, the PW F100 engine had accumulated 2,000,000 hours of operational service. Even with this extensive experience with the engine, over the following 25 years PW and the Air Force made numerous improvements to the engine as it competed for business with GE. By comparison, the 18,000 hours of testing appears to be a modest foundation to make projections of the F119's future performance.

It does not appear that there are any overt performance or reliability problems with today's fighter aircraft engines that an alternate engine would be required to remedy. It may be worth noting, however, that in the future the JSF will be the only fighter aircraft in service. If any engine problems are encountered, the entire fighter aircraft fleet may be affected, not just one model of aircraft. In 1984 when the decision was made to award engine production contracts to both contractors, the Air Force, Navy, and Marine Corps flew about 11 different models of combat aircraft.²⁰ While DOD was experiencing problems with some combat aircraft engines, it also had sufficient aircraft diversity that an F-4, for example, might be able to perform a mission if an F-14 or F-18 was grounded due to engine problems. DOD will not have this diversity in the future, and so consequences of potential engine problems again appear to be more troubling than in the past.

DOD's statements about grounding aircraft may be incomplete. A number of aircraft have been grounded over the past five years, including the KC-135, C-130, and B-1B, and none of these groundings was for engine-related problems. However, aircraft *have* been grounded for engine-related problems. The Marine Corps, for example, grounded 106 AV-8B Harriers in July 2000 after a faulty engine bearing was cited as the cause of a crash.²¹ Further, aircraft groundings, whether for engine-related problems or not, may not occur often because as a matter of policy, the Services try not to ground aircraft. If aircraft are grounded, a positive action or

¹⁸ (...continued)

30 September 1998 Executive Summary. Chaired by Deputy Chief of Staff (Aviation), Lt.Gen. T. Dake. Since its introduction the AV-8B has outpaced all aircraft types with 68 (Now 77) Class A mishaps for a cumulative rate of 12.1 per 100,000 flight hours. The Class A mishap rate for the first model of the Harrier, the AV-8A, was 31.77 mishaps per 100,000 hours.

¹⁹ Alan C. Miller and Kevin Sack. "The Widow Maker." *Los Angeles Times*. December 15, 2002.

²⁰ Air Force: A-7D, A-10, F-4, F-15, F-16. Navy: A-6E, A-7E, F-4, F-14. Marine Corps: A-4M, A-6E, AV-8C, F-4N, F-18.

²¹ Mark Oliva, "Pilots defend Harrier jet." *Stars and Stripes*. (Pacific Edition). January 19, 2003.

finding must take place before the aircraft return to service. Instead, the Services try to “stand down” aircraft when safety is a concern. These stand downs are typically for a defined period of time and are either anticipatory, or in response to some general concerns. As one example, on March 6, 2006, the commander of Naval Air Forces directed a mandatory, half-day safety stand down for all naval aviation squadrons and detachments. Although safety stand downs for individual wings or squadrons take place more frequently, this was the first service-wide stand-down in four years.²²

One issue that pertains to operational risk that has not been discussed by DOD is that of reduced fleet readiness due to, for example, a lack of spare parts. Two manufacturers would maintain two supply chains, and perhaps additional suppliers for critical parts. Eliminating one manufacturer could lead to fewer suppliers and potentially leave the remaining supply chain more vulnerable to disruptions caused by labor disagreements, foreign takeovers, or natural disasters.

Finally, it may be noted that DOD statements on the potential risk of operating the F-35 with a single engine-type appear to be inconsistent, or potentially contradictory. For example, DOD’s Office of Program Analysis & Evaluation (PA&E) claims that “Relying on single engine supplier incurs minimum operational risk.” In the same document, PA&E notes that the JSF alternate engine offers “significant benefits” in readiness, reliability, availability, and protection from fleet grounding.²³ Logic suggests that if a course of action offers “significant benefit,” the elimination of that course of action would elicit a negative or harmful effect. During a March 1, 2006 hearing, Secretary of the Air Force Michael Wynne discussed the potential cost and risk of having one engine supplier versus two. Secretary Wynne said that the decision to terminate the F136 was “a very tough call because it involves industrial base and involves long-term reliability statistics and involves economics.” In the context of reliability and risk, Secretary Wynne continued with the statement that “I don’t like to see our industrial base go to a single supplier.”²⁴

Cost and Savings²⁵

Many believe that estimating cost lends itself to quantitative analysis more than estimating risk. However, this may not be the case. The time lines involved in these

²² “CNAF Directs Half-Day Stand-Down.” Naval Safety Center. U.S. Navy. [http://www.safetycenter.navy.mil/articles/a-m/CNAF_directs_standdown.htm].

²³ JSF Alternate Engine Decision” Briefing. OSD/PA&E. February 27, 2006.

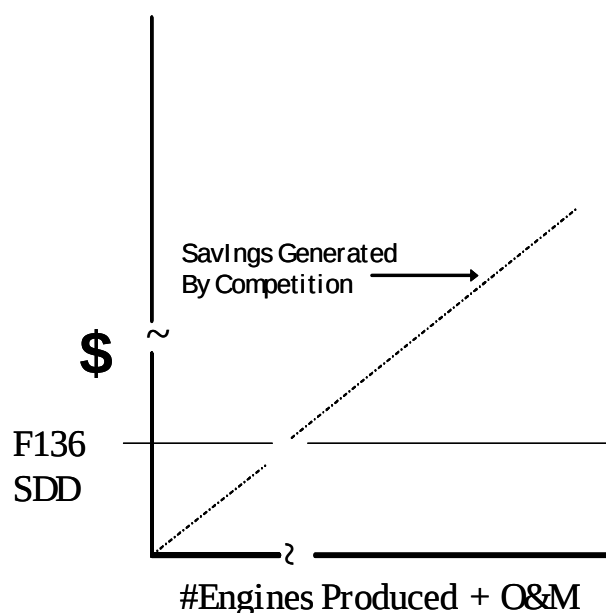
²⁴ CONGRESSIONAL TRANSCRIPTS. *Reuters*. Congressional Hearings. March 1, 2006. House Armed Services Committee Holds Hearing on FY2007 Budget: Air Force

²⁵ To date, \$1.08 billion has been obligated to the F136 program. A \$2.4 billion contract awarded in August 2005 would have funded the program’s system development and demonstration phase, slated to run until September 2013. DOD estimates that if it cancels the F136 it could incur between \$50-\$70 million in termination costs and an increase of approximately \$100 million in the F135 program due to the need for additional flight test assets. Source: “Information Paper.” Department of Defense. February 27, 2006. Provided to CRS by SAF LLW.

estimates are long, the variables are numerous, and cost estimating tools are imperfect.²⁶ Like any quantitative assessment, assumptions made about the variables measured can influence significantly the analyses' output. When calculating the amount of competition-generated savings required to recoup the costs of developing the F136 engine, two variables can sway the analysis considerably: the amount of money being amortized over the life of the F-35, and the number of engines to be purchased. Additional assumptions and assertions can also affect the analysis. Therefore, costs and savings estimates by parties on *both sides* of the F136 debate may be matters of some subjectivity.²⁷

Figure 1 below is intended to help illustrate the potential impact that assumptions made in the various cost analyses can effect conclusions on whether it is cost effective or not to fund an alternate engine for the JSF.

Figure 1: Illustrative and Simplified Depiction of Cost Analysis



Source: CRS.

²⁶ Obaid Younossi, et al. *Military Jet Engine Acquisition: Technology Basics and Cost-Estimating Methodology*. RAND. Santa Monica, CA. 2002.

²⁷ The Navy's F404 engine competition may serve as an example of the difficulties involved in estimating cost savings resulting from competition. A press account stated that "Although Navy officials were able to identify the direct costs of establishing a second source for the F404, they could not estimate the total cost of keeping two production lines open. (emphasis added)" "Navy Spent At Least \$58.6 Million To Set Up Second F404 Line." *Aerospace Daily*. August 30, 1989.

Deputy Secretary of Defense Gordon England has written that “The Department’s analysis concluded that a second (engine) source would not yield program cost savings.”²⁸ The analysis that DOD shared with Congress and CRS on JSF Alternate Engine cost issues contained a single chart that depicts the output from its analysis, and a number of anecdotes and historical examples that DOD maintains support its analysis.

DOD’s “Break Even Analysis” chart is meant to show the percentage of savings required to “break even” (i.e., recoup F136 costs) over a 16-year period in which DOD purchases 3,036 JSF engines. (X axis on **Figure 1** above.) If competition in the production of these engines were to result in 25% cost savings, DOD would recoup the F136 \$2.8 billion System Development and Demonstration (SDD) costs in FY2019 when the 2,259th engine is purchased. If 20% savings occurs, DOD will break even in FY2021. Fifteen percent savings will come close to \$2.8 billion (approximately \$2.6 billion) by the end of the production run, never fully recouping F136 SDD costs by DOD’s calculations. Thus, DOD argues that to fund an alternate engine for the F-35, the alternate must generate at least 15% cost savings to justify itself on a cost basis.

DOD states that this much cost savings is unlikely because its experience during the “Great Engine War,” and the competition between GE and PW for the Navy’s F404 business in the late 1980s,²⁹ indicate that engine competition generates only “minimum cost benefit.”³⁰ Cost benefit is minimized DOD asserts because “Splitting the buy between two competitors can make production and support costs increase.” DOD cites reduced “learning curve effect,” decreased buying power for each source, and amortizing fixed costs over fewer units for each source as specific cost pressures.³¹

On its “Break Even Analysis” chart, DOD expresses these projected cost increases as \$700 million that is added to the \$2.8 billion in SDD costs that must be recouped. To recoup the SDD costs *and* make up for this “loss of learning” caused by a second competitor, DOD argues that 25% savings will be required to break even by FY2021, and that 20% savings generated by competition will almost break even by the end of the production run in FY2026 (approximately \$3.4 billion).

Pratt & Whitney (PW) has offered a similar analysis, but using a slightly different methodology and different assumptions. PW estimates that the amount of money needed to be recouped through competition generated savings is \$3.5 billion, apparently including the \$1.08 billion spent on the F136 prior to SDD. PW estimates that 4,000 JSF engines will be purchased, but amortizes the \$3.5 billion over only the engines that GE might win in a competition. A 50% win rate, or 2,000

²⁸ Cover letter. JSF Alternate Engine Decision” Briefing. OSD/PA&E. February 27, 2006.

²⁹ The Navy awarded PW approximately \$59 million starting in 1985 to initiate a competition between it and GE (the incumbent) for production of different F404 engine variants for the F/A-18 and other Navy aircraft.

³⁰ “JSF Alternate Engine Decision” Briefing. OSD/PA&E. February 27, 2006.

³¹ JSF Alternate Engine Decision” Briefing. OSD/PA&E. February 27, 2006.

engines, is assumed for the analysis. By this methodology, GE would have to generate over \$1.7 million worth of savings per engine to pay for the cost of development. It is unreasonable to expect, PW argues, \$1.7 million worth of savings on a \$6 million engine.³²

There are a number of observations that can be made regarding DOD's cost estimating methodology, and its underlying arguments. Perhaps the most important observation is on some of the assumptions made in DOD's and PW's analyses. In both analyses it appears that the number of engines over which the SDD costs is amortized may be too small (X axis in **Figure 1**). Further, it can be argued that the \$3.5 billion figure cited by both studies as the F136 costs to be amortized, is too high. (Line intersecting Y axis. This is the "break even point.") Individually, the assumptions made on the number of engines, and the amount of money to be recouped, make competition appear to be less cost effective. Together, these assumptions may lead to the conclusion that competition is without any financial merit.

DOD's estimate of 3,036 JSF engines over which the SDD costs would be amortized appears to be too low because many more engines are typically purchased than the total number of aircraft. DOD currently plans to purchase a total of 2,443 F-35s, and international partners plan to purchase 733 for a combined purchase of 3,716 aircraft. Over the 20-30 year lifetime of a fighter aircraft, more engines and many spare parts will be purchased. DOD recognizes this, so it plans to purchase initial spare engines at 15% of the fleet for a total (366 for DOD, 110 for partners). More engines, however, will be needed.

A conservative and illustrative planning factor is that a single aircraft will require 2.5 engines equivalents (either whole engines, or piece parts) over its lifetime.³³ If this planning factor is applied to the JSF program, one can expect a total of 6,474 engines purchased for DOD and 8,417 engines total, *not including* additional potential future international sales. PW's figure of 2,000 engines appears to be low for similar reasons, but also because competition should decrease the cost of *both* engines, not just the alternate engine. So, SDD costs would be recouped by the cumulative cost savings of all engines produced, not just those awarded to the F136.

A key assumption implicit in both DOD's and PW's analysis is that SDD costs are only amortized over engine *production*. PW and GE would annually compete to

³² "Joint Strike Fighter - Engine Development," (JSF Talk-3) *Talking Points*. Pratt & Whitney. February 23, 2006.

³³ Rough estimates of the number of engine equivalents will be required per aircraft over its lifetime were provided by Pratt & Whitney and GE. One set of estimates was calculated by adding the value of initial engine spares to the value of forecasted replenishment spares, divided by the unit recurring flyaway (URF) cost of the propulsion system. In the case of the JSF engines, this equation leads to rough planning factors of 2.44 engines for the Navy variant, 2.17 for the Air Force variant, and 2.59 for the Marine Corps variant. Clearly, assumptions on spares will affect the analyses results. A planning factor of 1.5 engine equivalents, for example, per aircraft will result in a smaller total purchase, and a planning factor of 3.0 will result in a larger total engine purchase.

produce the F-35's engines, and also to support the engines over the 20-30 year life of the aircraft. A larger fraction of an aircraft engine's life cycle cost is attributed to support activities than to production. Therefore, it appears that both the DOD and the PW analysis ignore a considerable body of potential work over which the contractors would compete and potentially generate savings which could help defray up front SDD costs. Air Force officials who participated in the "Great Engine War" believe that cost savings from competition during operations and support (O&S) were considerably greater than cost savings from competition during engine production.³⁴

It can be argued that PW's inclusion of \$1.08 billion in F136 costs to be recouped during competition is inappropriate because these are "sunk costs." No decision made today, or next year, will recoup them. If DOD were to cancel the F136 program, it could recoup all of the \$2.8 billion awarded for SDD, minus termination liability. Thus, the savings from canceling the program can be weighed against the potential costs and savings of keeping it. It is noteworthy that DOD does not include this \$1.08 billion in its cost analysis.

DOD's assertion that costs to DOD increase by \$700 million when it funds a second engine producer because of a "loss of learning" appears to be central to DOD's claim that a second manufacturer does not save money. Yet, it is unclear how this "loss of learning" has been quantified, and whether this figure is offset by the competitive forces that can increase learning, productivity, and innovation. Similarly, DOD's argument that "splitting the buy between two competitors can make production and support costs increase" has not been substantiated.

To support its "Break Even Analysis," DOD states that it experienced only "minimum cost benefit from engine competition," during the Great Engine War. This assertion is at odds with statements made earlier by senior Air Force officials. Several sources estimate that through competition, the Air Force saved 21% (\$4 billion of an \$18.8 billion program) over the 20-year life cycle of the improved F100 and F110 engines compared to operating legacy F100 engines over the same period of time.³⁵ Also, the Navy's aborted F404 engine competition may not be the best cost analogy to today's potential JSF engine competition, because it reportedly was not pursued to save money. Navy spokespersons stated that Secretary of the Navy Lehman "opted to open the second F404 line to ensure 'that an adequate industrial mobilization base existed to meet the national defense needs and to promote competition. It was not based on projected cost savings.'"³⁶ Evaluating the F404

³⁴ Telephone interview with Col. James Nelson (Ret.) Former Deputy for Propulsion, Aeronautical Systems Division, Air Force Systems Command. March 5, 2006.

³⁵ Prepared Statement of Hon. Thomas Cooper. U.S. Congress, House, Committee on Armed Services, *Air Force Alternative Fighter Engine, Hearings before the Subcommittee on Procurement and Military Nuclear systems*, 98th Cong. 2nd Sess., March 8, 1984. *Point Paper on Air Force Alternate Fighter Engine (AFE) Competition*. Aeronautical Systems Division. Directorate of Development and Production, DCS/Research, Development and Acquisition. February 18, 1987.

³⁶ Statement by Naval Air Systems Command (NAVAIR) August 23, 1989, as cited in "Navy Spent At Least \$58.6 Million To Set Up Second F404 Line." *Aerospace Daily*. (continued...)

competition is more complicated because PW reportedly was found guilty of illegally obtaining GE's confidential pricing data, and conspiring with Navy officials to defraud the government.³⁷ This may have played a more significant role in DOD's decision to terminate the competition than cost savings estimates.

Industrial Base

As noted earlier, DOD officials have instead expressed concern over the potential impact of this proposed termination on the industrial base. Further, DOD analyses acknowledge that the F136 alternate engine provides "significant" industrial base benefits.³⁸ Therefore, it is reasonable to assume that the decision to terminate the F136 may have negative consequences on the industrial base. The debate focuses on *how* significant these negative consequences may be.

The industrial base issues discussed and debated in hearings and other public fora have focused on whether a single supplier of fighter aircraft engine will result in costlier engines over time and whether reliable access to engines and spare parts might be jeopardized. The root of this question is what effect canceling the F136 engine will have on GE's ability to continue to compete in the high performance fighter aircraft engine business. Currently, the only U.S. manufacturers of fighter aircraft engines are PW and GE.

GE is a dominant player in the large, commercial aircraft engine market. By most estimates, GE has captured approximately 50% of this market. GE's current business in building and supporting high thrust, high performance, fighter aircraft engines is more modest. Currently, GE builds and maintains engines (F400 series) for the Navy's 462 F/A-18E/F *Super Hornets*. It is expected to also build engines for the Navy's 90 EA-18G *Growlers*. GE supports the F110 series of engines for domestic and international clients. Finally, GE may be competitive in engine competitions for large unmanned aerial vehicles (UAVs).

It appears that if the F136 were cancelled, GE's fighter aircraft design and manufacturing capabilities would not peter out immediately. The business outlined above likely is sufficient to maintain GE's design teams, engineers, and assembly line workers, and much technology and expertise can be extracted from the commercial business lines. GE's own experience during the Great Engine War shows that a company on the periphery of a business area can "catch up," and beat an incumbent in head-to-head competition, even if that incumbent had been producing a particular type of engines for a decade.

If the F136 program were canceled today, and if in 10 years time, for example, DOD requested GE to design and build an alternate to the F135, GE might face

³⁶ (...continued)
August 30, 1989.

³⁷ "United Technologies Admits 'Ill Wind' Role, Will Pay Fine." *Aviation Week & Space Technology*. September 7, 1992.

³⁸ "JSF Alternate Engine Decision" Briefing. OSD/PA&E. February 27, 2006.

noteworthy challenges. It already trails PW by three years of development, for example, and PW's lead would grow with each year GE was out of this business. GE's successful competition with PW in the Great Engine War was expedited by GE already having an engine (the F101) in the same thrust class as the PW F100. GE was developing the F101 for the B-1B bomber, and this work gave the F110 program considerable leverage.

GE does not have another engine in the same thrust class (~40,000 lbs) as the F136, and no other high performance fighter aircraft programs after the JSF appear to be in DOD plans. The F110 and F400 series engines that GE maintains are in a different class than the F136 and are the focus of maintenance and upgrade efforts, not design efforts. The leverage that GE's commercial engine business might offer to developing a new 40,000 lb thrust engine is unclear. Commercial engines share some qualities with fighter aircraft engines, but they are also very different. Commercial engines do not employ afterburners, for example, they are designed to meet fuel efficiency goals, not performance goals, and their thrust-to-weight ratios are very different than that of fighter aircraft engines.

Additional industrial base issues have not yet been widely debated, but may also inform decisions on the future of the F136. One issue concerns export and competitiveness. The JSF is a centerpiece of the federal government's fighter aircraft policy. Since the program's beginning, the desire to produce a cost-effective, multirole aircraft appears to have been shaped by consideration of what the international market would bear.³⁹ The F-35 is designed as an export aircraft, and one that is hoped to leverage the international success of the F-16 Falcon (another cost effective, single engine, multirole fighter) to perpetuate U.S. dominance in this market. Foreign participation in the JSF program was sought to defray development costs, but also to "prime the pump" for export.⁴⁰

A key question appears to be whether the JSF will achieve the same export success with one engine-type as it might with two. Some argue that the F-16's export success is directly attributable to having two engine types: "The F-16 became a much more exportable aircraft when GE and Pratt were killing each other in the international market. So, if you are selling these JSF's and you have got one engine...that reduces the attractiveness to these international customers..."⁴¹ Singapore and South Korea have both selected the GE F110 engine to power their F-15 *Eagles*, and Saudi Arabia is giving serious consideration to re-engining its F-15s with GE engines. These decisions contrast with U.S. Air Force decisions to power its *Eagles* with PW engines. Further, while GE engines power a large fraction of

³⁹ See for instance John Tirpak. "World Market Forces Improved Military Exports." *Aviation Week & Space Technology*. February 14, 1994. John Morrocco. "No JAST Prototypes to Fly Until After 2000." *Aviation Week & Space Technology*. December 13, 1993, and "Brits Visit JAST to Position for Next Round of Contracts." *Aerospace Daily*. June 1, 1994.

⁴⁰ "Australia, Belgium Enter Joint Strike Fighter Program as EMD Partners," *Inside the Air Force*, April 21, 2000.

⁴¹ Carlo Munoz. "Congress, Defense Department Square Off Over Second JSF Engine." *Inside the Air Force*. March 3, 2006.

USAF F-16 *Falcons*, PW engine sales to international F-16 customers have dominated GE sales. This background lends credence to the suggestion that competition in engine selection can enhance U.S. fighter aircraft export success.

Would cancelling the F136 and the attendant competition with the F135 adversely affect potential future advances in engine performance, reliability, and maintainability? If so, might this be at the expense of U.S. competitiveness? Many of those who participated in, or studied the “Great Engine War” assert that the competition between GE and PW made *both* companies better and “proved invaluable to future engine development.”⁴²

The economic stakes in international fighter engine competition appear to be high. U.S. companies face competition from France, Sweden, Russia, and a European consortium of companies, and it is argued that some of these governments heavily subsidize their aerospace industries. Aerospace is an important export for the United States. Despite this competition, aerospace has at times provided the U.S. economy with its highest trade surplus.⁴³ Many observers project that the size of the international market for fighter aircraft will remain high for the next decade, after which it may peak and then decline.⁴⁴ Thus, the importance of maintaining the competitiveness of the U.S. fighter aircraft engine industry may grow, if U.S. fighter aircraft manufacturers are to “make hay while the sun shines.”

Acquisition Reform and Accountability

The final point one can make about the potential termination of the F136 pertains to acquisition reform, or “good government.”⁴⁵ Congress has recently held multiple hearings on defense acquisition reform, and members have consistently expressed concern about perceived shortcomings in the current acquisition system, or a lack of personal accountability in acquisition decisions. As this Congress has tried to determine and correct the root causes of growing weapon system cost growth it has heard from witnesses a litany of problems such as funding instability, unrealistic requirements, poorly structured contractor incentives, too much reliance

⁴² Maj. John Nix and Maj. Riley Shelnett. “Behind the Alternate Fighter Engine Competition.” *Aerospace America*. May 1984.

⁴³ “The trade surplus generated by aerospace foreign trade in 2005 totaled \$37 billion. With an \$8.4 billion increase in exports and \$2 billion rise in imports, the industry’s trade surplus expanded \$6.4 billion. The aerospace trade balance, before its sharp rise this year and last, had fallen \$14 billion from its \$41 billion peak in 1998 due to \$12 billion fewer exports and \$2 billion more imports. In 2004, the latest year of comparative data, the U.S. aerospace industry posted the highest trade balance of all industry categories. (emphasis added).” *2005 Year-End Review and 2006 Forecast — An Analysis*. David H. Napier, Director, Aerospace Research Center. Aerospace Industries Association.

⁴⁴ “Market Overview: Fighter/Attack Aircraft.” *World Military & Civil Aircraft Briefing*. Teal Group Inc. (Fairfax, VA) February 2006.

⁴⁵ For example, Air Land Subcommittee of the Senate Armed Services Committee, November 15, 2005, and Readiness and Management Support Subcommittee of the Senate Armed Services Committee, November 9, 2005.

on lead system integrators, and the improper use of commercial contracts to purchase military items.

In this context, it may be worth noting that the competition during the “Great Engine War” appears to have conferred a number of benefits to government that today’s acquisition officials would have a difficult time duplicating. For example, prior to the first contract award, the Air Force demanded that GE and PW provide six years of cost projections to include the production of engines, but also the price of support equipment, spare engines, technical data and dual sourcing data and second sourcing data for operations and support. The contractors were held to these cost projections for six years: the Air Force let six years of firm-fixed price, or “not-to-exceed” contracts from the first production lot. Prior to the “Great Engine War,” government had succeeded in negotiating firm-fixed price contracts only after the engine had been operating in the field for several years. Never before had contractors agreed to provide cost projections into the future, and contracts were typically for production only, not O&S work.

By requiring GE and PW to compete for annual production and O&S work, DOD may have reaped a number of benefits such as better contract terms and conditions, better warranties to assure engine quality, consistency, and long term stability of support.⁴⁶ Further, after competition was introduced, the incumbent (PW) offered “engine improvements to the Air Force earlier than the Air Force had been led to expect without the competition.”⁴⁷ To avoid potential disruptions in production, and to protect itself against price gouging, DOD “required (each contractor) to provide his plan for providing dual sources of critical parts. These separately priced options in the proposals would allow the Government to repurchase spare parts from sources other than the prime contractors.”⁴⁸

Successfully orchestrating the “Great Engine War” in the mid-1980s required a considerable amount of effort and skill by Air Force leaders. It is unclear whether today’s environment would allow, or whether DOD leadership would be able to exploit the JSF Alternate Engine competition as effectively as Air Force leaders in the past. It appears clear however, that the very large production run of JSF engines required to make competition between two producers cost effective, is unlikely to be replicated in future aircraft programs.

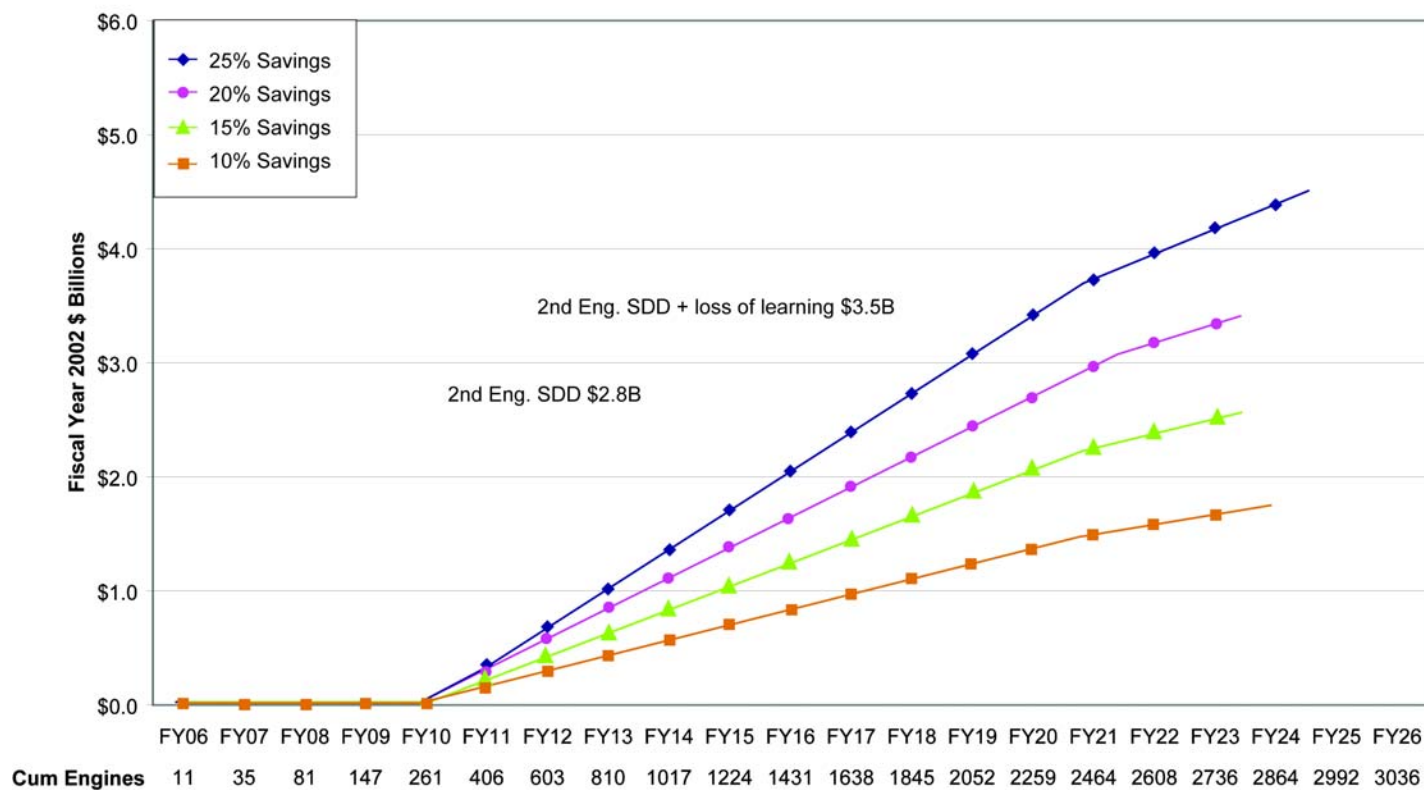
⁴⁶ U.S. Congress, House, Committee on Armed Services, *Air Force Alternative Fighter Engine, Hearings before the Subcommittee on Procurement and Military Nuclear systems*, 98th Cong. 2nd Sess., March 8, 1984.

⁴⁷ Robert W. Drewes. *The Air Force and the Great Engine War*. NDU Press (Washington, DC) 1987.

⁴⁸ Prepared Statement of Hon. Thomas Cooper. *Air Force Alternative Fighter Engine, Hearings OpCit*.

Appendix: DOD F136 Cost Analysis

Break Even Analysis



Source: Program Management Advisory Group 2002