US FIGHTER MODERNIZATION PLANS: NEAR-TERM CHOICES

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Thinking Smarter About Defense

Center for Strategic and Budgetary Assessments

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by

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This report is one in a series of CSBA analyses on future US military strategy, force structure, operations, and budgets. Additional CSBA reports on strategy, force structure and budgets include *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects* (2007), *A New US Global Defense Posture for the Second Oceanic/Joint Expeditionary Era* (2007), *Know When to Hold 'Em, Know When to Fold 'Em: Thinking About Navy Plans for the Future Surface Battle Line* (2007), *Spending on US Strategic Nuclear Forces: Plans and Options for the 21st Century* (2006), *The Quadrennial Defense Review: Rethinking the US Military Posture* (2005), *Long-Range Strike: Imperatives, Urgency and Options* (2005), *Matching Resources with Requirements: Options for Modernizing the US Air Force* (2004). These assessments are also integral to CSBA's research on the emerging revolution in military affairs.

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Executive Summary

This report explores the near-term modernization choices now facing the Department of Defense (DoD) in fixed-wing air power. Presently, the F-35 Joint Strike Fighter (JSF) program is the largest programmatic element in the Pentagon's plans for modernizing US air power. At $242 billion (fiscal year 2008 dollars) for 2,443 aircraft, the F-35 program, if executed as currently constituted, would be the most costly single aircraft program in DoD history. As such, the focus of this report is on the need for and affordability of the three JSF variants now planned:

1. a conventional take-off landing (CTOL) variant (the F-35A) for the Air Force;
2. a short take-off, vertical-landing (STOVL) variant (F-35B) for the Marine Corps; and
3. the F-35C carrier variant (CV) for the Navy's aircraft carriers.

From the standpoint of military necessity, a major concern is that DoD's current air power modernization plans may be unbalanced in favor of fighters, vice longer-range strike aircraft. In future wars, US aircraft may have to operate at far greater distances than they have in the recent past. In particular, US air forces operating in Asia and the Pacific might well have to travel several times farther than US air forces typically had to during the Cold War. There also appears to be a growing need for aircraft that can loiter over the battlefield long

enough to find emerging, fleeting or otherwise time-sensitive targets. In recognition of the importance of these evolving requirements, the 2005-2006 Quadrennial Defense Review directed the US Air Force to field an air-breathing follow-on to the B-2 by 2018. But it is unclear how committed the Air Force is to this program, and there is reason to worry that the JSF's funding requirements will crowd out future investment in long-range strike capabilities.

Table A: Costs of Fighter and Attack Aircraft (Millions of FY 2008 dollars)

Aircraft	Unit Cost
A-10	$14 M
F-16A-D	$28 M
F-117	$73 M
AV-8B	$42 M
F-18A-D	$54 M
F-35A	$74 M
F-35B/C	$97 M
Block-60 F-16	$50 M
F/A-18E/F	$65 M

Source: CSBA estimates based on DoD and CBO data.

Questions about the high cost and affordability of the JSF program are also a major concern. Table A shows CSBA's estimates of the unit procurement costs of the three F-35 variants compared to older fighters and attack aircraft, as well as to newer models of the Air Force's F-16 (the Block-60 produced for the United Arab Emirates) and the Navy's F/A-18 (the E/F variant now in production for the Navy). These estimates omit research and development (R&D) costs. Two points emerge from Table A. First, the F-35 variants will cost far more to procure than the older tactical aircraft they have been projected at various times to replace. Second, the last two entries—for the Block-60 F-16 and F/A-18E/F—raise the possibility of saving money by buying newer models of current fighters in lieu of JSFs.

This report explores four alternative options for restructuring the JSF program, including:

- Option 1: Cancel the JSF entirely and procure 2,443 Block-60 F-16s and F/A-18E/Fs instead;
- Option 2: Cut the planned Air Force buy of 1,763 F-35As in half and substitute Block-60 F-16s for the forgone JSFs;
- Option 3: Cancel the F-35C carrier variant and buy F/A-18E/Fs instead; and
- Option 4: Buy F/A-18E/Fs instead of F-35Cs and substitute Block-60 F-16s for half of the Air Force's F-35As.

The estimated *annual* savings from each of these options are summarized in Table B.

Table B: JSF Options and Savings (in FY 2008 dollars)*

Option	Description	Average Annual Savings through 2034
Option 1	Cancel all variants	$3-3.7 billion
Option 2	Cut Air Force buy in half	$300-500 million
Option 3	Cancel Navy variant	$450-550 million
Option 4	Cut Air Force buy in half, cancel Navy variant	$800 million to $1.1 billion

* Estimates include procurement and R&D savings, and are net of the costs associated with purchasing alternative systems in place of the forgone F-35s.

These four options do *not* represent CSBA recommendations. Rather, they are intended to bound the range of alternative options planners seeking to reduce the cost of the JSF program—while still achieving important improvements in capabilities, and holding force structure constant—might reasonably consider. It is important to understand that the annual savings in Table B are highly sensitive to a number of assumptions, about which there is considerable uncertainty. These include assumptions about further cost growth in the JSF program, the impact of reductions in procurement quantities on unit-procurement costs, and the actual procurement costs of alternative aircraft, especially the Block-60 F-16. Obviously further savings would accrue should a decision be made to reduce the number of short-range fighters operated by the US military.

The most radical option would be to cancel the F-35 program entirely (Option 1). However, if one looks beyond bare costs and takes into account the political, strategic, and operational benefits of continuing the F-35 program, the case for outright cancellation appears weak and risky. To begin with, the JSF offers some capabilities that the Block-60 F-16 and F/A-18E/F will not. The most important of these are all-aspect low observability and an "open" avionics architecture that promises to allow the plane's computational capacity to be affordably upgraded on a regular basis, rather than falling multiple generations behind state-of-the-art commercial microprocessor technology. Given the likelihood that the JSF will be in active service three or four decades, canceling the F-35 program altogether would run the considerable risk of assuming that US security challenges several decades in the future will not prove appreciably more challenging for American fixed-wing air power than current operations in Iraq and Afghanistan. Politically, cancellation would leave close allies such as the British without advanced aircraft on which they are planning and possibly confirm perceptions, especially in China, of growing American weakness. Strategically, cancellation would signal US willingness to abandon its longstanding position as the world's leader in advanced combat aircraft. And doing so would forego the JSF's advanced capabilities despite the $29 billion (FY 2008 dollars) of sunk cost already invested in their development.

While cancelling the JSF program would appear to make little strategic or tactical sense, scaling back the planned buy of aircraft may. Even absent affordability concerns, force-structure considerations suggest that the number of JSFs in the current plan exceeds the needs of the military Services. In the Air Force's case, the planned procurement of 1,763 JSFs was originally intended to replace the Service's inventory of F-117s, A/OA-10s, F-15Es, and F-16s. Under the Air Force's latest plans, however, the 52 F-117s are to be retired by the end of FY 2008, over 60 percent of the Air Force's roughly 350 A/OA-10s are to be refurbished and retained through 2028, and the 223 F-15Es will continue in service through at least 2025. These developments suggest that the Air Force needs the JSF primarily to replace its rapidly aging inventory of F-16s. Today the Air Force operates over 1,300 F-16s (including Air Force Reserve and Air National Guard units). Even the later-block models of the F-16 have been experiencing age-related engine problems, and the fly-by-wire flight controls has enabled pilots to reach operational load limits (nine times the force of gravity) more often and more quickly than anticipated when the plane

was designed. While the original airframe life of 4,000 flying hours has been extended to 8,000 hours, it is unclear whether further service-life extensions are feasible. So there is a need to begin replacing the Air Force's F-16s.

Might a smaller number than 1,763 suffice to replace just over 1,300 planes? Indeed, if the F-35A is superior to any of the F-16s now in the Air Force's inventory, then might as few as 800-1,000 F-35As suffice? Air Force officials have acknowledged that the F-35A will be so much more capable than the F-16 that the older planes need not be replaced one-for-one.

When the Air Force began procuring F-16s and the Navy, F/A-18s, both Services' fighter and attack crews were still wedded to the notion that strike operations would be conducted primarily with unguided munitions, most of which would miss their aim-points or targets. Today, however, most of the munitions expended by US strike aircraft are guided: they either hit their targets or come close enough to inflict significant damage. Moreover, with the first successful combat use of the Joint Direct Attack Munition (JDAM) in 1999, the clear-air limitations of laser-guided bombs (LGBs) were overcome. This meant, as was demonstrated during Operation Iraqi Freedom (OIF) in 2003, that fixed-wing air power could achieve precision or near-precision accuracy against all but the most elusive targets, day or night, in good weather or bad. Air power, then, has been moving from what could be described as an industrial era in which many aircraft sorties were needed to take out most targets to one in which each aircraft can attack multiple targets on a single sortie. Further, the advent of smaller guided munitions like the Air Force's 250-pound-class Small Diameter Bomb reinforces this trend. While it is beyond the scope of this report to estimate what a sensible F-35A/F-16 replacement ratio might be, it seems clear that one-for-one is too high. The maturation of guided munitions and battle networks argues that fewer advanced fighters will be needed in the future than were required in the prior era of industrial-style warfare in which most munitions missed their aim-points or targets.

This line of thought can be extended to fixed-wing air support of US ground forces. In OIF loitering B-1Bs with JDAM were able to provide 24/7 fire support for soldiers and marines even in the worst weather. Additionally—and this point is crucial—airmen have the intelligence, surveillance, and reconnaissance (ISR) capabilities for

deep, over-the-horizon targeting. By and large, the ground components of the Army and Marine Corps do not, although the Army's hope is that its Future Combat Systems program will eventually duplicate Air Force and Navy ISR at least to the depth of a corps commander. On the ground, the Army's experience since 2005 employing guided rounds designed for the Multiple Launch Rocket System (MLRS) and the High Mobility Artillery Rocket System (HIMARS) suggests that guided MLRS (GMLRS) rounds are acquiring the capability for organic field-artillery systems t0 provide precision fires support similar to that provided by fixed-wing air power. This strengthens the argument that the one-for-one replacement of A/OA-10s with F-35s is not necessary. Indeed, as field artillery in both the Army and the Marine Corps moves into the guided-munitions era, the A/OA-10 appears likely to become increasingly redundant relative to its original purpose of providing direct fire support for soldiers and marines. Thus, the case for replacing any A/OA-10s with F-35s looks weak.

Turning to the Marine Corps, much the same argument could be made against replacing its AV-8Bs with F-35Bs. Guided munitions from fixed-wing aircraft together with easily employed guided shells and missiles for field artillery would seem to render traditional close air support from "jump jets" redundant. Nevertheless, cancellation of the STOVL variant of the JSF appears unlikely. First, the British military is adamant that Great Britain needs the plane. Second, the Marine Corps' basic force structure is not as negotiable as are the numbers of Air Force fighter wings or Navy ships. Title 10 of US Code specifies that the Marine Corps will have no less than three combat divisions and three air wings.

What about the Navy's planned buy of perhaps 330 F-35Cs? Can this part of the planned US JSF procurement be reduced? If, as seems likely, the F-35C's learning curve is distinct from that of the other two variants, then the production quantity for the carrier variant of the F-35 is small enough that it should probably be considered an either/or proposition. Either the Navy should buy 300-400 in order to keep the unit-price within bounds, or else the F-35C carrier variant should be dropped altogether.

Given the difficulties that the Navy now faces in filling its ten carrier air wings, events may already be moving toward a reduction in the F-35C buy. In its budget submissions for the FY 2008 defense budget, the Navy added 32 F/A-18E/Fs to its planned buy, increasing

the total from 462 to 494. This increase in the F/A-18E/F buy suggests slippage toward more F/A-18E/Fs and fewer F-35Cs in Navy air wings. If that is where things are headed, then a better plan may be to cancel the F-35C altogether, extend F/A-18E/F production to fill out the Navy's carrier air wings, and push the Navy to field its Unmanned Air Combat System Demonstrator (UCAS-D) as early as possible. Since UCAS-D is projected to have 2-3 times the unrefueled combat radius of the F-35C, this option would add a medium-range platform to the Navy's carriers. By contrast, no matter how many F-35C are procured, its acquisition would still leave US carrier-based aviation without this critical medium-range strike capability.

More detailed, thoughtful, and strategically informed analysis should undoubtedly be done before the Defense Department decides on any specific alternative to the JSF program of record. But such analysis now appears to be at least a couple years overdue. The one unequivocal recommendation that can be made on the basis of this report is that a clear decision on the future of the F-35 program should be reached by senior Pentagon officials sooner rather than later.

Introduction to the Issues

Aim and Historical Context

The aim of this report is to highlight the near-term choices and dilemmas now facing the United States and the Department of Defense (DoD) in the area of fixed-wing air power. Since the Second World War, this category of military force or capability has become ever more central to the way in which the US military Services conduct high-intensity, non-nuclear combat operations. The most recent example of such operations is exemplified by the third phase of Operation Iraqi Freedom (OIF) during March-April 2003. Airman would probably add that even in what retired British general Rupert Smith has characterized as "wars amongst the people"—illustrated by OIF since May 2003—air power has assumed a greater role in Western practice.[1] Soldiers and marines would be quick to counter that while air power may have assumed a greater role in wars amongst the people, it has failed to produce clear-cut victory. Of course, neither has the presence of as many as 150,000 "boots on the ground" during OIF Phase IV—at least as of early 2007.

Although soldiers and marines may disagree with airmen over the decisiveness or importance of fixed-wing air power in the early 21st

[1] Rupert Smith, *The Utility of Force: The Art of War in the Modern World* (New York: Alfred A. Knopf, 2007), pp. 19-20.

century, the fact remains that the United States possesses the technologies and resources to maintain air arms second to none. Further, there is little chance that this strategic preference will be reversed in the foreseeable future. Thus, the issues of strategically prudent, tactically necessary and affordable air power modernization will continue to be real ones for the Department of Defense.

The difficulty of resolving these issues is exacerbated by the fact that fixed-wing air power is very capital-intensive. Bombers and fighters, together with the munitions they employ (whether for air control, strike, or the support of ground forces) along with the battle networks that provide targeting information, have become ever more expensive since the 1960s. The principal driver behind these increasing costs has been the platforms. The unit program-acquisition price (development plus procurement) of the 21 B-2 bombers that the US Air Force fielded in the 1990s was over $2.1 billion each (in then-year, or current, dollars).[2] The comparable average unit-acquisition price for the buy of 175 operational F-22s is around $338 million each, and that of the US Navy's 462 F/A-18E/Fs is now just over $95 million per jet.[3] Capital costs of these magnitudes for platforms alone inevitably raise questions about the affordability of, and need for, air-power modernization programs as ambitious as those the US Air Force, Navy and Marine Corps have been inclined to pursue since the Vietnam War.

Quite justifiably, then, concerns about DoD's fixed-wing modernization plans have become a recurring feature of American debates over national defense—especially since the 1960s. As far back as 1970, a special defense panel of the National Security Council raised the possibility that the United States might be "pricing" itself out of the long-term competition with the Soviet Union due to the much higher unit costs of American weapon systems. Strategists and defense analysts pointed out, for instance, that the US F-4 fighter-bomber, the work-

[2] Then-year, current, or nominal dollars do not remove the effects of inflation from one year to another. Existing data on the B-2 program do not permit conversion into constant dollars, which remove the effects of inflation. Hence these initial comparisons are given in then-year dollars.

[3] DoD, OUSD(AT&L) ARA/AM, "Selected Acquisition Report (SAR) Summary Tables," November 14, 2006, pp. 4, 5. Note, however, that Navy budget justification documents for FY 2008/2009 show a total of 494 F/A-18E/Fs.

horse of American tactical air (Tacair) power during the 1960s and 1970s, cost four times as much as the Soviet MiG-21 interceptor.[4]

During the late 1970s and early 1980s, defense "reformers" attacked the cost, size, and complexity of the large, two-engine F-15, arguing that its likely combat effectiveness could never justify its high price compared to the F-4. This line of argument—influenced by considerations of cost effectiveness and a preference for smaller, lighter and, hence, cheaper fighters—led both the Air Force and Navy to adopt a high-low mix in their post-Vietnam Tacair force structures. In the Air Force's case, only about 870 "high-end" F-15A/B/C/Ds were procured from 1974 to 1986 (of which around 500 remain in service).[5] By comparison, prior to the high-low-mix debate of the 1970s the Air Force accepted over 2,300 relatively high-end F-4C/D/Es. In addition to the F-15s, after Vietnam, the Air Force procured more than 2,200 "low-end" F-16s from 1978 to 2005 (of which some 1,315 are still in the active inventory).

The Department of the Navy's Tacair force structure exhibited a similar pattern after Vietnam. Prior to the high-low mix debate, the Navy and Marine Corps procured over 1,200 F-4B/Js. Subsequently, the Navy only bought some 740 F-14s armed with the long-range Phoenix missile. These high-end interceptors were designed to protect Navy carriers from air attack. On the low-end of the Navy Department's post-Vietnam mix, the Navy and Marine Corps procured 1,048 F/A-18A/B/C/Ds. The last of the F-14s were retired from operational service in 2006 and today the Navy operates approximately 350 F/A-18C/Ds and about 270 of the newer F/A-18E/Fs. Marine Corps squadrons operate just over 200 F/A-18A/B/C/Ds (as well as somewhat smaller inventory of AV-8B/C Harrier II jump jets). Like the Air Force's F-16s, the older F/A-18s are aging rapidly and becoming more difficult and expensive to maintain.

Looking back, the military reformers and other critics of high-end fighters like the F-14 and F-15 largely won the high-low-mix ar-

[4] In air-to-air combat in Southeast Asia during 1965-1973, US F-4s shot down around two MiG-21s for every F-4 lost to the Soviet interceptor.

[5] However, from 1988 to 2004 the Air Force accepted 238 strike versions of the F-15. Some 220 F-15E Strike Eagles remain in service, and are likely to be retained through at least 2025.

gument of the 1970s and 1980s in terms of overall Tacair force structure. Worth noting, though, is that the F-15 has proven far more effective in combat than anyone, even its proponents, anticipated at the time. The F-15's record in air-to-air engagements since 1979—currently 96-to-0 against opposing fighters—suggests that the reformers may have gone too far in denigrating its potential lethality in the hands of well-trained, proficient pilots.[6] Moreover, in initial operational evaluation and testing, the far more expensive but stealthy F-22 dominated older fighters, including the F-15, even when substantially outnumbered.[7] Nonetheless, the reformers' prediction that rising unit costs would eventually yield smaller and smaller buys of advanced fixed-wing platforms has been borne out by both the B-2 and F-22. In the early days of these programs, the Air Force planned to buy 132 B-2s and 750 F-22s. These quantities are a far cry from the existing inventory of 21 B-2As and an F-22 procurement now capped at 175 aircraft.[8]

The Choices Ahead

These issues of Tacair affordability and need have, if anything, grown more acute over the last decade. With regard to long-range strike platforms, the 2001 and 2005-2006 Quadrennial Defense Reviews (QDRs) both endorsed moving ahead to develop a B-2 follow-on after nearly a decade of recurring studies of options ranging from an improved B-2 to unmanned strike platforms, hypersonic vehicles and ballistic missiles. QDR guidance not withstanding, it remains any-

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[6] The F-15's combat record probably owes more to the superior training of the American, Israeli, and Saudi F-15 pilots than to the inherent superiority of the platform, its avionics, or munitions. Nonetheless, in the hands of skilled pilots armed with reliable missiles and backed by sensor platforms like the E-3 Air Warning and Control System (AWACS), the F-15 has proved astonishingly lethal against MiG-21s, MiG-25s, MiG-29s, and other opposing fighters.

[7] By and large, the F-22 pilots in the initial operational evaluation were able locate, target and "kill" opposing F-15s and F-16s with beyond-visual-range missile shots before the pilots of the older fighters were able detect them. Of course, the F-22 was the first fifth-generation fighter whose design aimed, from the outset, at maximizing pilot situation awareness.

[8] Program Decision Memorandum 753 (PBD 753), issued December 23, 2004, stopped F-22 procure beyond FY 2008 (p. 9). PBD 753 effectively limited the F-22A buy to 181 aircraft. Air Force backup budget materials for FY 2008/2009 indicate that production will now continue through FY 2009, but the total quantity is 175 aircraft.

one's guess whether the announced goal of fielding a new land-based, penetrating, long-range strike system by 2018 will be realized.[9] Similar doubts pertain to the fielding of conventionally armed ballistic missiles able to strike targets anywhere on the globe from the continental United States in less than an hour. On the one hand, the occasions when such a capability would be needed are likely to be relatively few and far between. On the other hand, as with a B-2 follow-on of any sort, the issue seems less one of technical feasibility than of institutional commitment by an air arm still overly focused on short-range fighters.

Turning then to Tacair, while the F-22 and F/A-18E/F procurements could be increased beyond currently planned quantities, the fact is that both airplanes are well along in their production runs. At the same time, the F-35 Joint Strike Fighter (JSF) is entering full-scale engineering development, and the program of record envisions an eventual US buy of 2,443 aircraft (excluding 15 developmental test aircraft, the first of which flew in December 2006). The goal of the JSF program is to produce three variants with a high degree of commonality (around 80 percent for the airframe):

1. a conventional take-off landing (CTOL) variant (designated the F-35A) for the Air Force;
2. a short take-off, vertical-landing (STOVL) variant (F-35B) for the Marines; and
3. the F-35C carrier variant (CV) for the Navy's big-deck aircraft carriers.

As of early 2007, the Defense Department's program envisions the US Air Force procuring 1,763 JSFs to replace its F-16s and some of its other tactical aircraft, and the Department of the Navy buying 680

[9] DoD, *Quadrennial Defense Review Report*, February 6, 2006, p. 46. Air Force justification materials for FY 2008/2009 contain a program element (0604015F) titled Next Generation Long Range Strike (NGLRS). The R-2 exhibit stated that a "wide variety of concept options are being considered for a Long Range Strike air platform"—Department of the Air Force (DoAF), *Fiscal Year (FY) 2008/2009 Budget Estimates: Research, Development, Test and Evaluation (RDT&E) Descriptive Summaries*, Vol. II, February 2007, p. 783. However, the R-2 also shows no funding for program element 0604015F during FY 2008-2010.

JSFs.[10] The mix of the Navy's 680 F-35s, between STOVL variants for the Marine Corps and CV variants for its carrier air wings, remains unsettled. However, unofficial indications suggest that this total will include some 350 STOVL versions of the F-35 for the Marine Corps and 330 CV variants of the aircraft for the Navy. In addition, the British plan to buy 138 JSFs (down from 150), although they are still considering the proper mix between the STOVL and CV models for the Royal Air Force and Royal Navy.[11]

The Defense Department has planned to procure some 2,433 F-35s since late 2002, when the buy was reduced by almost 400 aircraft. The unit procurement cost of the F-35A CTOL appears to be about $74 million in fiscal year (FY) 2008 dollars, with the cost of the F-35B STOVL and F-35C CV versions averaging about $97 million (see Table 2 in the next section).[12] Including research and development funding, the total cost of the US portion of the JSF program through 2034 comes to about $242 billion (in FY 2008 dollars). This makes it more expensive than any other DoD acquisition program, including the US Army's ambitious Future Combat Systems (FCS) family of sensors, munitions, and vehicles. The F-35 will also be, chronologically, among the Defense Department's longest acquisition programs. The Defense Department recently announced that production of the aircraft, which began in FY 2007, will continue through FY 2034 (vice FY 2027 in the previous plan). The magnitude of the resources needed to execute the program of record argues that affordability is a major issue for the F-35.

This reality suggests a further point. While it may be tempting to try to separate the need for this aircraft from its affordability, doing so is not really possible. As Charles Hitch and Roland McKean observed in 1960, "Resources are always limited in comparison with our wants, always constraining our action. (If they were not, we could do everything, and there would be no problem of choosing preferred courses of

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[10] Besides F-16s, the Air Force has also mentioned replacing some A/OA-10s and possibly all the F-117s with F-35s. The Air Force currently operates around 350 A/OA-10s and 55 F-117s.

[11] John A. Tirpak, "Struggling for Altitude," *AIR FORCE Magazine*, September 2006, p. 43.

[12] Authors' estimates based on DoD and CBO data.

action.)"[13] So while affordability and need will be the primary focus of successive parts of this report, there will necessarily be interplay between the two.

As daunting as the resource requirements of the F-35 may be, changes since September 2001 in the international security environment and the demands being made on the US military by operations in Iraq and Afghanistan raise equally fundamental questions about the need for the JSF. In light of the limited utility of fixed-wing air power in defeating the insurgency in Iraq and the Taliban in Afghanistan, should DoD modernization efforts over the next couple decades give greater priority to ground forces? In January 2007, newly confirmed Secretary of Defense Robert Gates recommended that Army and Marine Corps end strength grow by 92,000 soldiers and marines over the next several years. President George W. Bush endorsed this recommendation, which will require an estimated $100 billion in defense expenditures over the next six years, and $15-20 billion annually thereafter to sustain the additional force structure. In addition, the Army and Marine Corps face substantial "reset" costs to replace capital equipment being consumed in ongoing operations in Southwest Asia. While funding tradeoffs across Service boundaries remain politically and bureaucratically difficult, these developments certainly raise the issue of funding "boots on the ground" versus air power to a level that was not nearly as acute when the JSF program began in 1996.

Finally, beyond the preceding issues of priorities and resource allocation *between* the Services, there is one long-neglected recapitalization issue *within* the Air Force: new tanker aircraft for aerial refueling. Air Force, Navy and Marine Corps Tacair platforms are short range (i.e., have unrefueled combat radii of well under 1,000 nautical miles), which means they depend on aerial refueling to extend their range or duration on-station. Today, however, the mainstay of the Air Force's tanker fleet consists of 535 KC-135s (117 KC-135D/Es and 418 KC-135R/Ts), all of which were delivered to Strategic Air Command between 1957 and 1966.[14] Under the Air Force's latest plan, procurement of a new tanker is projected to begin over the next several years.

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[13] Charles J. Hitch and Roland N. McKean, *The Economics of Defense in the Nuclear Age* (New York: Atheneum, 1986; RAND 1960), p. 23.

[14] The Air Force also operates 59 KC-10s, which were delivered during 1981-1990. The KC-135s are modified 707s, and the KC-10s are modified DC-10s.

Affording these aircraft, as well as the new long-range strike system called for the 2006 QDR, in addition to the F-35, may prove difficult for the Air Force.

Broader Issues and Implications

Insofar as fixed-wing air power is concerned, the JSF program will be one of the top resource-allocation issues the United States military will face over the next decade. For this reason, the main focus of the rest of this report is the F-35. The principal findings that emerge from this initial, top-level look at the program of record are three:

1. Canceling the JSF program altogether would be unwise for both strategic and budgetary reasons. Strategically there is too much uncertainty about the future security environment to confidently conclude that no JSFs will be needed. From a budgetary perspective, the $29 billion already sunk in getting the plane to the brink of production (see Table 1) would be wasted if the F-35 was canceled this late in its development.

2. However, the magnitude of the JSF's planned resource commitment to short-range Tacair through 2034 appears unbalanced when framed in the context of the long distances—1,500-2,500 nautical miles—fixed-wing aircraft may need to go from their last air refueling to reach targets in Asia and other parts of the world outside Central Europe. Thus, if DoD *is* over-investing in short-range fighters, then some reduction of the planned JSF buy would be warranted.

3. As for how many F-35s should be bought, and which variants, precise options are beyond the scope of this brief report. There are too many uncertainties about the program, the Tacair demands of future conflicts and wars, and the extent to which those needs could be met by new systems such as unmanned combat air vehicles (UCAVs). That said, rough calculations indicate that DoD's procurement could be reduced by as much as 50 percent without necessarily driving unit-procurement prices through the roof or leaving close allies such as the British and the Australians, who also plan to buy the F-35, without an aircraft.

To preclude misunderstanding, this last observation is offered as a *sensible upper bound* on possible reductions in the numbers of F-35s to be procured by the US military, not as a specific proposal for a restructured program. As will become apparent in discussing both the affordability of the current program and the war-fighting need for the F-35, the underlying technical, financial, and operational issues are complex. For example, since the STOVL variant for the Marine Corps and the British is presumed by many to be the most challenging part of the program in terms of meeting weight and performance goals, observers have suggested simply deleting the F-35B. However, allies—particularly the British—have made substantial investments in the program. Eliminating the variant most desired by a close ally that has already invested the more than $2 billion in its development may not be the wisest choice from a political perspective.

This point reveals that any decision to restructure, much less cancel, the JSF program has broader implications going well beyond the usual criteria of cost, schedule, and performance—the terms by which major DoD acquisition programs are typically debated. One of those broader issues concerns the long-term ramifications on foreign perceptions of American military power in the event that the United States elects not to field so-called "fifth-generation" fighters beyond the 175 operational F-22s now planned.[15] Yet another issue that falls outside the narrow concerns of cost, schedule, and platform performance has to do with the relative importance of platforms, guided muntions, and battle networks in modern warfare. The late Vice Admiral Arthur Cebrowski argued during his tenure leading the Pentagon's Office of Force Transformation that the main source of combat power had shifted away from the industrial-age concept of massing platforms and munitions to the networks that supply military forces with information.[16] Yet, while the effectiveness of platforms and precision munitions are certainly enhanced by timely access to critical

[15] The F-22 is usually characterized as a fifth-generation fighter because of its all-aspect stealth, ability to cruise at Mach 1.5 without using afterburners ("supercruise"), and advanced avionics such as its AN/APG-77 active electronically scanned array (AESA) radar. Of late, proponents of the F/A-18E/F have labeled it a fifth-generation fighter even though it only has front-aspect stealth and cannot supercruise. The point is that the label "fifth-generation" does not have a precise meaning.

[16] William B. Scott an David Hughes, "Nascent Net-Centric War Gains Pentagon Toehold," *Aviation Week & Space Technology*, January 27, 2003, p. 50.

information, information alone is not sufficient to neutralize or destroy most targets. In fact, Cebrowski's paradigmatic example of a battle network, the US Navy's Cooperative Engagement Capability, remains essentially a targeting network designed to provide better tracking data on airborne threats to a surface action group defended by Aegis destroyers and cruisers armed primarily with Standard Missiles. These observations suggest that neither platforms nor guided munitions are minor components of military forces compared to battle networks. Consequently, there are broader, more strategic considerations that need to be taken into account in reaching a responsible decision to truncate the JSF program. These will be discussed more fully in exploring the need for the F-35 in the third section of this report. First, however, it seems prudent to consider its affordability.

Affordability

Cost of Current Fighter Modernization Plans

The centerpiece of the Services' long-term tactical aircraft modernization plans is the F-35 fighter. Altogether acquisition costs for this program are projected by DoD to total about $242 billion in FY 2008 dollars.[17] This includes some $45 billion for research and development (R&D) and $197 billion for procurement.[18] Of this total, about $29 billion has been provided through FY 2007, primarily for R&D (see Table 1). Thus, assuming the Services can meet current cost goals for the program, unit acquisition costs for the F-35 would amount to $99 million, while unit procurement costs would average $81 million for the aircraft. This average cost is somewhat misleading, however, since costs would vary considerably among the different F-35 variants.

The least expensive version would be the Air Force variant, the F-35A, which would have unit procurement costs of about $74 million.[19] In the case of the Navy and Marine Corps variants, the F-

[17] Unless otherwise noted, all figures cited in this chapter are expressed in FY 2008 constant dollars.

[18] The authors' estimate based on DoD and GAO data.

[19] Estimates of the unit procurement costs of the different variants of the F-35 provided in this report are the authors' based on DoD and CBO data.

35C and F-35B, unit procurement costs would be about $97 million—with costs being somewhat lower than this for the F-35B and higher for the F-35C.[20] As Table 2 shows, each F-35 would cost far more to procure than the older tactical aircraft it has been projected at various times to replace.

Table 1: Acquisition Funding for the F-35 Program (Billions of FY 2008 dollars)

Type of Funding	Through 2007	2008 & Beyond	Total
R&D	$28 B	$17 B	$45 B
Procurement	$1 B	$196 B	$197 B
Total	$29 B	$213 B	$242 B

Table 2: Costs of Selected US Fighter and Attack Aircraft (Millions of FY 2008 dollars)

Aircraft	Unit Procurement
A-10	$14 M
F-16A-D	$28 M
F-117	$73 M
AV-8B	$42 M
F-18A-D	$54 M
F-35A	$74 M
F-35B/C	$97 M

Source: CSBA estimates based on DoD and CBO data.

The total number of operational F-35s to be procured by the United States under current plans has not been changed since 2002, remaining at 2,443 of all types.[21] However, in the administration's FY 2008 defense budget submission, released in February 2007, the number of F-35s to be procured over the next four years was significantly reduced. Under last year's plan a total of 183 F-35s were

[20] The Navy has not, in recent years, provided separate estimates of the unit procurement costs of the F-35B and F-35C.

[21] Under current plans, another 15 aircraft to be used for testing would be purchased with R&D funds, for a total of 2,458 F-35s.

to be procured over the FY 2008-11 period. By comparison, the new plan calls for the procurement of 101 F-35s over these same years.

DoD recently announced that it would also reduce planned production rates for the F-35 over the longer term, and push back the completion date for the program. Under last year's plan, annual production of the F-35 was projected to reach 160 (including 110 Air Force and 50 Navy and Marine Corps variants) by around 2015, and remain at that level for roughly a decade before tapering off, with the last F-35s procured in FY 2027. Under the latest plan, production of the F-35 is to be extended to FY 2034. Consistent with this change, Air Force and Navy officials reportedly plan to reduce the maximum annual production rate for the F-35 (all versions) to about 115 per year.[22] Assuming the Services' can meet their cost goals for the program, implementing DoD's latest plan to buy 2,443 F-35s would require an average of about $7.3 billion a year in procurement funding over the FY 2008-34 period.

Funding requirements for the F-35 program could be higher, perhaps substantially so, if it experiences additional cost growth in coming years. Typically, weapon systems end up costing significantly more to acquire than they are initially projected to cost, in part because the costs associated with new cutting-edge technologies are frequently underestimated. The unit procurement cost projected for the F-35 has already risen substantially over the past decade. In 1997, DoD estimated that unit procurement costs would average about $60 million for the F-35—with those costs ranging from $56 million for the Air Force version to $67 million and $75 million, respectively, for the Marine Corps and Navy versions of the aircraft.[23] At $81 million, the most recent DoD estimate of the unit procurement cost for the F-35 (all versions) is about 35 percent higher than projected in 1997.

Some of this cost growth is due to the reduction in the overall number of aircraft to be procured (from 2,978 in the 1997 plan to 2,443 under the Services' current plans). Cutting procurement quantities tends to cause some loss of production efficiency, leading to

[22] Government Accountability Office (GAO), "Joint Strike Fighter: Progress Made and Challenges Remain," GAO-07-360, March 2007, p. 20.

[23] Lane Perrot, *A Look at Tomorrow's Tactical Air Forces* (Washington, DC: Congressional Budget Office, January 1997), p. 5.

higher unit procurement costs. But, given the relatively modest size of this reduction and the fact that it was announced several years ago, before the aircraft had entered even limited production, it seems unlikely that the reduction in the planned buy explains much of the cost growth.

Historically, the greatest growth in procurement costs typically occurs between the time the decision is made to move a new weapon system into full-scale development and the point at which it enters production. Since the F-35 entered full-scale development several years ago and the FY 2007 budget includes funding to begin procurement of the first F-35s, this may suggest that little or no further cost growth will occur.

On the other hand, additional cost growth is certainly possible. In a March 2007 report on the F-35 program, the Government Accountability Office (GAO) concluded, among other things, that the "degree of concurrency between development and production in the JSF program's acquisition strategy still includes significant risks for cost and schedule overruns."[24] Likewise, DoD's own Cost Analysis Improvement Group (CAIG) indicated to GAO in 2006 that it expected F-35 costs to be higher than estimated by the F-35 program office.[25] Moreover, recent experience with the F-22 program would also seem to suggest that, even at this stage in the F-35's development, further (perhaps significant) cost growth is possible.[26]

Deriving an estimate of how much, if any, additional cost growth the F-35 program might incur in coming years is beyond the scope of this report. However, given the size of the program, even modest additional cost growth could have significant budgetary consequences. For example, a further rise in unit procurement costs of just 10 per-

[24] GAO, "Joint Strike Fighter," p. 3.

[25] Ibid., p. 21.

[26] Some of the potential cost growth projected by GAO and the CAIG may already be captured in DoD's latest cost estimate for the F-35 program, since that estimate was publicly released only in April 2007, after the GAO report was published and after the CAIG had indicated to GAO that it expected further cost growth. However, according to DoD, most of the cost growth included in its latest estimate simply reflects the impact of stretching out the program (i.e., adopting a lower, less efficient production rate).

cent[27] would increase annual procurement funding requirements for the overall program by about $700 million, from some $7.3 billion to $8 billion, over the FY 2008-34 period.[28]

Although the F-35 is the focus of the Services' long-term tactical aircraft modernization plans, it is not the only element. Under current plans, over the next several years the Air Force will complete its purchase of F-22 fighters, and the Navy will complete its purchase of the F/A-18E/F and the electronic warfare variant of that aircraft, the EA-18G. Specifically, the Air Force will buy 40 F-22s over the FY 2008-09 period, while the Navy will buy 108 F/A-18E/Fs and 68 EA-18Gs between FY 2008 and FY 2012. Completing these programs will require about $21.4 billion in procurement funding. Adding these costs to the $196 billion needed for the F-35 program brings total procurement funding requirements for the Services' tactical fighter modernization plans to some $217 billion over the FY 2008-34 period, or an average of about $8 billion a year. If the F-35 program were to experience further cost growth of 10 percent, adding the cost of the F-22, F/A-18E/F and EA-18G programs would bring average annual procurement funding requirements for US fighter modernization programs to $8.8 billion over these years.

Affordability of Current Fighter Modernization Plans

It is unclear whether the Services' current tactical aircraft modernization plans are affordable given likely future budget levels, especially if the F-35 program experiences significant additional cost growth. Although DoD's recent decision to significantly reduce the annual production rate for the F-35 and to extend its production from 2027 to 2034 has increased the total acquisition costs projected for the program, by substantially reducing the *annual* funding requirements for the program, the change may have made the program more affordable.

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[27] Additional cost growth of this magnitude would result in unit procurement costs for the F-35 somewhat higher than those projected by CBO based on its analysis of historical relationships between price and aircraft performance. (Lane Perrot, *A Look at Tomorrow's Tactical Air Forces*, p. 5.) However, CBO also noted that, based on historical rates of cost growth, unit cost for the JSF could be higher than it projected. Ibid., p. 39. See also, ibid., Figure 7, p. 37.

[28] Although not considered in this analysis, it is also possible that the R&D portion of the F-35 program will experience additional cost growth.

In the past, funding for tactical combat aircraft has accounted for an average of about 9.9 percent of DoD's overall procurement budget.[29] If total DoD funding for procurement stays flat in real (inflation-adjusted) terms[30] at the level requested for FY 2008 ($102 billion), and the share of that budget allocated to fighter programs remains unchanged, the Air Force and the Navy (combined) would have an average of about $10.1 billion a year available for fighter procurement over the FY 2008-34 period.

This is $2.1 million a year more than would be needed to pay for the Services' procurement plans assuming current F-35 cost goals can be met. Even if the F-35 program was to experience further cost growth of 10 percent, this projected funding level would be some $1.3 billion a year above the level needed to meet the Services' funding requirements. By contrast, under the previously projected production profile for the F-35, covering the program's costs within a procurement topline averaging $102 billion a year would have been possible only if the share of funding allocated to tactical combat aircraft could be increased above its historical level.

Moreover, overall funding for procurement is projected to reach some $113 billion by FY 2013, the last year of DoD's most recent Future Years Defense Program (FYDP). If this level of funding could be sustained over the long term, covering the costs of the F-35 program would be even easier for the Services. In fact, viewed in these simple terms, the F-35 program would appear to be affordable even should DoD's overall procurement budget, in coming years, fall to its average annual level of the past 34 years, [31] or about $89 billion. This suggests that the restructured F-35 program may be affordable even if, as some expect, US spending on defense—which is now very high by

[29] These figures reflect funding over the FY 1974-FY 2007 period. Data limitations make it difficult to include earlier years in such an analysis.

[30] Unless otherwise noted, changes in funding levels or costs cited in this analysis are expressed in real terms using constant dollars.

[31] This period (FY 1974-2007) was selected to be consistent with the analysis of funding for fighter modernization. While overall DoD procurement budget data is available for earlier years, as noted earlier, such data is not available for fighter procurement in particular.

historical standards, even excluding war-related funding—declines in future years.[32]

On the other hand, despite the recently announced decision to reduce the annual production rate of the F-35, the program may still prove difficult to afford. Even if the defense budget topline is not reduced, competition from other areas of the DoD budget—namely, operations and support (O&S) and R&D activities—may force DoD to make significant reductions in procurement funding.

Funding requirements for O&S activities—driven by growing personnel, health care, equipment operations, maintenance and repair costs, and other factors—tend to increase persistently and substantially over time. Historically, this cost growth has been offset, to some extent, by cuts in the size of the US military. Current plans call for modestly cutting the end strength of the Air Force and the Navy over the next few years. But, as a result of the administration's recent decision to increase the permanent end strength of the Army and the Marine Corps by a total of 92,000 troops, overall, the size of the US military is projected to increase in coming years. With O&S costs per troop typically growing at some 2 percent a year, and overall end strength projected to increase, given a flat DoD topline, the share of funding absorbed by O&S would increase significantly over time—leaving progressively less funding available for weapons acquisition.

A second trend that is likely to exacerbate the pressures on procurement funding is the growth and resilience of defense research and development funding. Under current plans, the level of funding provided for defense R&D is projected to decline by some 20 percent over the next six years. In fact, under those plans, the increase in funding projected for procurement through FY 2013 would be paid for, in large part, by shifting funding out of the Services' R&D accounts and into procurement. In practice, however, it is unclear whether such a shift in resources will prove feasible. Historically, R&D and procurement funding have tended to move in the same direction. There has never been a sustained period over the past half century

[32] In particular, growing concerns about deficit spending, budgetary pressures related to the upcoming retirement of the baby boomer generation (and, specifically, the impact of demographic changes on Social Security and, particularly, Medicare spending) and continued resistance to tax increases, may make it politically difficult to sustain current levels of funding for defense.

during which procurement funding was increased while R&D funding was cut. Moreover, R&D funding has proven remarkably resistant to budget reductions, even during periods when overall funding levels for defense are in decline. For example, between FY 1985 and FY 1998, when total DoD funding was cut by some 36 percent and procurement funding was reduced by 66 percent, R&D funding suffered only a 16 percent cut. Weapons development efforts have also been plagued by cost growth that, in recent years, has been at least as dramatic as the cost growth impacting weapons procurement.

If, in addition to these internal O&S and R&D pressures, concerns about the federal deficit and other considerations lead Congress and future administrations to cut the defense topline, it may prove especially difficult to sustain procurement funding levels sufficient to fully fund the F-35 program, assuming tactical combat aircraft programs continue to receive only their historical share of procurement dollars. In that case, it might still be possible to afford the Services' existing fighter modernization plans if offsetting cuts could be made to other weapons programs. However, it could be difficult to make cuts in other procurement programs sufficient to fully cover the cost of these plans. Given the recently announced plans to substantially expand the size of the Army, its reset requirements related to ongoing military operations in Iraq and Afghanistan, and the Army's ambitious plans to modernize its inventory of combat vehicles, helicopters and other equipment, it seems unlikely that funding will be taken from Army procurement to help cover the costs of the F-35 program.

This means that the Air Force, Navy and Marine Corps would likely have to examine their own long-term procurement plans to find possible savings that could be shifted to the F-35 program. Shifting funding within the Air Force and Navy procurement budgets could also be difficult.[33] In the case of the Air Force, such funding shifts might only be possible if the Service made significant cuts in existing plans to modernize its long-range strike capabilities, tanker fleet or command, control, communications and intelligence assets. In the

[33] Both Navy and Marine Corps aircraft are funded through the Navy's procurement budget.

case of the Navy, providing additional funding for the F-35 program might require cutting existing shipbuilding plans.[34]

It is also unclear what the impact of extending production of the F-35 from 2027 to 2034 will have on the ability of the Services' to meet their existing force structure and readiness goals. Unless the Services plan to make cuts in the number or size of their fighter wings, stretching out the production of the F-35 will inevitably cause the average age of their aircraft inventories to increase beyond the already unprecedented ages projected in previous plans. In addition to raising readiness and capability concerns, this further aging of the Services' fighter forces could cause O&S costs to grow, at least partially offsetting the reduction in annual procurement funding requirements projected to result from the recent restructuring of the program.

Potential Savings Associated with Cutting the F-35 Program

As discussed in the first part of this report, it is unclear whether, from the standpoint of military capabilities and operational effectiveness, it is necessary or even prudent to move ahead with the F-35 program as currently constituted. Moreover, it is also unclear whether the current plan is affordable, given likely future funding levels for defense, and the competition the F-35 program faces from other DoD and Service priorities. If, for whatever reason, a decision is made to scale back the F-35 program in coming years, the level of savings that would result from that decision could vary substantially depending on a number of considerations. Among other things, these include: how many fewer aircraft are procured, how the cuts are implemented, and what offsetting steps are taken to compensate for the reduced purchase of F-35 aircraft.

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[34] It may be more likely that the Navy will be forced to shift funding from combat aircraft to shipbuilding. The Navy's current shipbuilding plan would require roughly doubling the amount of funding currently allocated to shipbuilding and maintaining funding at that level over the next 30 years. Eric Labs, "Resource Implications of the Navy's 2008 Shipbuilding Plan," CBO, March 23, 2007. See also, Robert O. Work, *Know When to Hold'Em, Know When to Fold'Em: A New Transformation Plan for the Navy's Surface Battle Line* (Washington, DC: Center for Strategic & Budgetary Assessments, 2007).

In this analysis, four illustrative options for scaling back the F-35 program are considered (see Table 3). The first option cancels the program entirely. The second option moves ahead as planned with the Navy and Marine Corps variants of the F-35, but cuts in half the planned purchase of Air Force F-35As. The third option is to continue as planned with the acquisition of the Air Force and Marine Corps variants of the F-35, but to cancel the Navy version of the aircraft. The fourth option is to reduce by half the Air Force's planned buy of F-35As and cancel the Navy's version of the aircraft. These options do not represent CSBA recommendations. Rather, they are examined because they reasonably bound the range of options that could be pursued.

The greatest savings would accrue if the F-35 program was cancelled outright and no F-35 aircraft were procured (Option 1). Direct savings from this cancellation would amount to some $213 billion (assuming no further cost growth) to $223 billion (assuming additional procurement cost growth of 10 percent) in R&D ($17 billion) and procurement ($196-216 billion) funding. However, *net* savings could be significantly lower. If the Services still intended to maintain the same number of fighter aircraft called for under current plans and wanted to prevent further aging of the fighter inventory beyond the level projected in those plans, they would have to purchase an alternative aircraft.[35] The least costly alternative might be to purchase the latest versions of fighters such as the Block-60 F-16 and the F/A-18E/F in place of the cancelled F-35s. These aircraft would be less capable than the F-35, but would generally be substantially more capable than the earlier models of the F-16, F/A-18 and other aircraft they would be replacing.[36]

[35] In February 2007 CBO examined the option of cancelling the F-35 and, instead, purchasing 2,443 Block-60 F-16s and FA-18E/Fs as one of over 250 budget options for the US Senate and House budget committees to consider during this year's deliberations on the FY 2008 federal budget. CBO, *Budget Options* (Washington, DC: CBO Publication No. 2921, February 2007), p. 13.

[36] Since the F/A-18E/F is not a STOVL aircraft, however, in at least this one respect it would be less capable than the AV-8B Harrier aircraft it would be replacing in the Marine Corps.

Table 3: Estimated Net Acquisition Savings for FY 2008-2034 from Canceling or Restructuring the F-35 Program (in FY 2008 dollars)*

Option	Description	Average Annual Savings
Option 1	Cancel all variants	$3-3.7 billion
Option 2	Cut Air Force buy in half	$300-500 million
Option 3	Cancel Navy variant	$450-550 million
Option 4	Cut Air Force buy in half, cancel Navy variant	$800 million to $1.1 billion

* Estimates include procurement and R&D savings, and are net of the costs associated with purchasing alternative systems in place of the forgone F-35s.

A reasonable estimate is that, if purchased in the same numbers and at the same annual rates currently projected for the F-35, the Block-60 F-16 and the F/A-18E/F would have unit procurement costs of about $50 million and $65 million, respectively. In this case, total procurement costs for this alternative would amount to about $132 billion between FY 2008 and FY 2034, or an average of $4.9 billion a year. Compared to the current plan, this option would save some $64-83 billion through FY 2034, or an average of $2.4-3.1 billion a year in procurement funding. Canceling further R&D on the F-35 program could save another $17 billion, for total savings of about $81-101 billion, or $3-3.7 billion a year through FY 2034.

Under Option 2, the development of all three versions of the F-35 would be completed, and the Navy and Marine Corps would purchase the full number of aircraft (680) projected in the current plan. The Air Force, however, would procure only half as many F-35As (882) as currently projected. Thus, the total number of F-35s (all versions) procured would be cut by about 36 percent, from 2,334 to 1,562. In place of the forgone F-35As, in this option the Air Force would buy an equivalent number of F-16 Block 60s. Under this option, a total of 2,443 new fighters would still be procured, but rather than 680 F-35B/Cs and 1,763 F-35As, the total would include 680 F-35B/C, 882 F-35As and 881 F-16 Block 60s.

Under this option, it is assumed that F-35 development costs would be unchanged from the current plan. Since 36 percent fewer F-35s would be procured than called for in the current plan, there

would be significant savings in Tacair procurement funding. However, those savings would amount to less than 36 percent of the direct savings in procurement funding that would accrue if the F-35A program was canceled outright. This is because reducing the number of aircraft to be produced would likely lead to increased unit procurement costs. The marginal cost of producing additional aircraft (or any other item) tends to decrease, among other things, because each additional aircraft produced moves the manufacturer further down the learning curve.[37] Conversely, truncating planned purchases precludes the achievement of this same level of efficiency and, thus, tends to result in higher unit procurement costs.

While reducing the number of F-35As to be produced would almost certainly lead to some increase in unit procurement costs, it is unclear just how much of an increase it would cause. Depending on the extent to which the various versions of the aircraft do, or do not, make use of common parts and common production facilities, the impact of a cut in quantity on unit procurement costs could vary substantially. A reasonable estimate, based on historical and other evidence from similar programs, and assuming a moderate level of commonality in production, is that reducing by half the number of F-35As to be produced would lead to an increase in unit procurement costs of some 15 percent for the F-35A, and an increase of some 5 percent for the Navy and Marine Corps versions of the aircraft.[38]

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[37] An 85-percent learning curve, for example, means that the unit-production price declines 15 percent every time the number of units produced doubles. Industry usually assumes roughly an 85-percent learning curve for advanced combat aircraft.

[38] The following methodology was used to generate these estimates of the affect of cuts in procurement quantities on unit procurement costs: First, an estimate was made based on the assumption that the production of all variants of the F-35 operated along a single (85 percent) learning curve (i.e., that there is perfect commonality between the different variants). Second, an estimate was made based on the assumption that each variant of the F-35 operated along a separate (85 percent) learning curve (i.e., that there is no commonality). Third, estimates were derived for each variant of the F-35 which assumed that the impact on unit procurement costs would fall at the midpoint between the two previous estimates. These last estimates were then used to calculate the cost impact of changing procurement quantities. This same methodology was also used in Options 3 and 4.

Total procurement costs for Option 2's truncated F-35 buy would amount to $144-158 billion over the FY 2008-34 period.[39] In addition, some $44 billion would be needed to pay for the Block-60 F-16s that would be procured under this option. Altogether, net savings under this option would amount to $8-14 billion, or $300 million to $500 million a year.

Under Option 3, the Air Force and Marine Corps variants of the F-35 would be purchased in the numbers called for in the current plan, while the Navy's version of the aircraft, the F-35C, would be cancelled. Although DoD has not, in recent years, publicly stated how many of the 680 F-35B/Cs called for in its current plan would be Navy F-35Cs and how many would be Marine Corps F-35Bs, as noted earlier, a reasonable estimate is that 330 of the former and 350 of the later would be purchased. Thus, canceling the F-35C would cut the total number of F-35s (all versions) to be produced by about 14 percent, from 2,443 to 2,113. In place of these forgone F-35Cs, Option 3 assumes that the Navy would procure an equivalent number of F-18E/F aircraft (or a combination of F/A-18E/Fs and Navy UCAVs[40]).

Since the total buy of F-35s would be cut much less deeply in this option than in the previous one, and because the reduction would come through the outright elimination one of the variants, the impact of this option on the unit procurement costs of the remaining F-35s to be procured would presumably be relatively modest. Specifically, it is assumed that under this option unit procurements costs for the F-35A and F-35B variants would increase by only some 2 percent.[41]

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[39] The lower figure assumes the F-35 incurs no further cost growth (exclusive of growth in unit procurement costs associated with changing the procurement quantity), while the higher figure assume a further 10 percent cost growth (again, exclusive of cost growth caused by changing the procurement quantity).

[40] In estimating costs and savings under this option, it is assumed that the Navy UCAV would have unit procurement costs similar to that of the F/A-18E/F. This appears to be consistent with CBO's estimate of unit procurement costs for the Navy UCAV. CBO, "The Long-Term Implications of Current Defense Plans and Alternatives: Detailed Update for Fiscal Year 2006," January 2006, p. 36.

[41] For an explanation of the methodology used estimate the impact of changing procurement quantities on unit procurement costs, see footnote 38.

This option would cut total F-35 procurement funding requirements to $166-183 billion over the FY 2008-34 period. In addition, some $22 billion would be needed to pay for the additional F/A-18E/Fs that would be purchased. Altogether, net savings under Option 3 would amount to $9-12 billion, or $300 million to $450 million a year. Since no F-35Cs would be procured, there would be no need to complete development of that version of the aircraft. Thus, this option would also generate some savings in R&D. A reasonable—though perhaps high—estimate is that canceling the Navy's version of the F-35 would yield R&D savings of some $3.5 billion. This would increase total annual savings under this option to some $450 million to $550 million.[42]

Under Option 4, it is assumed that DoD would cut in half the planned buy of the F-35As (Option 2) and cancel the F-35C (Option 3). In place of these forgone aircraft, it is also assumed (consistent with Options 2 and 3) that the Air Force would buy an equivalent number of Block-60 F-16s and the Navy would buy an equivalent number of F/A-18E/Fs. Thus, under Option 4, the total number of F-35s (all variants) to be procured would decline by about 50 percent, from 2,443 to 1,232. Total F-35 procurement costs, under this option, would be $112-123 billion over the FY 2008-34 period.[43] In addition, some $66 billion would be needed to pay for the Block-60 F-16s and F/A-18E/Fs that would be procured under this option. Altogether, net savings would amount to $22-30 billion, or $800 million to $1.1 billion a year.[44]

Possible strategic rationales for selecting one or another of the four options described above are discussed in the next section of this report. However, as noted earlier, these options are offered primarily for illustrative purposes, and do not represent CSBA recommenda-

[42] This estimate assumes that roughly half of the R&D funding projected in future Navy budgets for the F-35 program is for the F-35C variant (with the remaining R&D funding allocated to the F-35B variant), and that all of this funding could be saved if development of that variant was cancelled. This may overstate the likely level of savings, since some portion of the Navy's R&D budget for the F-35 may be for systems common to both the F-35B and C versions.

[43] For an explanation of the methodology used estimate the impact of changing procurement quantities on unit procurement costs, see footnote 38.

[44] As with Option 3, this includes about $3.5 billion in R&D savings.

tions. It is also important to understand that the level of savings that could be achieved by canceling or scaling back the F-35 program is highly sensitive to a number of assumptions made in the above analysis, around which substantial uncertainty exists. Changing those assumptions could markedly increase or decrease the estimated savings. These areas of uncertainty include assumptions about:

- additional cost growth in the F-35 program, exclusive of cost growth caused by reducing procurement quantities (e.g., cost growth associated with technological risk);
- the impact of reductions in procurement quantities on unit procurement costs; and
- the unit procurement costs that could be achieved for alternative current-generation systems, and the F-16 Block 60 in particular.[45]

For example, if the F-35A program suffered further cost growth of 20 percent (exclusive of quantity-related cost growth), halving the number F-35As procured raised unit procurement cost by only 10 percent (rather than 15 percent) and the Block-60 F-16 could be procured for $45 million each (rather than $50 million), then net savings under Option 2 would increase to $34 billion, or about $1.25 billion a year, over the FY 2008-2034 period. Conversely, if the F-35A experienced no additional cost growth (exclusive of quantity-related cost growth), halving the number F-35As procured raised unit procurement cost by 20 percent and the Block-60 F-16 cost $55 million each, savings under this option would fall to essentially zero.

Another potential option for the Air Force, Navy and Marine Corps would be to cut their fighter force structure and use the savings accrued either to help pay for the F-35 program, or to increase the level of savings that could be achieved by canceling of scaling back that program. The level of savings that could result from cutting fighter force structure is difficult to ascertain. Among other things, this is because it is unclear how much reducing this force structure would allow the Services to also make cuts in training, support and other ca-

[45] Estimating the unit procurement costs of the F-16 Block 60 is difficult because it is currently being produced only in very small numbers for export, and the US Air Force has never procured this version of the F-16.

pabilities. However, the savings could be significant. Over the long-run, for example, reducing the number of Air Force fighter wings by just 10 percent could yield average annual savings in O&S activities of as much as $2 billion a year. Such a force structure cut might also allow the Service to reduce the number of fighters it needs to buy over the next two decades by 10 percent, providing perhaps $400-450 million a year in procurement savings. Moreover, because the oldest fighters in the Air Force's inventory would be retired first, under this option the average age of its fighter forces would be kept somewhat lower then under the current plan. This improvement might, in turn, yield some additional O&S savings.

These savings are quite large compared to those that are likely to be achieved in the absence of any force structure cuts. Instituting future cuts in force structure would also appear to be consistent with long-term trends in the US military generally, and US air forces in particular. Over time, the number of US combat aircraft has declined significantly. Implicitly, this trend appears to reflect a belief that as combat aircraft become more capable (and costly) it is not necessary (or possible) to replace those systems on a one-for-one basis.

Strategic and Tactical Needs

Is Cancellation Prudent?

The obvious benefit of canceling the F-35 and purchasing older-generation fighters now in production would be to save an estimated $81-101 billion (Option 1 in the previous section). Doing so would also have the virtue of avoiding the possible expense of further cost growth in the JSF program, which some observers see as likely given the F-35's sophistication and the challenges of building different variants for the US Air Force, Navy and Marine Corps. Is this option prudent from the perspective of operational needs? CBO has suggested that Congress consider this option—observing that the transfer of "upgraded radar systems, precision weapons, and digital communications" to older fighters may provide capabilities "sufficiently advanced to meet the threats the nation is likely to face in the foreseeable future."[46]

The strategic difficulty with the view that Block-60 F-16s and F/A-18E/Fs are "good enough" is that it ignores the substantial uncertainties regarding America's national-security needs over the next several decades. The initial operational capability (IOC) for the F-15 was

[46] CBO, *Budget Options* (Washington, DC: CBO Publication No. 2921, February 2007), p. 13. The option of canceling the JSF in favor of Block-60 F-16s and F/A-18E/Fs is simply a budget *option*, not a CBO recommendation.

in 1975. Some 500 of these fighters are still in service 32 years later, and there is good reason to expect that fifth-generation fighters such as the F-22 and JSF will have comparably long service lives. Given this likelihood, it is surely necessary to take seriously, among other prospects, the possibility that the People's Republic of China (PRC) might emerge as a major military adversary to the United States during the next several decades. Or, short of that, there is the prospect that the government in Beijing might feel compelled to seize Taiwan by force, and in that contingency JSFs operating from aircraft carriers could well prove essential in coping with China's anti-access/area-denial capabilities.[47] Furthermore, PRC military doctrinal writings have included in so-called "non-war" uses of military force, not only missile firings into the Taiwan Strait and amphibious exercises, but also "air and missile strikes, assassinations, and sabotage."[48] Such thinking certainly suggests that there is a real possibility of an accidental or inadvertent conflict with the PRC. American policy should, of course, do everything possible to preclude overt military rivalry, much less open conflict, between the United States and the PRC. Nevertheless, if relations between the two countries fail to turn out as hoped or the PRC's leaders feel compelled to risk using force against Taiwan, can one really be confident that the more advanced capabilities of the F-35, including all-aspect low observability and other features, will not be needed? Implicitly at least, dismissing any future need for the JSF's advanced capabilities is the bet contained in a decision to cancel the F-35 altogether.

Certainly in the case of China, this bet about the future appears to be a risky one. The PRC's military is already operating some fairly advanced Soviet fighters and surface-to-air missile (SAM) systems. Examples include the Su-30MKK multi-role fighter, the Su-30MK2 maritime-strike aircraft, the S-300PMU-1 (or SA-10) SAM, and the

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[47] For a discussion of the difficulties posed by such capabilities, see Andrew Krepinevich, Barry Watts and Robert Work, *Meeting the Anti-Access and Area-Denial Challenge* (Washington, DC: Center for Strategic & Budgetary Assessments, 2003). Anti-access strategies aim to prevent the entry of US forces in a theater of operation. Area-denial operations aim to limit the freedom of action of US forces within areas under the enemy's direct control.

[48] Office of the Secretary of Defense (OSD), *Annual Report to Congress: Military Power of the People's Republic of China*, 2006, p. 14.

SA-N-20 naval SAM for its LUZHOU-class (Type 051C) destroyers.[49] Beijing also has negotiated an agreement with Russia for indigenous production of the Su-27SMK, is working to reverse-engineer a domestic version of the S-300 SAM (the HQ-9), has completed development of an indigenous "4th-generation" fighter (the F-10), and recently demonstrated an anti-satellite capability against low-earth satellites. More broadly, the Chinese military is endeavoring to develop anti-access/area-denial capabilities extending out to the first-island chain off of its coast (Japan, Okinawa and the Philippines). These capabilities include the ability to conduct precision strikes against US bases such as Kadena Air Force Base on Okinawa and US aircraft carriers in the western Pacific.[50] Such aspirations and efforts to realize them suggest that cancelling the JSF might prove a strategic mistake in the long run. As long as significant uncertainty persists about whether the rise of China will produce a military competitor or a responsible member of the global community, prudence dictates a hedging strategy on the part of the United States, and the JSF can be plausibly seen as a component of such a strategy.

To repeat, the American aim is to dissuade China from becoming a military adversary or, failing that, to deter conflict with the PRC in Asia and the Pacific or elsewhere. However, perceptions of military power matter. There is growing evidence in Chinese debates about the future security environment that the US "hegemon" is perceived as a declining power, and that many Chinese writers expect the world of 2010-2030 to be a turbulent, multi-polar one resembling China's "Warring States" period of some 2,500 years ago.[51] For the United States to cancel the JSF program after investing $29 billion in its development seems likely to encourage Chinese inclinations to see US power and resolve as inevitably declining relative to their own. Such perceptions, in turn, are unlikely, over the long haul, to promote US dissuasion and deterrent goals with regard to China. Granted, if the money saved from canceling the JSF were to be invested in military capabilities even more worrisome to the Chinese, then the decision

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[49] OSD, *Annual Report to Congress: Military Power of the People's Republic of China*, pp. 4-5.

[50] OSD, *Annual Report to Congress: Military Power of the People's Republic of China*, pp. 25-26, 27-29.

[51] Michael Pillsbury, *China Debates the Future Security Environment* (Washington, DC: National Defense University Press, 2000), pp. xxiii-xxvii.

might not embolden the PRC's leaders. But as will emerge in the discussion of long-range capabilities below, there appears to be considerable resistance to such alternatives within the US military Services.

The preceding argument presumes that canceling the F-35 altogether and instead procuring similar numbers of fighters currently in production would preclude adding at least some advanced capabilities to the US Tacair inventory. In this regard, it is legitimate to note that Block-60 F-16s and F/A-18E/Fs substituted for JSFs would undoubtedly be equipped with active electronically scanned array (AESA) radars and digital communications. The older fighters would also be capable of employing precision munitions such as laser-guided bombs, Joint Direct Attack Munitions, and Small Diameter Bombs.[52] But these capabilities, which are largely common to the Block-60 F-16, F/A-18E/F, F-22 and F-35, ignore the more significant advances inherent in the JSF.

From a life-cycle standpoint, the most important of these is the F-35's "open" avionics architecture. In all prior US combat aircraft built since the advent of solid-state electronics, the designers have been forced, early in engineering development, to settle on specific microprocessors for the plane's sensors, targeting systems, cockpit displays, and other avionics systems. The result of these previously unavoidable choices has been that, by the time the aircraft reached operational service, the microprocessors inside it were already obsolescent compared to state-of-art commercial computer technology. The reason is that, since the early 1960s, the number of transistors engineers have been able to put onto a single microchip has been doubling every 24 months or so in accordance with the "law" Gordon E. Moore first proposed in 1965. While one can question, as Moore himself did in 2005, how much longer this regular doubling of computational power can or will continue, the practical consequence has been that wholesale avionics upgrades of combat aircraft have been difficult and costly—especially if software has to be rewritten. The JSF's open architecture has sought to overcome this problem by designing system software that will continue to work even when the individual microchips in its Common Integrated Processors (CIPs) have been replaced by newer, more powerful models. This feature of the F-

[52] The first deliveries of Block-60 F-16s with APG-80 AESA radars were to the United Arab Emirates and took place in May 2005.

35's avionics architecture has already been successfully demonstrated in the laboratory in moving from Motorola G4 to G5 chips.[53] It will make the JSF the first combat aircraft whose computational capabilities will be able to keep pace with advances in the commercial computer industry at affordable costs.

Another feature of the JSF is all-aspect low observability that, when combined with suitable employment tactics, yields stealth. While some modifications have been made to late-model F-16s and the F/A-18E/Fs to lower their front-aspect radar signatures compared to earlier models, the fact remains that the F-35 is the only one of these three designs in which all-aspect signature reduction was a major design goal from the outset. With an eye toward recent operations in Iraq and Afghanistan, some have argued that the B-2 and F-22 will provide enough all-aspect "stealth" platforms for the foreseeable future. Here the view seems to be either that only a small fraction of American's fixed-wing inventory will ever need to penetrate enemy air defenses before they are sufficiently rolled back or suppressed for less stealthy aircraft to be survivable, or else that front-aspect stealth will be adequate even in high-threat environments. These views may well prove to be right much of the time. However, the rest of the time they could prove tragically mistaken. Again, those inclined to cancel the JSF outright seem to assume that operational requirements over the next several decades will not be appreciably more challenging than those the US military has confronted in recent years. From a long-term perspective, though, this appears to be a fairly risky assumption.

Other opponents of the JSF argue that low observability is of declining value due to ongoing advances in radar detection and tracking. Two systems usually mentioned in this regard are the Australian Jindalee over-the-horizon (OTH) radar and the Czechoslovakian VE-RA-E. Jindalee is an active radar that uses wavelengths around 10-60 meters and frequencies of 5-30 Megahertz (MHz).[54] These are long wavelengths and low frequencies compared to those used by X-band

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[53] By comparison, the B-2's avionics are using a militarized version of the pre-Windows Intel 286 processor, and the F-22's CIPs are running i960 chips comparable to the Intel 386.

[54] 1 MHz = 1,000 Hertz (cycles per second). The relationship between frequency, f, and wavelength, λ, is $c = f\lambda$, where c is the speed of light in a vacuum (299,792,458 meters/second).

fire-control radars for guiding air-to-air and surface-to-air missiles to airborne targets. X-band radars use wavelengths around 2.5-3.75 centimeters and frequencies of 8-12 Gigahertz (GHz).[55] Consequently, while long-wavelength OTH radars like Jindalee may be able to detect and roughly track F-22s and B-2s, they lack the resolution for precise location or missile guidance. The best they can do is detect, localize, and loosely track stealth aircraft. They can then alert SAMs and interceptors to the presence of stealthy aircraft, and direct defending interceptors to a general area. But defending fighters and SAM batteries still have to acquire the intruders with their own fire-control radars, which typically operate in the X-band where B-2s and F-22s are the most difficult to detect.[56]

VERA-E, by contrast, is a passive system that endeavors to triangulate and track airborne targets using the electronic signals they generate when using on-board radars, transponders, jammers and other electronic equipment. Suffice it so say that the F-117, B-2, and F-22 can negate VERA-E by controlling their electronic emissions. So neither long-wavelength OTH radars nor passive systems like VERA-E argue that low observability against fire-control radars has suddenly lost its tactical value. Signature reduction does not confer invisibility to radar, as the loss of an F-117 to Serbian SAMs in 1999 illustrates. Properly understood, stealth results from the combination of signature reduction with appropriate employment tactics. Jindalee and VERA-E simply demonstrate that the aircrews of stealth aircraft operating in the presence of these systems will need to pay closer attention to their employment tactics.

One further point warrants mention regarding the JSF's advanced capabilities. Since the final years of the Vietnam War, airmen have accumulated a growing body of empirical data arguing the pilot situation awareness (SA) is the dominant factor in air-to-air engagements around 80 percent of the time.[57] Soldiers and marines have

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[55] 1 GHz = 1,000 MHz, 1 MHz = 1,000 Hertz, and 1 meter = 100 centimeters.

[56] For a discussion of how radar signatures vary with aspect and frequency, see Rebecca Grant, *The Radar Game: Understanding Stealth and Aircraft Survivability* (Arlington, VA: IRIS Independent Research, 1998), pp. 30-32.

[57] Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects* (Washington, DC: Center for Strategic & Budgetary Assessments, 2007), pp. 45-56.

reached similar conclusions based on their own tactical training and experiments. In 2003, for example, the Stryker certification exercise at the Joint Readiness Training Center indicated that the increased SA of the networked Stryker brigade provided an order-of-magnitude improvement in effectiveness when compared with a non-digitized light-infantry brigade.[58] The F-22 was the first American fighter designed to maxime a pilot's situation-awareness advantage through a combination of low observability, speed, and sensors. All indications are that the JSF's sensor suite and low observability will provide a significant step in this direction, possibly beyond even the F-22, but *well beyond* anything late-model F-16s or F/A-18s will be able to provide.

If one looks beyond bare costs and takes into account the political, strategic, and operational benefits of continuing the F-35 program, the case for outright cancellation appears weak and risky—even if JSF variants turn out to cost as much more to procure than Block-60 F-16s and F/A-18E/Fs, as suggested in the preceding discussion of affordability. Politically, cancellation would leave close allies without advanced aircraft on which they are planning and possibly confirm perceptions, especially in China, of growing American weakness. Some in the Air Force probably would prefer to cancel the JSF and buy more F-22s instead. Politically, however, doing so would leave the Navy, Marine Corps, Great Britain, and other allies without a relatively affordable and readily upgradeable 5th-generation fighter. Strategically, cancellation would signal US willingness to abandon its longstanding position as the world's leader in advanced combat aircraft, a decision likely to be regarded warmly in both Beijing and Moscow. Canceling the F-35 program would also embrace the considerable risk that security challenges three or four decades in the future will not prove appreciably more challenging for America's fixed-wing air power than current operations in Iraq and Afghanistan. And, operationally, doing so would forego the JSF's advanced capabilities despite the $29 billion of sunk cost already invested in developing them.

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[58] Daniel Gonzales, Michael Johnson, Jimmie McEver, Dennis Leedom, Gina Kingston, and Michael Tseng, *Network-Centric Operations Case Study: The Stryker Brigade Combat Team* (Santa Monica, CA: RAND, 2005), pp. 104-106.

Long versus Short Range

The arguments in the preceding section only establish that *some* JSFs should be procured. They do not address how many should be bought or which variants. From a strategic perspective, the principal reason to consider buying fewer than the 2,443 JSFs called for in current DoD plans stems from the *short* range of all three variants. In a 2005 CSBA report, *short-range* was defined as fixed-wing aircraft with an unrefueled combat *radius* between 500 and 1,500 nautical miles (nm), or a similar one-way *range* for missiles such as the UGM/RGM-109 Tomahawk Land Attack Missile (TLAM). [59] Figure 1 shows the corresponding radius/range bands for *medium*- and *long-range* aircraft and missiles.[60] As mentioned in the introduction, the F-35 program of record plans to invest some $242 billion in short-range platforms. Because none of the JSF variants are likely to have unrefueled combat radii of as much as 700 nm in a clean configuration (no external stores), this investment falls in the left half of the short-range band depicted in Figure 1.[61] Granted, there are ways of extending the unrefueled reach of these aircraft. However, even with the addition of reduced-signature external-fuel tanks and stealthy standoff munitions such as the new AGM-158 Joint Air-to-Surface Standoff Missile (JASSM), the reach of the F-35 is unlikely to extend beyond 1,500-nm, thereby putting the combined system into the medium-range category. Even with external tanks plus a pair of extended-range (ER) JASSMs, the JSF's reach probably falls shy of the 1,500-nm threshold for medium-range. Among other reasons, the baseline AGM-158 is too large to be carried inside the F-35's weapon bays, and a pair of under-wing fuel

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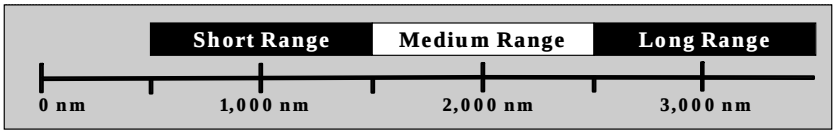
[59] Barry D. Watts, *Long-Range Strike: Imperatives, Urgency and Options* (Washington, DC: Center for Strategic & Budgetary Assessments, April 2005).

[60] The definitions of *short range*, *medium range*, and *long range* in Figure 1 are not entirely arbitrary. Centering long-range on an unrefueled combat radius of 3,000 nm reflects the performance attainable by heavy bombers using modern airframe and engine technologies (Watts, *Long-Range Strike*, p. 4).

[61] According to a September 2006 briefing by the program manager, the JSF variant with the longest unrefueled combat radius is the F-35C at "650+ nm" (Brigadier General Charles R. Davis, "F-35 Lightning II Program Brief," September 26, 2006, slide 26). However, combat radii for the different JSF variants have not all been calculated on the same mission profile, which makes direct comparisons problematic.

tanks plus two JASSMs tends to induce considerable drag and, possibly, degrade the aircraft's stealthiness.[62]

Figure 1: Unrefueled Radius/Range Regimes



In the cases of emergent, relocatable, moving, or time-sensitive targets, the theoretical maximum unrefueled reach of the JSF inside defended airspace tends to be an upper bound at best, since the aircraft will need to conserve some (and perhaps much) of its fuel to allow for sufficient loiter time over the suspected target area. In exploring the primary mission requirements for a future air-breathing, long-range strike system, the overriding design criteria arguably should be the aircraft's persistence and survivability inside defended airspace. Such persistence would enable the aircraft to loiter long enough for hidden or fleeting targets to reveal themselves.[63] Any appreciable time spent waiting for such targets to emerge obviously reduces the attainable mission radius. Moreover, current and prospective US adversaries have not been slow in recognizing that they can negate American precision-strike capabilities by locating critical targets deep inside their defended airspace, relocating them within US sensor-to-shooter cycle times, or keeping them hidden the majority of the time.[64] Mobile missile launchers provide a classic illustration of how hiding and the ability to move about can combine to deny US strike systems the pre-

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[62] Davis, "F-35 Lightning II Program Brief," September 26, 2006, slide 38. Generously granting the longest-range JSF a combat radius of 700 nm and adding 20 percent due to external-fuel tanks only yields a combat radius of 840 nm. The baseline JASSM would theoretically extend the JSF's reach another 200-300 nm and the ER JASSM 500-600 nm. Perhaps some additional range could be gained by jettisoning the drop tanks as soon as they run dry, but doing so is unlikely to be a standard operating procedure with low-signature tanks—especially operating off an aircraft carrier.

[63] Watts, *Long-Range Strike*, p. 56.

[64] In the 1991 Gulf War, the Air Force initially claimed that its aircraft had destroyed about 100 mobile Scud missile launchers located inside Iraq. After the war, however, it was determined that the Iraqi military possessed only some 20 such launchers, and that none of them had been destroyed during the course of the conflict.

cision-targeting information they need to be effective. During the 1991 Persian Gulf War, for example, it appears that US fixed-wing aircraft were unable to destroy any of Iraq's mobile, short-range ballistic missile launchers despite a considerable effort to do so.[65]

In light of the uncertainties about the future security environment, it would be foolhardy to speculate on the percentages of total targets that might require medium or long range in future conflicts. Nevertheless, it does not require much map study to realize that the distances from the last air refueling to many targets in the Western Pacific and Asia may not be accessible to short-range aircraft except under the most favorable of situations. China in particular has the strategic depth to locate key facilities beyond the reach of short-range systems. For example, the PRC's spaceport at Jiuquan is located in north-central China on the southern edge of the Gobi Desert. US strike aircraft setting out from Kadena Air Force Base in Okinawa would have to fly some 1,600 nm to reach Jiuquan, and all but 200 nm of that distance would be through Chinese airspace. By comparison, the direct distance from Ramstein Air Force Base in Germany to the former Soviet SU-24 FENCER base near Szrprotawa in southwestern Poland, is about 330 nm. Short-range Tacair could readily cope with such modest mission radii even without air refueling, and many former Soviet air bases in East Germany were closer than Szrprotawa to NATO (North Atlantic Treaty Organization) airfields. In Asia, though, the distances alone can demand medium range. If one tacks on sufficient loiter time in defended airspace for various emergent or time-sensitive targets to reveal themselves, then many missions would probably call for long range.

The contrast between representative range requirements in Central Europe during the Cold War and those of Asia and the Western Pacific in the 21st century warrant two further observations. First, the use of the Jiuquan spaceport in the illustration above is not meant to imply that this spaceport *will* be a critical target in some future US-PRC conflict, although the recent testing of a direct-ascent anti-satellite system by the Chinese certainly indicates that it could be. As Strategic Command's General James Cartwright recently noted, the PRC is working on a wide range of capabilities aimed at denying the

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[65] Thomas A. Keaney and Eliot A. Cohen, *Revolution in Warfare? Air Power in the Persian Gulf War* (Annapolis, MD: Naval Institute Press, 1995), p. 78.

United States full use of its assets in orbital space.[66] What Jiuquan does illustrate is just how deep inside China some of the targets are located that the United States might wish to hold at risk for purposes of dissuasion and deterrence.

Second, long range can have an important military utility even when fixed-wing aircraft do not have to penetrate long distances or operate in defended airspace. Long range also provides aircraft with the capability to loiter over target areas for extended periods of time: the fuel fraction, lift-to-drag ratio, and other parameters that enable an aircraft to fly long distances can also be converted into substantial loiter time.[67] The importance of this capability has been clearly demonstrated in recent conflicts in which heavy bombers armed with JDAMs have been used to provide friendly ground forces with round-the-clock, all-weather, on-call fire support. The long range capability needed to provide long-duration on-station times is much easier to achieve with heavy bombers than with today's tactical fighters.

A further complication, given the growing evidence of the Chinese military's commitment to developing anti-access/area-denial capabilities, is that airbases such as Osan in Korea or Kadena will eventually be within the reach of the PRC's growing inventory of ballistic missiles with terminal, precision guidance—if they are not already at risk. As this capability matures, US carrier battle groups and land-based air forces could be forced to operate from as far away from the Chinese mainland as the so-called second island chain, which includes Guam in the Mariania Islands. True, even short-range fighters could operate from Anderson Air Force Base on Guam with sufficient air refueling. However, the support "overhead" (including tanker requirements) and the practical difficulties are substantial at such distances—especially for fighter crews.

These observations suggest that the sheer magnitude of the JSF program's resource commitment to short-range platforms is unbalanced in the absence of convincing evidence that the Services will field at least some medium- or long-range air platforms between now

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[66] Bill Gertz, "China Has Gained and Tested Array of Space Weapons," *Washington Times*, March 30, 2007, p. 8.

[67] An aircraft's fuel fraction is the total weight of the fuel at takeoff divided by the aircraft's total takeoff weight, including fuel.

and 2034. In the case of medium-range platforms, the most plausible candidate on the horizon is the US Navy's Unmanned Combat Air System Demonstrator (UCAS-D). This system is the surviving part of the Joint-UCAS (J-UACS) program, which in turn was established in 2003 when the separate DARPA-Navy and DARPA-Air Force Unmanned Combat Air Vehicle (UCAV) programs were merged. From 2003 until 2005, DARPA managed J-UCAS, which included the Air Force's X-45 and the Navy's X-47 technology demonstrators. The X-45 aimed at developing a UCAV for the Suppression of Enemy Air Defense (SEAD) mission, while the Navy's less ambitious X-47 sought to demonstrate autonomous launch and recovery from an aircraft carrier. In October 2005 a decision was made to transfer the two UCAV efforts back to the Services under a joint Air Force/Navy program office.[68] By early 2006, the latest QDR announced the J-UCAS program would be restructured to focus on a longer-range, carrier-based variant that could be air refueled.[69] Around this same time, Air Force budget documents for FY 2007 revealed that the Air Force portion of J-UCAS was cancelled.[70] Since then, the Navy has requested industry proposals for UCAS-D and it is likely that bids will be submitted based on longer-range derivatives of both the X-45 and X-47.[71] The Navy has set the unrefueled range requirement for UCAS-D at around 2,800 nautical miles (nm), which would mean an unrefueled combat radius of 1,400 nm.

The foremost question about UCAS-D is, of course, whether its technology is mature enough to place it alongside manned platforms? At this juncture the UCAS-D's intended mission is primarily intelligence, surveillance and reconnaissance (ISR). Given recent experience with other unmanned ISR vehicles such as Predator and

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[68] DARPA, "Joint Unmanned Combat Air Systems Program Transitioning to the Services," new release, October 26, 2005.

[69] DoD, *Quadrennial Defense Review Report*, p. 46.

[70] DoAF, *Fiscal Year (FY) 2007 Budget Estimates: Research, Development, Test and Evaluation (RDT&E) Descriptive Summaries*, Vol. II, February 2006, p. 705.

[71] Amy Butler, "Bids Are in for the U.S. Navy's UCAS-D," *Aviation Week and Space Technology*, April 2, 2007, accessed April 27, 2007, online at <http://www.aviationweek.com/aw/generic/story.jsp?id=news/aw040207p1.xml&headline=Bids%20are%20in%20for%20U.S.%20Navy's%20UCAS-D&channel=defense>.

Global Hawk, the answer is probably "yes" during the time the UCAS-D is airborne. However, recovering the UCAS-D on Navy aircraft carriers may be another matter. There appears to be ongoing resistance among naval aviators to bringing any unmanned vehicle back aboard a large-deck aircraft carrier with other aircraft and tightly orchestrated operations under way on the flight deck.

Looking further ahead, should it prove possible to overcome these obstacles and field the UCAS-D in the ISR role, can it be transformed into an effective strike platform? The step from ISR to an unmanned "bomb truck" intended mainly for fixed targets does not appear to be a large one technologically or operationally. Predators have successfully attacked time-sensitive targets with Hellfire missiles under the oversight of remote human operators. Thus, if the cultural resistance to recovering UCAS-D and other unmanned platforms on the Navy's carriers can be overcome, there is some possibility that the program could eventually yield a medium-range strike system.

It is an open question as to whether the UCAS-D will survive or, eventually, face the same fate as the Air Force J-UCAS. Again, the primary mission for the X-45 was SEAD—perhaps the most difficult mission that could have been chosen for an unmanned air vehicle to tackle. By contrast, the ISR mission, chosen by the Navy for the initial version of the UCAS-D, is perhaps the easiest mission to address—at least if the 2006 QDR's air-refueling requirement is feasible. The Navy's decision to begin with the easiest, rather the most difficult mission, may suggest that prospects for the UCAS-D are more favorable. But, suffice it to say, these kinds of demonstration programs often never result in the actual procurement and fielding of weapon systems.

Turning to long–range platforms, the Air Force's commitment to fielding an air-breathing successor to the B-2 appears open to question, as it has been some for years. The reported transfer of the X-45 J-UCAS technology to the Next Generation Long Range Strike (NGLRS) program suggests that the Air Force may still be pursuing a long-range strike system, possibly an unmanned one.[72] The fact that funding for the NGLRS is zero for fiscal years 2008-2010 in the Pentagon's February 2007 submissions for the FY 2008 defense budget,

[72] Susan H. Young, "Gallery of USAF Weapons," *AIR FORCE Magazine*, May 2006, p. 151.

however, does raise doubts about what may, or may not, actually be occurring. Further, Air Force officials have further clouded the situation by declining to discuss what they are doing on long-range-strike in open testimony before two House committees as recently as late March 2007.[73]

Perhaps the Air Force is diligently pursuing a classified (or special-access) NGLRS development program as directed by the 2001 and 2006 QDRs, and perhaps such a system will be fielded by 2018. That is one plausible interpretation of the preceding facts. On the other hand, since the late 1990s the Air Force has repeatedly explored its options for a B-2 follow-on and, through 2005, was unable to settle on design criteria as basic as a cruise Mach number for the platform.[74] Moreover, given the long development times of recent platforms such as the B-2 and F-22, fielding a NGLRS by 2018 appears optimistic (though not impossible).

The most benign interpretation of Air Force's cancellation of its part of the J-UCAS program and the absence of NGLRS funding for the next three years is that NGLRS concept definition is proceeding behind the veil of a special-access program. Hopefully, a truly long-range system of some sort will emerge before 2020 despite repeated evidence of ambivalence and mixed feelings among Air Force leaders regarding the need for a long-range aircraft beyond the B-2. It is difficult, though, to be confident of this outcome. What is crystal clear is that the F-35 program represents a huge investment in short-range Tacair over a quarter century in which it is uncertain what progress, if any, is likely to occur regarding either medium-range or long-range strike.

The argument that emerges from considering the range issue, then, is as follows. First, an unmistakable trend confronting US fixed-wing air power is the growing need for medium range and, especially, long range as defined in Figure 1. Second, over the last decade or so

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[73] The occasion was a hearing on March 22, 2007, before the Joint Air and Land Forces and Seapower and Expeditionary Forces Subcommittees of the House Armed Services Committee.

[74] Cruise speeds from high subsonic to hypersonic (Mach 8) have been explored along with suborbital solutions multiple times without evidence of any clear decision.

the Air Force has not shown the commitment to long-range—or even medium-range—combat aircraft that it has manifested in the case of short-range fighters, above all else in the F-22. Third, ignoring earlier-generation fighters now in production, the most mature fixed-wing aircraft program by far is the F-35, and it is a short-range system. Thus, there appears to be a presumptive case that, through 2034, the Services' fixed-wing aircraft modernization plans are heavily imbalanced in favor of short-range fighters.

Force-Structure Considerations

What other considerations might bear on the question of whether the JSF program should be restructured by reducing the numbers or types of F-35s procured? During the Cold War, the Services' Tacair force structures were driven by the need to generate large enough numbers of strike sorties to compensate for the inaccuracy of unguided or "dumb" munitions. During 1965-1968, for example, the average circular error probable (CEP) recorded by F-105s attacking targets in the highly defended areas of North Vietnam using manual dive bombing and 750-pound (lb) general-purpose bombs was about 500 feet. What a 500-foot CEP meant was that, statistically, half the bombs dropped could be expected to fall inside a circle 500-feet in radius centered on the target or aim-point.[75] Against a target requiring much greater accuracy, many bombs and sorties usually had to be expended to take out the target. In one of the most famous cases from the American experience in Vietnam, during 1965-1968 some 870 strike sorties were flown against the Thanh Hoa Bridge and eleven US aircraft were lost. Yet neither span of the bridge was dropped during this period, and the Thanh Hoa Bridge was never closed for very long to truck or railroad traffic.

Paveway laser-guided bombs (LGBs)—first used in Southeast Asia in 1968—began the long process of moving fixed-wing air power from an industrial age in which most air-to-ground ordnance missed their targets by substantial distances to one in which most either hit them or came close enough to inflict serious damage. With a nominal CEP of 9.8 feet (3 meters), LGBs became the first precision air-to-ground munition to be both employed in significant numbers and

[75] The CEP refers to the distance (i.e., radius) from the aim-point.

prove highly effective in combat.[76] From the beginning in 1968, they achieved hit rates around 50 percent. In May 1972 LGBs enabled a handful of F-4s to drop a span of the Thanh Hoa Bridge. LGBs also proved cheap enough per round for the Air Force to expend some 28,000 of them in Southeast Asia.[77] Since the beginning of the 1991 Persian Gulf War, LGBs have been the most widely used precision-guided munition (PGM) expended by Air Force, Navy, and Marine Corps aircrews. During major combat operations in 1991, 1999, 2001-2002, and 2003 they accounted for almost 52 percent of the nearly 54,000 guided munitions delivered by fixed-wing aircraft.[78]

Laser-guided bombs, however, have some major limitations. Even today, successful employment requires clear air between the attacking aircraft and the target—from the time of release to munition impact. Clouds, rain, fog, smoke, and debris thrown up by earlier bombs can all cause misses. In addition, most of the LGBs used in Southeast Asia during 1968-1973 were delivered during the daytime because aircrews had to acquire their targets visually. By the time of Operation Desert Storm in 1991, forward-looking infrared (FLIR) targeting sensors such as Pave Tack enabled aircraft such as the F-111F and F-117 to overcome this limitation, and most LGB bombing by these aircraft occurred at night. The clear-air requirement, however, still limits the employment of laser-guided bombs.

The solution to the clear-air limitation was eventually provided by the Joint Direct Attack Munition. JDAM guides on Global Positioning System (GPS) coordinates using an accurate inertial system plus location and timing signals from GPS satellites. As a result, the JDAM is a true all-weather guided munition.

JDAMs were first employed by the B-2 against Serbian targets during Operation Allied Force in 1999. While the munition's original design CEP of 13 meters (42.7 feet) placed it toward the high end of the "near-precision" CEP range, on the B-2 its accuracy can be im-

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[76] The Air Force defines precision munitions as those with CEPs no greater than 9.9 feet; near-precision munitions have CEPs between 9.9 and 66 feet. John A. Tirpak, "Precision: The Next Generation," *Air Force Magazine*, November 2003, p. 46.

[77] These were primarily 2,000-lb Mark-84Ls.

[78] Watts, *Six Decades of Guided Munitions and Battle Networks*, p. 177.

proved by using the aircraft's radar to eliminate most of the target-location error, which is the largest contributor to JDAM's 13-meter CEP. As a result, the B-2 in particular has been able to achieve CEPs with JDAM in the neighborhood of 4-6 meters (13.1-19.7 feet). Thus, while the JDAM does not quite meet the Air Force's official criterion for a precision munition, in some circumstances it comes very close. Like LGBs, JDAMs have also proven to be highly reliable and relatively inexpensive per round.

What these developments in guided munitions mean is that most of the ordnance US strike aircraft drop these days either hits the target or comes close enough to damage most targets. System reliability against this hit/close-enough criterion has been 80-90 percent, although even 50 percent would have sufficed to move US strike operations into a very different world than that of the industrial era, characterized by reliance on sheer mass to compensate for the lack of accuracy.[79]

The implications for Tacair force structure are not difficult to discern. In what might be termed the evolving era of *guided munitions and battle networks*, far fewer munitions must be expended to achieve a given effect. Far fewer munitions, in turn, mean fewer sorties are required, and fewer sorties reduce the requirements for force structure relative to a given level of capability. What literally required hundreds of sorties during World War II can now be accomplished with one or two. Conceptually, whereas airmen used to think in terms of sorties-per-target, they now think increasingly in terms of targets-per-sortie. The ongoing fractionation of payloads implicit in the 250-lb-class Small Diameter Bomb, which builds on the JDAM's technology, means that a fighter like the F-35 can now cover a dozen or so aimpoints on a given sortie as compared with only two using a pair of 2,000-lb-class PGMs.

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[79] Ignoring no-drops due to weather, the F-117 recorded a hit-rate of 80 percent with LGBs during Operation Desert Storm (ODS) (Keaney and Cohen, *Revolution in Warfare?*, pp. 291-292). After Operation Allied Force (OAF) in 1999, the 509th Bomb Wing briefed that JDAM reliability from the B-2 had been 98 percent, and that 89 percent of the JDAMs dropped had landed within the munition's CEP (Brigadier General Leroy Barnidge, "Decade of Success," PowerPoint briefing on B-2 operations in OAF, 509th Bomb Wing, August 1999, slide 23).

These insights argue that replacing older aircraft with JSFs on a one-for-one basis is not necessary. A smaller number of F-35s than the 2,443 now planned could in fact provide greater capability than the 2,443 older F-16s, F/A-18s, AV-8Bs and other aircraft they would replace. In this regard, recall that the 1997 QDR reduced the Air Force's planned buy of F-22s from 442 to 341 on precisely these grounds—the greater capability provided by the new fighter.[80]

More recently, the heralded shift toward a "capabilities-based" approach to defense strategy in the 2001 QDR might have been expected to yield more force-structure decisions similar to the 1997 decision to cut the F-22 procurement by a wing.[81] By and large it has not. However, the efficiencies evident in the growing US arsenal of guided munitions, advanced sensors, and targeting networks suggest that steps beyond the 1997 QDR's F-22 decision are possible, and perhaps desirable. How might these improvements in precision-strike capabilities affect the Air Force's Tacair modernization plans? Ignoring the roughly 220 F-15Es and the 55 soon-to-be-retired F-117s,[82] the Air Force is currently operating some 1,675 other strike or ground-attack aircraft: 1,315 F-16s and 350 A/OA-10s. Insofar as the Air Force's planned buy of 1,763 F-35As had an obvious quantitative justification, it would appear to have been to replace these older attack aircraft one-for-one. Might 800-1,000 F-35As suffice?

The average age of the Air Force's F-16s is now over 17 years even though the roughly 790 F-16A/Bs originally procured in the 1980s have been retired. However, instead of fielding the F-16 strictly as a lightweight air-to-air fighter, the Air Force added air-to-ground capabilities, which increased both its weight and complexity. In recent years, many of the later-block F-16s have been experiencing age-related engine problems, and the plane's fly-by-wire control system has enabled pilots to reach its operational load limits (nine times the force of gravity) more often and with higher onset rates than were an-

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[80] William S. Cohen, "Report of the Quadrennial Defense Review," *Joint Force Quarterly*, Summer 1997, p. 12.

[81] DoD, *Quadrennial Defense Review Report*, September 30, 2001, pp. 12-13.

[82] The Air Force now plans to retire the last F-117s in FY 2008—DoAF, *Fiscal Year (FY) 2008/2009 Budget Estimates: Research, Development, Test and Evaluation (RDT&E) Descriptive Summaries*, Vol. III, p. 1435. The F-15Es are to be retained through 2025.

ticipated when the F-16 was designed. The F-16's original airframe life was expected to be only 4,000 flying hours. It has been extended to 8,000 hours or 32 years, but the plane was the first fighter made with large amounts of composite materials and it remains to be seen whether further service-life extensions are possible.[83] Finally, the operations tempo the Air Force has experienced since 1991 has only served to accelerate the aging of the F-16 fleet. The Air Force, then, certainly has reasons for desiring to replace its F-16s with F-35s as soon as possible. But Air Force leaders have also conceded that because the "F-35A will be so much more capable than the F-16," fewer JSFs will be needed to replace the F-16s.[84] While the detailed analysis that might justify a plausible F-16/F-35 replacement ratio is beyond the scope of this report, ratios in the vicinity of 3:2 to 2:1 do not seem unreasonable.

What about the Air Force's A/OA-10s? These so-called "blitzfighters" were originally built to support the US Army in Europe in the event of a Warsaw Pact (WP) invasion of NATO territory. The idea behind the A-10 was to field a rugged aircraft designed around a 30-millimeter cannon capable of destroying enemy tanks cheaply and efficiently, much as the German pilot Hans Rudel had done in various models of the Ju-87 Stuka during World War II.[85] Despite the demonstrated lethality of the A/OA-10 firing depleted-uranium rounds against ground targets, it is unlikely that in the foreseeable future US forces will face the kind of massive, tank-heavy forces presented by the Warsaw Pact during the Cold War. Moreover, in 1991 F-111Fs and other US aircraft had some success busting Iraqi tanks with 500-lb LGBs, and in 2003 fixed-wing aircraft were able to provide ground forces with on-call fire support round the clock, regardless of weather. Despite these experiences, mistrust persists between the Army and Air Force. "The Army does not trust the Air Force to be there when it is

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[83] John A. Tirpak, "Making the Best of the Fighter Force," *AIR FORCE Magazine*, March 2007, p. 43.

[84] General T. Michael Moseley in Tirpak, "Struggling for Altitude," p. 42.

[85] Rudel is credited with destroying 516 Soviet tanks, 150 self-propelled guns, four armored trains, 800 other vehicles, and nine Soviet planes during 2,530 combat sorties on the Eastern Front. It is worth remembering, though, that Rudel was shot down or forced to land 32 times.

needed, and the Air Force does not trust the Army to employ air power properly if it is in control of the resource."[86]

A further development bearing on Air Force support of the Army has been the latter's experience since 2005 employing guided rounds designed for the Multiple Launch Rocket System (MLRS) and the High Mobility Artillery Rocket System (HIMARS). The success of guided MLRS (GMLRS) means that US ground forces are acquiring organic field-artillery systems that can provide precision fires support similar to that provided by fixed-wing air power. These considerations strengthen the argument that one-for-one replacements of A/OA-10s with F-35s are not necessary. Indeed, as field artillery in both the Army and the Marine Corps moves increasingly into the guided-munitions era, one could even suggest that the A/OA-10 is becoming somewhat redundant relative to its original purpose of providing direct fire support for soldiers and marines. The fact that the Air Force plans to improve the capabilities of its A/OA-10s for employing PGMs simply reinforces this view. And because the Air Force now anticipates that service-life extensions to 223 of the 356 A/OA-10s will enable these planes to remain in service until 2028, the case for replacing any A/OA-10s with F-35s looks weak.[87]

Taken together, the success of GMLRS and the Air Force's decision to retain the majority of its A/OA-10s through almost the entire planned JSF production run argue that Air Force's main requirement for the F-35 is to replace its F-16s. From this perspective, the planned buy of 1,763 JSF is excessive even on a one-for-one replacement basis. This conclusion alone makes a strong case for restructuring the program. As a point of departure for future debate and analysis, reducing the Air Force buy to 800-1,000 F-35As would probably be adequate, while not increasing the unit costs of the F-35A and F-35B dramatically. Perhaps the only caveat that needs to be added is that prospective reductions in the total US buy be accompanied by a firm commitment to predictable production rates and sizeable annual production quantities.

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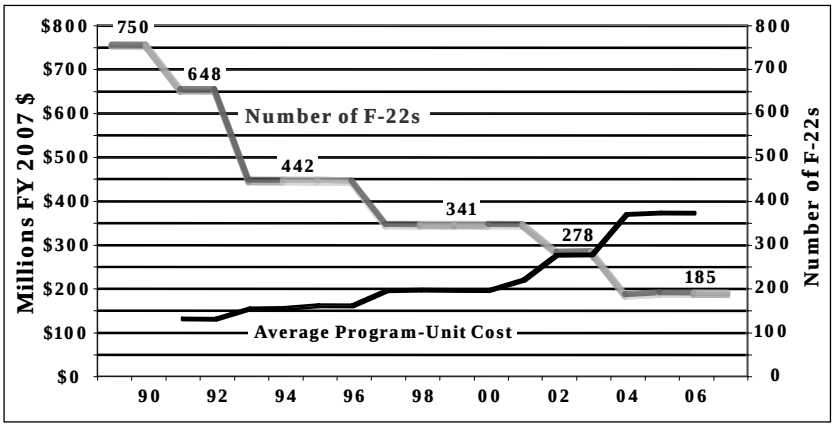
[86] David E. Johnson, *Learning Large Lessons: The Evolving Roles of Ground Power and Air Power in the Post-Cold War Era* (Santa Monica, CA: RAND, 2007), p. 197.

[87] Tirpak, "Making the Best of the Fighter Force," p. 45.

Turning to the Marine Corps, much the same argument could be mounted against replacing its AV-8Bs with F-35Bs as was just made regarding the Air Force's A/OA-10s. Guided munitions from fixed-wing aircraft together with easily employed guided shells and missiles for field artillery would appear to render traditional close air support from "jump jets" redundant.[88] Nevertheless, cancellation of the STOVL variant of the JSF appears unlikely. First, as previously noted, the British military is adamant that Great Britain needs the plane. Second, the Marine Corps' basic force structure is not as negotiable as are the numbers of Air Force fighter wings or Navy ships. Title 10 of US Code specifies that the Marine Corps will have "not less than three combat divisions and three air wings."[89]

Figure 2: F-22 Unit-Acquisition Cost versus Quantity



Finally, what about the Navy's planned buy of perhaps 330 F-35Cs? Can this part of the planned US JSF procurement be reduced? If, as seems likely, the F-35C's learning curve is distinct from that of the other two variants, then the production quality for the carrier variant of the F-35 is rather small. Figure 2 shows the relation-

[88] The Army's original guided round for its 155-mm howitzers, the laser-guided Copperhead, proved difficult to employ and less than reliable. The GPS-aided Excalibur round, though roughly triple the price of a JDAM, promises to be far better suited to the needs of soldiers and marines for on-call fire support.

[89] "United States Marine Corps: Composition; Functions," US Code, Title 10, Subtitle C, Part I, Chapter 507, § 5063.

ship to date between the unit-acquisition price of the F-22 and the procurement quantity. This relationship suggests that the F-35C should probably be considered an either/or proposition. Either the Navy should buy 300-400 in order to keep the unit-price within bounds, or else the F-35C carrier variant should be dropped altogether.

Given the difficulties that the Navy now faces in filling its ten carrier air wings, events may already be moving toward a reduction in the F-35C buy. In its submissions for the FY 2008/2009 defense budget, the Navy added 32 F/A-18E/Fs to its planned buy, increasing the total from 462 to 494.[90] The Navy's preference for its future air wings appears to be two F/A-18E/F and two F-35C squadrons of 10-12 aircraft for each of its ten carrier air wings. The increase in the F/A-18E/F buy suggests slippage toward a 3-to-1 mix of F/A-18E/Fs and F-35Cs. If that is in the cards, then a better plan may be for cancel the F-35C altogether, extend F/A-18E/F production to fill out the Navy's carrier air wings, and push the Navy to field its UCAS-D as early as possible. This option would have the virtue of eventually adding a medium-range platform to the Navy's carriers. The F-35C will not do so regardless of how many are procured.

Conclusions: Affordability versus Need

To reiterate the principal caveat regarding this section's discussion of the strategic and tactical needs bearing on present choices in fixed-wing air power, CSBA is *not* recommending a specific alternative to the JSF program of record. Some possibilities worthy of further investigation have been raised. However, the principal aim has been to surface *possibilities*, thereby provoking serious debate over the affordability and need for the F-35.

While significant uncertainties exist regarding the cost of the JSF program, and the recent restructuring of the program (i.e., stretching out production of the aircraft to FY 2034) has significantly reduced the program's *annual* (but not total) funding requirements, there are ample grounds for suspecting that the Services will be hard pressed to afford the JSF program as it is presently structured. The

[90] Department of the Navy, *Fiscal Year (FY) 2008/2009 Budget Estimates: Aircraft Procurement*, Vol. I, *Budget Activities 1-4*, February 2007, P-40 for o14500 F/A-18E/F.

total resource commitment through 2034 would make the F-35 program the most expensive combat-aircraft program in DoD history. Can the Services really afford 2,443 F-35s—either in total cost or in terms of annual funding levels for Tacair in the Air Force and Navy budgets? After all, besides the possibility of further cost growth in the program itself, there are important competing priorities such as funding increased end strength for the Army and Marine Corps and replacing the ground-force equipment that is being consumed by ongoing operations in Iraq and Afghanistan.

Nevertheless, outright cancellation of the F-35 does not appear prudent. To reiterate the essential point, the United States has been the world leader in fixed-wing air power for decades. Giving up a position of advantage in so important an area of military competition makes no strategic sense. America's post-Cold War strategy should be to maintain critical areas of military advantage, not abandon them. In addition, cancellation would be a blow to the British, the Australians, and other American allies. It would also mean wasting some $29 billion in sunk costs already invested in the program.

That said, the JSF program of record seems to ignore the growing requirement for long-range platforms by investing too much and too exclusively in short-range fighters. At the same time, the maturation of guided munitions and battle networks argues that fewer advanced fighters will be needed in the future than were required in the prior age of industrial warfare in which most air-to-ground munitions missed their aim-points or targets. In addition, the success of GMLRS together with all-weather munitions such as JDAM tend to undermine the need for planes like the A/OA-10 and the AV-8B in a direct close-air support role. Hence, as the preceding examination of Tacair force structure indicates, there do appear to be viable options for making the JSF more affordable by changing the program of record in light of existing political, strategic, tactical, and programmatic realities. The planned buy of 2,443 operational JSFs now seems neither affordable nor needed, and the US buy can probably be reduced by as much as 50 percent without driving unit costs through the roof or abandoning close allies. Because the Air Force has decided to retire its F-117s and keep its F-15Es along with around 63 percent of its A/OA-10s through 2025-2028, a rough guess is that 800-1,000 F-35As would be an adequate replacement for the F-16 fleet. Beyond enabling Marine Corps' landing ships (LHAs and LHDs) to go to sea with the far more capable F-35B compared to the range and payload limited AV-8B, adding pre-

cision munitions to field artillery appears to undermine the need for the F-35B, just as they do for the A/OA-10 in its original role. Nevertheless, for political reasons stemming from Title 10 legislation on Marine Corps force structure and the British need for a Harrier replacement, a decision to cancel the F-35B STOVL variant may be politically unwise. The F-35C carrier variant, however, may be another matter. From the standpoint of achieving at least some medium-range strike capability, canceling this variant in favor of early fielding of the UCAS-D may make more sense.

Again, more detailed, thoughtful, and strategically informed analysis should undoubtedly be done before the Defense Department decides on a specific alternative to the JSF program of record. But such analysis now appears to be at least a couple years overdue. The one unequivocal recommendation that can be made on the basis of this report is that a clear decision on the future of the F-35 program should be reached by senior Pentagon officials sooner rather than later.