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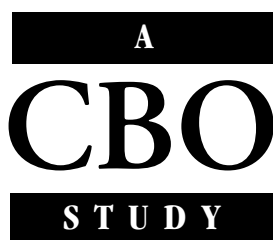
A
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STUDY

MAY 2009

Alternatives for
Modernizing
U.S.
Fighter Forces



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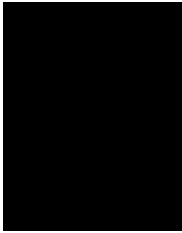
Alternatives for Modernizing U.S. Fighter Forces

May 2009

Notes

Unless otherwise specified, all years referred to in this study are federal fiscal years, and costs are expressed in constant 2009 dollars.

Cover photograph of the Joint Strike Fighter courtesy of Lockheed Martin.



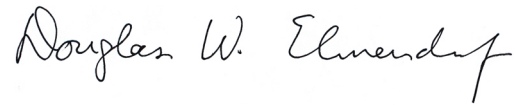
Preface

The United States Air Force, Navy, and Marine Corps have long maintained tactical fighter forces that provide capabilities for air-to-air combat and air-to-ground attack. The three services are in the process of replacing the bulk of today's fighter aircraft—most of which were purchased in the 1980s—with new F/A-18E/F, F-22, and F-35 (Joint Strike Fighter) aircraft. Although current procurement plans call for the purchase of about 2,500 aircraft over the next 25 years, the services are projecting that those purchases will not keep pace with the need to retire today's aircraft as they reach the limit of their service life.

The Senate Report on the National Defense Authorization Act for Fiscal Year 2008 directed the Congressional Budget Office (CBO) to prepare a study examining the capabilities and costs of the fighter force that would be fielded under the Department of Defense's fiscal year 2009 plans and the potential implications for DoD's long-term budget and inventory levels if planned purchases of new aircraft are insufficient to maintain fighter inventories at levels called for by current service requirements. (Just prior to the publication of this report, the new Administration released its budget request for fiscal year 2010. Although the general implications of the changes in DoD's plans are discussed in the Summary, sufficient details for a complete reassessment of DoD's new plans were unavailable when this report went to press.) The study also compares the advantages, disadvantages, and costs of seven alternative approaches that DoD might adopt to modernize its fighter forces—three that satisfy today's inventory requirements, two that maintain aggregate weapons capacity with fewer aircraft, and two that replace portions of the fighter force with longer-range aircraft. In keeping with CBO's mandate to provide objective, impartial analysis, this study makes no recommendations.

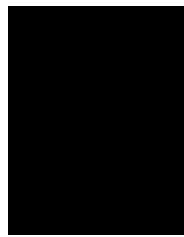
David Arthur and Kevin Eveker of CBO's National Security Division prepared the study under the supervision of J. Michael Gilmore. David Newman of CBO's Budget Analysis Division prepared the cost estimates under the supervision of Sarah Jennings. Alec Johnson assisted with fact checking the document. Christopher Wright of the Johns Hopkins University Applied Physics Laboratory provided thoughtful comments. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Loretta Lettner edited the study, and Sherry Snyder proofread it. Cynthia Cleveland produced drafts of the report. Maureen Costantino designed the cover and prepared the document for publication. Lenny Skutnik oversaw the printing of the report, Linda Schimmel handled the print distribution, and Simone Thomas prepared the electronic version for CBO's Web site (www.cbo.gov).

A handwritten signature in black ink that reads "Douglas W. Elmendorf". The signature is written in a cursive, flowing style.

Douglas W. Elmendorf
Director

May 2009



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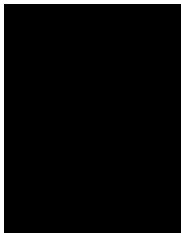
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Summary

The United States Air Force, Navy, and Marine Corps maintain an inventory of approximately 3,500 fixed-wing fighter and attack aircraft that provide unsurpassed air-to-air and air-to-ground combat capabilities. Most of those aircraft were purchased at high annual rates during the 1980s, however, and are expected to reach the end of their service life at similarly high rates over the next decade. To counteract those impending retirements and simultaneously modernize their fleets, the service branches have outlined acquisition plans for equipping their force structures with new aircraft over the next 25 years. Specifically, the Air Force plans to replace the A-10 Thunderbolt II, the F-16 Fighting Falcon, and the F-15 Eagle with two types of aircraft: the F-22 Raptor and the F-35A Lightning II, the land-based version of the Joint Strike Fighter (JSF).¹ The Navy and Marine Corps plan to replace the AV-8B Harrier and F/A-18A/B/C/D Hornet with three types of aircraft: the F/A-18E/F Super Hornet; the F-35B, the short takeoff vertical landing version of the JSF; and the F-35C, the carrier-based version of the JSF.

The F-22 and F/A-18E/F are in active service today, but production of those aircraft is slated to end in 2011 and 2014, respectively. Development of the F-35 began in the 1990s, and initial production began in 2007. The services' schedules call for the first squadrons of F-35s to be operational in the Marine Corps, Air Force, and Navy by 2012, 2013, and 2015, respectively. Procurement is expected to continue through 2025 for the F-35B/C and through 2034 for the F-35A.

Those procurement plans notwithstanding, the Air Force and Navy have projected that, as laid out in fiscal year 2009 plans developed by the previous Administration, the rate of fighter production over the next 25 years would be insufficient to keep pace with the rate at which aircraft in current inventories would wear out and need to be replaced. As a result, the services are warning of an approaching “fighter gap” after 2015, when inventories of fighter aircraft are expected to drop below the levels needed to equip their planned force structures. That shortfall could be exacerbated by other issues that might arise. For example, production rates of the JSF might need to be reduced if unit costs increase; production of JSFs might be delayed if further technical problems arise in its development; or unanticipated problems with today's older aircraft might require that they be removed from service earlier than expected.²

This Congressional Budget Office (CBO) study looks at the composition of today's fighter fleets and at how the Department of Defense's (DoD's) plans for modernizing fighter forces—as set forth in the Bush Administration's 2009 Future Years Defense Program (FYDP) and other DoD documents—would affect inventories and war-fighting capability over the next several decades. (Just prior to the publication of this report, the Obama Administration released its budget request for fiscal year 2010. Summary Box 1 describes the proposed program changes that are relevant to this study.) As part of its analysis, CBO assessed the overall cost of executing DoD's fiscal year 2009 procurement plans. In addition, CBO explored seven alternative approaches to modernization that, in comparison with DoD's fiscal year 2009 projections, would offer varying levels of war-fighting

1. These aircraft are briefly described in Chapter 1. More detailed descriptions of their functions and capabilities can be found on the services' Web sites (www.af.mil/factsheets/; www.navy.mil/navydata/fact.asp, and <http://hqinet001.hqmc.usmc.mil/AVN/documents/aircraft/fixedwing/fixedwing.htm>) and at www.jsf.mil.

2. The inventory shortfalls projected by the services are due in part to delays that have already been experienced by the JSF program; those delays are largely attributable to the challenges of developing three aircraft around a common airframe.

Summary Box 1.

Implications of the New Administration's Fiscal Year 2010 Plans for Modernizing Fighter Forces

The analysis presented in this report is based largely on the Department of Defense's (DoD's) modernization plans for tactical aircraft as outlined in the Fiscal Year 2009 Future Years Defense Program (FYDP), which the Bush Administration submitted to the Congress in conjunction with its fiscal year 2009 budget request. In early April 2009, Secretary of Defense Robert M. Gates outlined a series of changes to those plans—several of which involve programs for modernizing tactical aircraft forces—that he recommended be incorporated in the Obama Administration's fiscal year 2010 defense budget request. The Office of Management and Budget released the 2010 request shortly before CBO published this report. However, the budget request did not contain sufficient programmatic details to allow CBO to conduct a complete reassessment of the modernization plans for U.S. tactical fighter forces. Moreover, DoD's comptroller announced that, unlike previous budget requests, the fiscal year 2010 request would not be accompanied by a FYDP, which would have supplied programmatic details for the out-years.

CBO determined that its analysis would be largely unaffected by the changes that Secretary Gates announced as part of DoD's proposed fiscal year 2010 plans for tactical aircraft forces. Three of DoD's changes were, nevertheless, directly relevant to CBO's comparison of DoD's fiscal year 2009 plans with the alternative modernization plans described fully in Chapter 3 of this report:

- First, the new budget proposes retiring 250 of the oldest Air Force tactical fighters in fiscal year 2010. In CBO's projection (based on fiscal year 2009 plans), the retirement of the 250 oldest Air Force fighters—as measured by the fraction of service life expended—would occur between 2010 and 2014. Consequently, the Air Force's inventory of legacy fighter aircraft and the weapons capacity they provide would be lower than CBO's projection from 2010 until 2014, at which time the inventory of legacy aircraft should come back into alignment with CBO's projection.
- Second, Secretary Gates stated that DoD plans to buy 513 F-35 Joint Strike Fighters (JSFs) over the five-year defense plan, about 160 more jets over the 2010–2014 period than indicated in fiscal year 2009 plans. That acceleration in production is similar to the increase of 132 F-35s postulated in the first of the alternative modernization plans CBO describes in this study. Those additional aircraft would offset somewhat the early retirement of older Air Force fighters. Unlike the provisions of CBO's Alternative 1, however, which would increase total production of F-35s to over 2,600 aircraft, DoD's total planned production of JSFs would remain at 2,443 aircraft.
- Third, Secretary Gates indicated plans to increase the procurement and use of Predator-class unmanned aerial vehicles. Although presented in the context of increasing intelligence, surveillance, and reconnaissance capabilities, those aircraft could be armed and used to augment strike capabilities, as postulated in two of the alternatives (Alternatives 5 and 7) examined in this report.

capability and require varying levels of financial commitment. The study makes no judgments about the affordability or sufficiency of DoD's fiscal year 2009 plans or the seven alternatives. CBO's analysis points to several general conclusions:

- If realized, the services' *goals* for modernizing their fighter forces over the next several decades would result in a significant increase in capability over that offered by today's forces. Inventories would remain about the same, but the modernized fleets would be equipped with state-of-the-art aircraft that offer substantial technological advances over today's fighters, including increased payload capacity and greater stealth capabilities (and, as a result, enhanced survivability). Notwithstanding DoD's emphasis on fielding aviation forces with greater flight endurance, the distance that newer aircraft could fly without requiring refueling ("unrefueled ranges") would not increase to the same extent.³
- Under DoD's fiscal year 2009 procurement *plans*, fighter inventories are likely to fall below the services' stated goals in the coming years. Nevertheless, many aggregate capabilities would remain equal to or improve relative to today's force because of the enhanced lethality and survivability that is expected from the new fighters. Some of those improvements might be offset by the increased capabilities of potential adversaries, however.
- Alternative approaches that included purchasing additional F/A-18E/F Super Hornets or purchasing upgraded versions of so-called legacy aircraft—such as the F-16 Fighting Falcon and F-15E Strike Eagle, which are still in production but based on older designs—would offer an opportunity for short-term inventory relief, long-term cost savings, or both, albeit with lesser capability improvements (especially in terms of survivability) than would be realized by purchasing JSFs.

3. Greater flight endurance is of interest to DoD because it allows aircraft to remain aloft for longer periods of time with less reliance on aerial refueling tankers. The increased time aloft can be used to reach targets over longer distances or to increase persistence—the amount of time a plane can loiter over a location close to where it might be needed.

- Compared with forces equipped solely with fighter aircraft, forces equipped with a mix of fighters (which are designed for supersonic speed and high maneuverability) and subsonic attack aircraft (designed, instead, to carry large payloads over long distances) would offer improved basing flexibility and persistence over the battlefield during air-to-ground missions. Force structures that replaced some fighters with smaller numbers of attack aircraft could provide air-to-ground weapons capacities comparable to those of today's forces and be fielded at costs similar to those projected for DoD's plans. Such forces would have fewer aircraft capable of air-to-air combat, however.

The Department of Defense's Fiscal Year 2009 Plans for Modernizing Fighter Forces

As articulated in the 2009 Future Years Defense Program and other DoD documents, such as the Selected Acquisition Reports, funding to modernize U.S. fighter forces over the 2010–2034 period would average over \$8 billion per year in 2009 dollars. Most of that funding would be for the JSF. During the period of highest annual production of the JSF—currently projected to run from 2015 through 2022, when DoD plans to purchase 130 aircraft per year—funding would average over \$10 billion per year.⁴ Orders for what could be the final F-22s to be produced were placed in 2009, and final orders for the F/A-18E/F were planned for 2012. Production of both aircraft could be extended, however.

Plans for Fighter Inventories

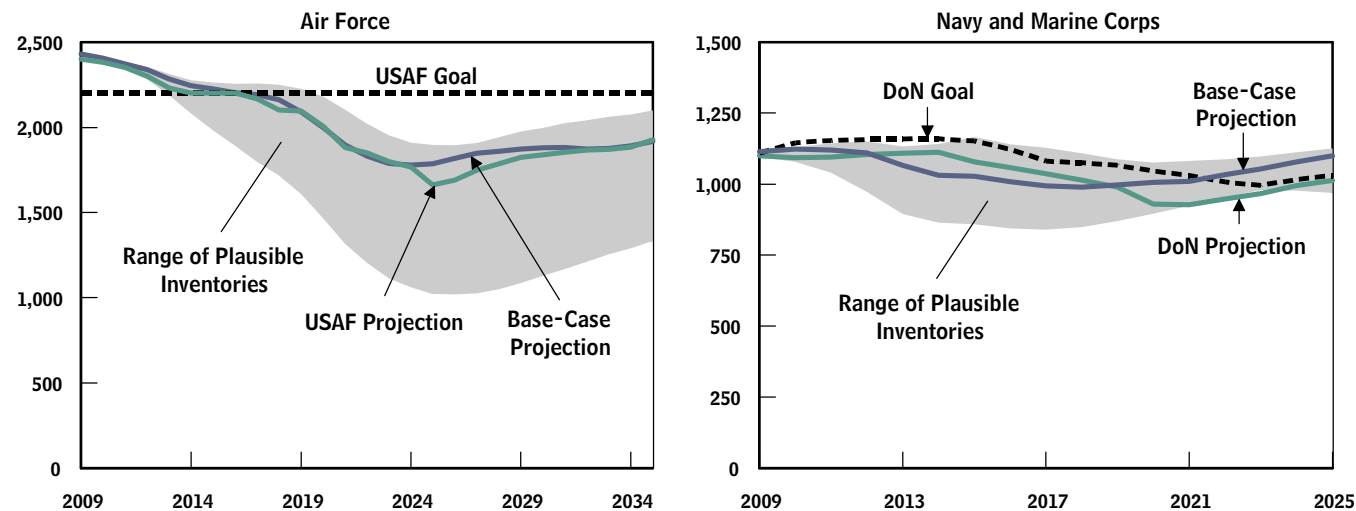
Today, the Air Force's fighter inventory is higher than its stated goal of 2,200 aircraft. However, the Air Force anticipates that, by 2017, its inventory will drop below that level because the rate at which certain aircraft (primarily F-16s and F-15s) will reach the end of their service life will exceed the rate of production—80 aircraft per year—planned for F-35As (see the left panel of Summary Figure 1). CBO estimates that, under its base-case assumptions—production of the F-35A proceeds as laid out in DoD's fiscal year 2009 plans, today's Air Force fighters accumulate flight hours at past rates, and

4. Production for the U.S. military would decrease after 2022 as purchases for the Navy and Marine Corps began to wind down. Under DoD's fiscal year 2009 plans, the only U.S. orders after 2025 would be for F-35As for the Air Force. Continuing sales to foreign governments are anticipated at that time, however.

Summary Figure 1.

Potential Fighter Inventories Under a Range of Projections

(Total aircraft inventory)



Source: Congressional Budget Office based on the Department of Defense's fiscal year 2009 plans.

Notes: DoN = Department of the Navy; JSF = Joint Strike Fighter; SLEP = Service Life Extension Program; USAF = United States Air Force.

Air Force:

Base-Case Projection:

- The A-10 and F-15 reach 16,000 and 12,000 flight hours, respectively
- Production and fielding of the F-35A JSF remain on schedule
- Average annual flight hours accrued per aircraft equal those of the past 10 years

Optimistic Case (Upper edge of shaded region):

- The A-10 and F-15 reach 16,000 and 12,000 flight hours, respectively
- Production and fielding of the F-35A remain on schedule
- Average annual flight hours accrued per aircraft are reduced by 10 percent (relative to the average of the past 10 years)

Pessimistic Case (Lower edge of shaded region):

- The A-10 and F-15 reach 12,000 and 8,000 flight hours, respectively
- Production of the F-35A slips by two years and peak production is reduced from 80 aircraft per year to 64
- Average annual flight hours accrued per aircraft equal those of the past 10 years

Navy and Marine Corps:

Base-Case Projection:

- F/A-18A/B/C/Ds reach 8,500 flight hours
- Average annual flight hours accrued for F/A-18A/B/C/Ds equal 325 hours per aircraft
- AV-8B Harriers are retained through 9,500 flight hours
- Production of the F-35B/C JSF remains on schedule

Optimistic Case (Upper edge of shaded region):

- F/A-18C/Ds reach 10,000 flight hours (including an as-yet-unfunded SLEP)
- Average annual flight hours accrued for F/A-18A/B/C/Ds equal 325 hours per aircraft
- AV-8Bs are retained through 9,500 flight hours
- Production of the F-35B/C remains on schedule

Pessimistic Case (Lower edge of shaded region):

- F/A-18A/B/C/Ds reach 8,000 hours
- Annual flight hours accrued for F/A-18A/B/C/Ds equal 420 hours per aircraft
- AV-8Bs are retired as F-35Bs are delivered
- Production of the F-35B/C slips by two years

unforeseen problems do not ground today's aircraft sooner than is currently anticipated—the Air Force's shortfall relative to current requirements will peak in about 2025 at over 400 aircraft and then begin to decrease thereafter. The shaded regions in the figure illustrate a range of inventories that could be realized under a variety of alternative assumptions—both optimistic and pessimistic—about the JSF's rate of production and the service life of today's aircraft.⁵ The Air Force's projections are similar to CBO's, although some officials have questioned whether procuring 80 F-35As per year will be achievable under anticipated budget constraints. According to CBO's estimates, by 2035, DoD's fiscal year 2009 plans—including extending the service life of some existing aircraft and purchasing 187 F-22s and 1,763 F-35As—would yield an inventory that was about 200 aircraft short of the Air Force's goal.

The Navy's and Marine Corps' inventory today is close to the stated goal of 1,110 aircraft.⁶ The services' fiscal year 2009 modernization plans called for the purchase of a total of 506 F/A-18E/F Super Hornets (over 380 had been delivered as of February 2009) and 680 F-35B/C JSFs over the 2008–2025 period. The exact mix of F-35Bs and F-35Cs has not yet been determined by the Navy and Marine Corps. Although that total quantity would be sufficient to meet the Navy's and Marine Corps' inventory goals when production of the F-35B/C ends in 2025, the Navy projects a shortfall in the interim as F/A-18A/B/C/D Hornets and AV-8B Harriers are retired (see the right panel of Summary Figure 1). According to the Navy's estimates, that shortfall will peak at about 125 aircraft in 2017.

CBO projects somewhat greater shortfalls for the Navy and Marine Corps through 2018 because it assumed that extending the service life of F/A-18A/B/C/Ds beyond 8,500 flight hours, which the Navy proposes, could prove

to be impractical. (The Navy's projection assumes that, with modifications, Hornets could reach 10,000 flight hours. However, such a program is not currently funded, and there is considerable uncertainty as to whether it will be practical to implement the necessary modifications.) CBO's estimates for the years following 2018 indicate a lower shortfall than the Navy and Marine Corps projected because CBO assumed that, instead of being retired as F-35s are delivered to the Marine Corps, AV-8Bs would be retained as long as they were flight-worthy. If production of the JSF is further delayed, the Navy's and Marine Corps' fighter inventory could dip significantly lower than the services projected (see the lower edge of the shaded region in the right panel of Summary Figure 1). Alternatively, if the Hornet proved to be more robust than the Navy currently expects, and if efforts to manage fleet usage meet with success, inventory shortfalls could be less severe than expected.

Capabilities Offered Under Fiscal Year 2009 Plans

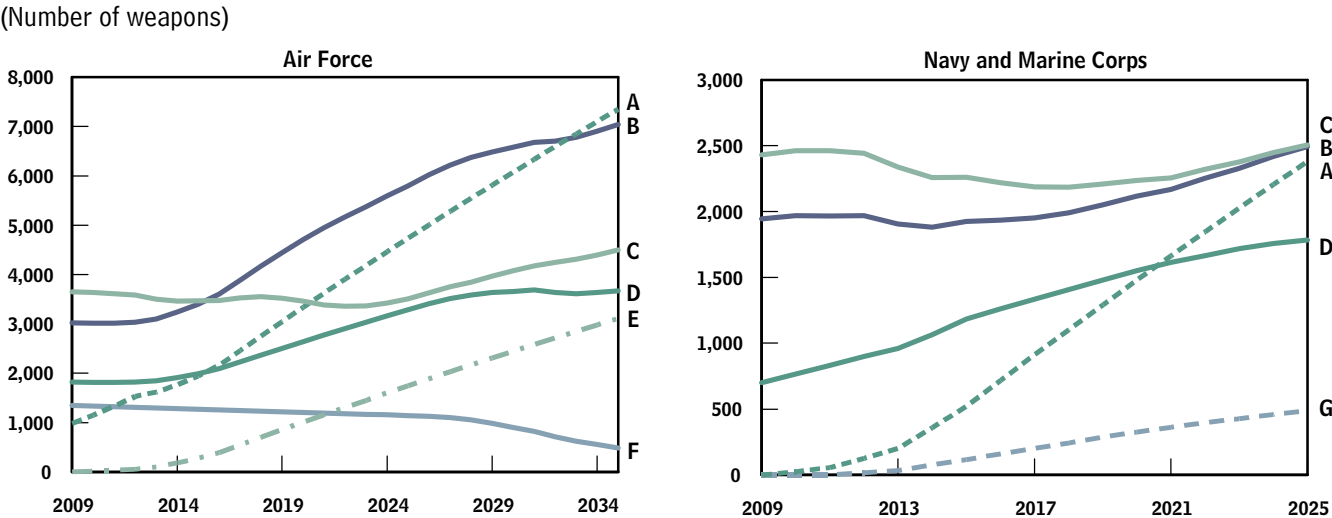
Although fiscal year 2009 fighter modernization plans could result in inventory shortfalls relative to the services' stated requirements, aggregate fleet capabilities could nevertheless improve in many respects because the JSF is expected to perform significantly better than the aircraft it is meant to replace. CBO developed several performance metrics that allow comparisons between the capabilities of today's fighter forces and those envisioned under DoD's plans. On the basis of those comparisons, CBO determined that many air-to-ground and air-to-air capabilities would improve relative to today's even during periods with inventory shortfalls (see Summary Figure 2). The capabilities shown in the figure correspond to CBO's base-case inventory projections shown in Summary Figure 1.

The air-to-ground weapons capacity of the Air Force's fighter force—as measured by the fleet's aggregate capacity to carry 2,000-pound, satellite-guided Joint Direct Attack Munitions (JDAMs)—would increase substantially under fiscal year 2009 plans because the F-35A is designed to have larger payload capacity and somewhat longer flight ranges than the F-16 Fighting Falcons it is slated to replace and because the F-15C/D Eagles it is intended to replace are strictly air-to-air fighters. For example, relative to today, the fleet's aggregate capacity to deliver JDAMs when operating in a nonstealthy configuration (with weapons carried by the F-35A both internally and externally) would increase by over a factor of

5. Although they do not strictly represent “best-case” or “worst-case” inventory scenarios, the shaded regions in Summary Figure 1 incorporate a wide range of assumptions—from very optimistic to very pessimistic—that have been put forth by the services or other analysts. Not included are the implications of large changes in funding or requirements that could be made in the future.
6. This report does not consider tactical fighter aircraft specialized for airborne electronic attack—in particular, the EA-6B and its replacement, the EA-18G—in its discussion of inventory goals. The Navy's and Marine Corps' inventory goals change slightly over time as the composition of their forces evolves. The number of squadrons would remain unchanged.

Summary Figure 2.

Changes in the Weapons Capacity of Fighter Forces Under DoD’s Fiscal Year 2009 Modernization Plans



Source: Congressional Budget Office based on the Department of Defense’s (DoD’s) fiscal year 2009 plans.

Notes: JDAM = Joint Direct Attack Munition; n. mi. = nautical miles.

Estimates of mission range are based on the distance an aircraft could fly from an aerial refueling orbit.

For air-to-ground missions, weapons capacity is based on loads of 2,000-pound JDAMs.

For air-to-air missions, weapons capacity is based on aircraft-specific loads of AIM-9 and AIM-120 missiles.

Stealth-only capacity (dashed lines) indicates that weapons are carried exclusively in internal bays. Total capacity (solid lines) indicates that weapons are carried both in internal bays and on external weapons racks.

Mission type (air-to-ground or air-to-air)/Weapons carriage (stealth-only or total)/Mission radius (air-to-ground missions only):

- A = Air-to-air/Stealth-only
- B = Air-to-ground/Total/500 n. mi.
- C = Air-to-air/Total (divided by 4)
- D = Air-to-ground/Total/600 n. mi.
- E = Air-to-ground/Stealth-only/600 n. mi.
- F = Air-to-ground/Total/700 n. mi.
- G = Air-to-ground/Stealth-only and total/700 n. mi.

two for missions against targets located about 500 nautical miles (n. mi.) from the orbit of the nearest aerial refueling tanker.⁷ As the service’s inventory of F-35As began to grow, moreover, the fleet’s aggregate capacity to deliver

2,000-pound JDAMs out to a radius of 500 n. mi. when operating in a stealthy configuration (with weapons carried only in the F-35A’s internal weapons bay) would eventually—in about 2030—equal today’s total capacity and continue to increase in subsequent years. The air-to-ground strike capacity of Air Force fighters at ranges of 700 n. mi. and farther would decrease under fiscal year 2009 plans, though, because at that range the F-35A cannot replace the capacity provided by F-15Es and A-10s, which will begin to be retired from service after 2025.

7. The mission radii cited in this report are distances from an aerial refueling orbit. Mission radii from a land base, aircraft carrier, or amphibious ship would be shorter because additional fuel is consumed while taking off and climbing to altitude. The range estimates are limited to external fuel tanks typically used by the U.S. military. Longer ranges might be possible with larger tanks.

The air-to-ground capacity of the Navy's and Marine Corps' fleets would also be higher than today's, even during periods of inventory shortfall. However, the increases in air-to-ground capacity (as measured by the capacity to carry 2,000-pound JDAMs) would be less substantial than those experienced by the Air Force because all aircraft being replaced are air-to-ground capable (unlike the F-15C/D) and because the F-35B will be unable to carry 2,000-pound weapons in its internal weapons bay.

In addition to weapons capacity, other aspects of the modernized force would offer enhanced strike capability in the future. For example, new air-to-ground weapons are expected to result in greater lethality for a given aircraft payload. In particular, the 250-pound Small Diameter Bomb (SDB) that has recently been fielded by the Air Force is expected to provide current and future aircraft with the ability to destroy more targets per sortie than is possible with today's weapons. More-capable communications systems and radars—for example, radars with active electronically scanned array (AESA) antennae in place of older, mechanically scanned antennae—are expected to improve the ability to detect and identify targets both in the air and on the ground. In areas with strong air defenses, the stealth characteristics of the JSF will enable greater freedom of action for strike forces early in a conflict before those defenses can be destroyed.⁸

Improved radars and stealth airframes will also enhance fighter jets' air-to-air capabilities relative to those of today's force. The move to AESA radars will enable the new fighters to detect enemy aircraft at longer ranges while stealth features will reduce an enemy's corresponding capability. The capacity to carry air-to-air missiles in a stealthy configuration (with all weapons in internal bays) would markedly increase under DoD's fiscal year 2009 modernization plans as JSFs and the final F-22s entered the force. Total air-to-air missile capacity, which includes provisions for external missile carriage on the F-22 and JSF, would remain about the same as today's capacity, although internal carriage would be preferred for the F-22 and JSF in order to fully maintain their stealth characteristics.

8. Some of the improvements in survivability offered by stealth capability and by more-advanced onboard systems would be offset, however, if potential adversaries fielded more-effective defensive systems.

Alternative Approaches for Modernizing Fighter Forces

DoD's fiscal year 2009 modernization plans have led to calls for increased production of fighter and attack aircraft (from those who believe that satisfying inventory requirements is of primary importance) as well as calls for decreased or deferred production (from those who believe that the capability improvements offered by new aircraft can compensate for lower inventories). In the course of its analysis, CBO examined seven alternative plans for modernization, which can be grouped into three general categories:

- Those that would accelerate and increase purchases of fighters to maintain inventories equal to service-defined requirements—essentially eliminating any fighter gaps (Alternatives 1 through 3);
- Those that would result in smaller inventories but maintain aggregate weapons capacity at least at today's levels (Alternatives 4 and 5); and
- Those that would allow inventories of manned fighters to shrink but would replace some lost capabilities with either medium-range bombers or unmanned attack aircraft (Alternatives 6 and 7).

Each general approach could be implemented in a wide variety of ways other than CBO's illustrative alternatives, and combinations of approaches would also be possible.⁹

Approaches That Satisfy the Services' Current Inventory Goals

Under Alternatives 1 through 3, DoD would not only purchase additional aircraft, but would also purchase those planes earlier than fiscal year 2009 plans stipulate to avoid inventory shortfalls relative to the services' stated requirements. Projected shortfalls would be eliminated under Alternative 1 by purchasing 164 more F-35As for the Air Force and shifting purchases of the JSF for all the services to earlier years.¹⁰ For Alternative 1 to be feasible,

9. For example, one approach might maintain weapons capacity for the Air Force and Marine Corps and inventory level for the Navy.

10. Because development of the JSF has not been completed, CBO assumed that peak production rates would be increased to higher levels than planned but that the ramp-up to those levels would proceed as currently scheduled. The higher production rates are within the planned capacity of Lockheed Martin's assembly facilities.

Summary Box 2.

The Possible Role of the F-22 Program in Mitigating the Air Force's Projected Inventory Shortfall

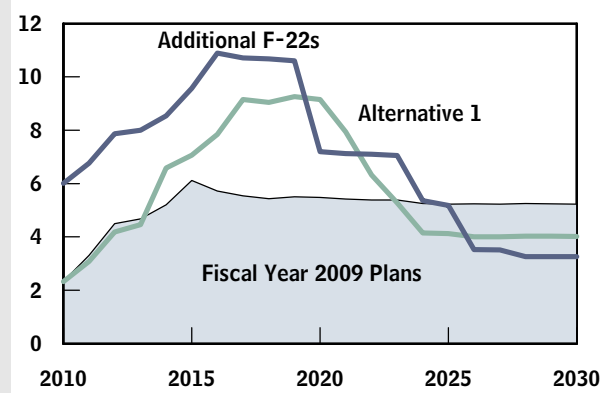
Instead of increasing the number of F-35A Joint Strike Fighters procured over the 2010–2034 period and accelerating the pace at which those jets are purchased—as the Congressional Budget Office (CBO) outlined in the first of seven alternatives to the Department of Defense's (DoD's) fiscal year 2009 fighter modernization plans—the Air Force could eliminate the projected shortfall in its fighter inventory and still build an all-stealth fighter force by continuing to purchase F-22 Raptors. CBO estimates that the Air Force could maintain an inventory of 2,200 aircraft by purchasing 200 more F-22s at a rate of 20 per year from 2010 through 2019 and by shifting purchases of 240 F-35As from the 2025–2034 period to the 2016–2023 period.¹ (Total purchases of the F-35A would decrease by 35 aircraft, from the planned 1,763 to 1,728.)

That modernization approach would require significantly greater resources in the coming years, however, because continued production of the F-22 would

1. Funding for what were to have been the last 20 F-22s ordered by the Air Force was included in the fiscal year 2009 budget. In April 2009, DoD indicated that it would not include additional F-22s in its forthcoming budget request for fiscal year 2010. Funding for four F-22s, which would bring total procurement to 187 aircraft, was requested by the Administration in its proposed supplemental appropriation for fiscal year 2009, however.

Funding Needed by the Air Force Under DoD's Fiscal Year 2009 Plans Plus Two Alternatives

(Billions of 2009 dollars)



Source: Congressional Budget Office.

coincide with early, large-scale production of the F-35A, when unit prices are the highest (see the figure above). Under that approach, about \$37 billion would be needed between 2010 and 2014 (compared with about \$20 billion under DoD's fiscal year 2009 plans and under Alternative 1). About \$157 billion would be needed through 2034, when final purchases of the F-35A are scheduled to be completed (as opposed to the \$124 billion projected under fiscal year 2009 plans and the \$130 billion estimated under Alternative 1).

development and fielding of the JSF could not experience additional substantial delays. (A variant of Alternative 1 that would include purchases of additional F-22s for the Air Force is described in Summary Box 2.) Under Alternative 1, CBO estimates, total investment costs—specifically, those for research, development, test, and evaluation (RDT&E) and for the procurement of new aircraft—would be \$208 billion over the 2010–2034 period.¹¹ (See Summary Table 1.) Although the overall

costs of implementing Alternative 1 would be only about \$5 billion more than DoD's projections for total funding under fiscal year 2009 plans, costs over the next five years would increase by about \$12 billion as a result of accelerating purchases of the JSF. Although the total investment costs estimated for Alternative 1 would be only about 2 percent higher than is projected for DoD's fiscal year 2009 plans when measured in constant dollars, Alternative 1 would be about 7 percent more costly when measured on a net-present-value basis (at a real discount rate of 3 percent) because of the shift in funding to earlier years.

11. The figures cited do not include RDT&E and procurement costs for continuing upgrades to existing aircraft.

Summary Table 1.**Costs of Fighter Aircraft Under DoD's Fiscal Year 2009 Modernization Plans and Seven Alternative Plans**

Plan	Remaining Investment Costs (Billions of 2009 dollars)		Remaining Investment Costs (Billions of dollars, net present value)	
	2010–2014	2010–2034	2010–2014	2010–2034
DoD's Fiscal Year 2009 Modernization Plans	54	203	49	147
<i>Alternative 1:</i> Satisfy Inventory Requirements by Accelerating/Increasing Purchases of JSFs	66	208	59	157
<i>Alternative 2:</i> Satisfy Inventory Requirements by Purchasing JSFs and Improved Legacy Aircraft	71	211	64	160
<i>Alternative 3:</i> Cancel the JSF Program and Satisfy Inventory Requirements by Purchasing Improved Legacy Aircraft	44	154	39	117
<i>Alternative 4:</i> Purchase JSFs in Quantities to Match Weapons Capacity in 2009	53	136	48	105
<i>Alternative 5:</i> Purchase Enough JSFs to Match Weapons Capacity in 2009 and Satisfy Inventory Requirements by Purchasing Small, Armed UAVs	57	156	51	119
<i>Alternative 6:</i> Replace Some Fighter Aircraft with Medium-Range Bombers or UCAV-Ns to Improve Mission Range	64	200	58	153
<i>Alternative 7:</i> Replace Some Fighter Aircraft with Medium-Range Bombers or UCAV-Ns to Improve Mission Range and Augment Fleets with Small, Armed UAVs to Satisfy Inventory Requirements	67	220	61	165

Source: Congressional Budget Office based on the Department of Defense's (DoD's) fiscal year 2009 plans.

Notes: JSF = Joint Strike Fighter; UAV = unmanned aerial vehicle; UCAV-N = carrier-capable unmanned combat aerial vehicle.

Investment costs comprise expenses for research, development, test, and evaluation of new aircraft and for procurement of those aircraft.

Under Alternative 2, DoD would not purchase additional JSFs but would, instead, augment fighter inventories in the near term with purchases of new aircraft that are based on older designs; specifically, DoD would acquire 260 F/A-18E/Fs, in addition to those in the fiscal year 2009 plans, for the Navy and Marine Corps and 435 F-16Es for the Air Force.¹² Because of those purchases, 530 fewer JSFs would be produced in later years. According to CBO's estimates, investment costs under Alternative 2 would be \$211 billion—\$8 billion more than under DoD's fiscal year 2009 plans (or about 4 percent higher in constant 2009 dollars and 9 percent higher on a net-present-value basis) and \$17 billion more over the next five years.¹³

Under Alternative 3—which CBO estimates would require an investment of about \$154 billion—DoD would cancel the JSF program and modernize the fighter force by purchasing upgraded versions of aircraft that are based on older designs, including 680 F/A-18E/Fs, in addition to those already planned, for the Navy and Marine Corps and 1,925 F-16Es for the Air Force. In total, Alternative 3 would cost \$49 billion less than is projected for DoD's fiscal year 2009 plans over the 2010–2034 period (about 24 percent less in constant dollars and 21 percent less on a net-present-value basis) and \$10 billion less over the next five years, CBO estimates.¹⁴

12. Relative to the F-16C in today's fleet, the F-16E includes improved avionics, AESA radar, conformal fuel tanks for longer flight range, and a strengthened airframe for carrying larger payloads. The F-16E has been marketed to foreign militaries, and an earlier version (called the F-16 Block 60 at the time) was a modernization alternative considered by the Air Force prior to the selection of the JSF.

13. Alternative 2 would cost more than Alternative 1 because the decreased numbers of JSFs purchased would result in higher unit costs for that aircraft. The 530 JSFs not produced would be deleted from the end of the production run when unit costs would be the lowest.

14. U.S. cancellation of the JSF would most likely make it unaffordable for the program's international participants. (The United Kingdom, Norway, Denmark, the Netherlands, Canada, Italy, and Turkey have collectively contributed about \$5 billion to the JSF's research and development thus far.) Depending on the contractual arrangements underlying that participation, the United States could decide to take some action (for instance, arranging for financial compensation) to help mitigate the consequences that canceling the program would have for them. Other modern fighters that could be purchased in lieu of the JSF, including both U.S. and European designs, are currently in production.

Approaches That Maintain Current Weapons Capacity

Alternatives 4 and 5 would result in smaller fighter inventories, but the aggregate air-to-ground weapons capacity for short-range missions—those within a radius of 300 n. mi. from an aerial refueling tanker—would be maintained at today's level. Under Alternative 4, purchases of the F-35A for the Air Force would be cut approximately in half, to 850 aircraft, and the Air Force's fighter inventory would, as a consequence, drop to about 1,200 aircraft when production of the F-35A ends in 2033. For the Navy and Marine Corps, 150 F-35Bs and 330 F-35Cs would be purchased under Alternative 4, and the inventory of fighters would drop to about 900 aircraft when the final F-35B/Cs were delivered in 2022. Those smaller purchases would result in significantly lower investment costs—a total of about \$136 billion, CBO estimates, or about \$67 billion less than the amounts indicated in DoD's fiscal year 2009 modernization plans (33 percent less in constant dollars and 29 percent less on a net-present-value basis). Savings would be only about \$1 billion over the next five years, however, because CBO assumed that production of the JSF would initially ramp up as specified in fiscal year 2009 plans but level off at 90 per year (instead of 130 per year).

Under Alternative 5, purchases of relatively inexpensive armed unmanned aerial vehicles (UAVs) would be added to the fighters purchased under Alternative 4 to partially compensate for lower fighter inventories. Specifically, the Air Force would purchase nearly 1,000 MQ-9 Reapers. (The Reaper is a larger version of the Predator reconnaissance aircraft, which has generated much attention for attacking insurgent targets with Hellfire missiles during Operations Enduring Freedom and Iraqi Freedom.) Under this alternative, 151 Reapers—modified for carrier operations—would be purchased for use by the Navy or Marine Corps. Although they lack the speed and payload capacity of the typical fighter, those UAVs could fill an important role by orbiting over combat areas in order to be ready to rapidly respond to calls from ground forces for fire support. Investment costs under Alternative 5 would total \$156 billion (23 percent less in constant dollars and 19 percent less on a net-present-value basis than is projected for DoD's fiscal year 2009 plans), or about \$20 billion more than under Alternative 4. Costs over the next five years would be similar to those specified in DoD's fiscal year 2009 plans.

Approaches That Provide Greater Unrefueled Mission Ranges

Under Alternatives 6 and 7, DoD would replace some of the fighters that would be purchased under fiscal year 2009 plans with attack aircraft capable of undertaking longer-range missions—a capability that would increase both the range and endurance of U.S. strike forces.

Under Alternative 6, the Air Force would field about 500 stealthy fighter aircraft—187 F-22s and 325 F-35As—and 250 stealthy medium-range bombers that would each be able to carry a payload of 10 2,000-pound JDAMs at high subsonic speeds out to a radius of 1,500 n. mi.¹⁵

The Navy and Marine Corps would purchase 410 F-35B/Cs—270 fewer than planned—and 275 stealthy carrier-capable unmanned combat air vehicles (UCAV-Ns) that would be able to carry a load of two JDAMs weighing 2,000 pounds each out to a radius of 1,500 n. mi. Overall, implementing Alternative 6 would cost about \$200 billion, CBO estimates, slightly less than the projected cost of fiscal year 2009 plans (about 2 percent less in constant dollars and 4 percent less on a net-present-value basis). However, because of expenses related to RDT&E for the new aircraft, costs over the next five years would be about \$10 billion higher than those projected in DoD's fiscal year 2009 plans.

Under Alternative 7, Reapers would be added to the aircraft slated for purchase under Alternative 6—1,000 for the Air Force and 100 for the Navy—to round out inventories. The overall cost of implementing Alternative 7 would be about \$220 billion, CBO estimates—or about 7 percent more in constant dollars and 13 percent more on a net-present-value basis.

Capabilities of Alternative Forces

All of the alternative fighter forces examined by CBO would provide greater capacity to deliver air-to-ground weapons than today's forces under most circumstances (see Summary Figure 3). For the Air Force, the payload capacity of the F-35A relative to that of the F-16C would result in about a threefold increase in weap-

ons capacity for missions out to a radius of 500 n. mi. For all approaches analyzed by CBO—except for Alternative 3—the Air Force's weapons capacity while operating in a stealthy configuration would be close to or greater than today's total weapons capacity. Except for Alternatives 6 and 7, however, total weapons capacity at longer ranges (out to a radius of 700 n. mi. and beyond) would decrease. Alternatives 6 and 7 would offer the Air Force increased total weapons capacity (most of it stealthy) out to 700 n. mi. and beyond. (Total capacity at 700 n. mi. would decline under the other alternatives and under DoD's modernization plans as F-15Es were retired.)

The Navy and Marine Corps would show lesser improvement in total capacity at shorter ranges. However, the longer range offered by the F-35C, which is reflected in all but Alternative 3, would increase the Navy's unrefueled reach to a radius of 700 n. mi.; and the UCAV-Ns included in Alternatives 6 and 7 would extend the Navy's unrefueled mission radius to 1,500 n. mi. For the Air Force, Navy, and Marine Corps, improved weapons—such as the 250-pound SDB—would further increase future air-to-ground capabilities relative to today's. Alternative 3 would not include short takeoff vertical landing fighters for operation from amphibious ships, however.

All of the alternative forces examined by CBO would consist of aircraft with significantly improved systems relative to today's forces. At a minimum, under every alternative, today's conventional fleet would be replaced with a fleet made up almost entirely of stealthy aircraft or new conventional aircraft with more advanced avionics and radars (see Summary Figure 4).¹⁶ In the alternatives considered by CBO, new aircraft based on older designs that incorporated advanced avionics and radars would provide greater air-to-ground and air-to-air effectiveness than do DoD's current aircraft; but those planes would not provide the same freedom to operate against strong air defenses that would be enjoyed by the stealth aircraft DoD plans to purchase. Under the alternatives that would procure reduced quantities of stealthy aircraft, an appropriate mix of stealthy and nonstealthy aircraft could be deployed early in a conflict and used to help suppress

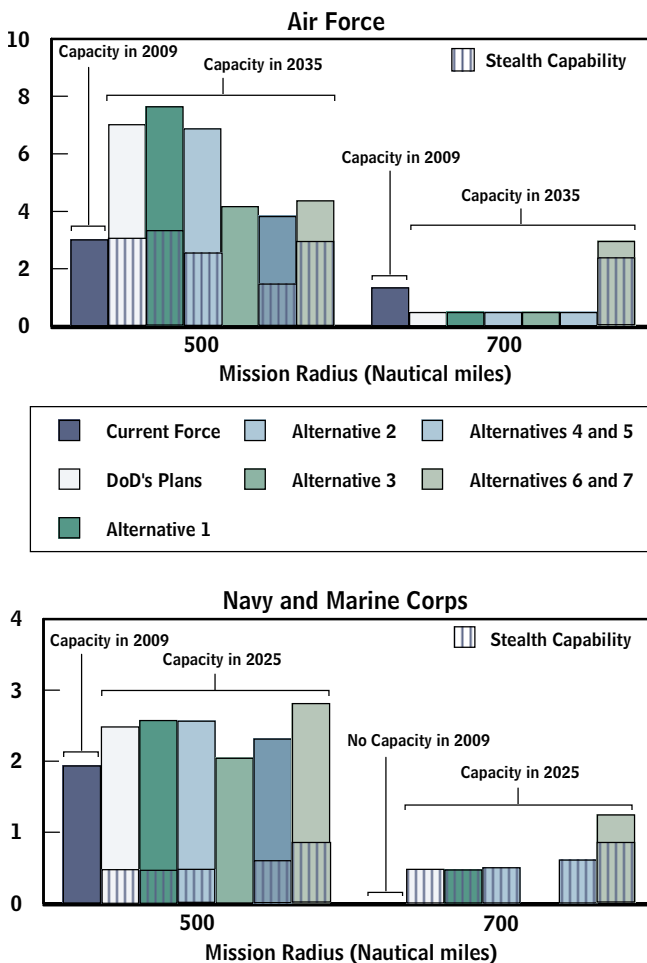
15. In addition to fighter aircraft, the Air Force also fields about 140 long-range bombers (B-52Hs, B-1Bs, and B-2As) that routinely contribute to conventional strike operations. CBO did not include those aircraft in its estimates of weapons capacity because many bombers are typically committed to other roles (such as nuclear deterrence) that are beyond the scope of this paper.

16. Avionics are the electronic systems and software that support various functions in aviation, including communications, navigation, flight control, collision avoidance, and so on.

Summary Figure 3.

Weapons Capacity of Fighter Forces Under DoD's Fiscal Year 2009 Plans and Seven Alternative Plans

(Thousands of 2,000-pound JDAMs)



Source: Congressional Budget Office.

Notes: DoD = Department of Defense; JDAM = Joint Direct Attack Munition.

Specific estimates of mission range reflect the distance an aircraft could fly from an aerial refueling tanker to a designated target and back with a fuel reserve of 30 minutes.

The years 2035 and 2025 correspond with the respective services' fiscal year 2009 plans for concluding production of the Joint Strike Fighter. After 2035 (or perhaps sooner), the Air Force will probably need to begin replacing or extending the service life of older F-22s. After 2025, the Navy will probably need to take similar measures for F/A-18E/Fs.

air defenses, clearing the way for subsequent operations by conventional aircraft.¹⁷

Under Alternatives 4 and 6, the Air Force would field a considerably smaller number of aircraft than would be fielded under fiscal year 2009 plans. The number of fighters operated by the Navy and Marine Corps would be only slightly smaller under Alternative 4. Although lower inventories could reduce the services' ability to operate in many places at once, fielding small and relatively inexpensive (when compared with the cost of a fighter) armed UAVs, such as the MQ-9 Reapers that are included in Alternatives 5 and 7, could potentially mitigate that shortcoming. In recent conflicts, fighters have been heavily tasked with remaining airborne and ready to respond at short notice to requests for air support. The success of the armed Predator aircraft illustrates that this type of mission can be successfully carried out with aircraft that lack the larger payloads and higher performance (and higher cost) of fighters.¹⁸ Endurance, a shortcoming of fighter aircraft designed for high speed and maneuverability, can be more important than payload capacity in many circumstances.

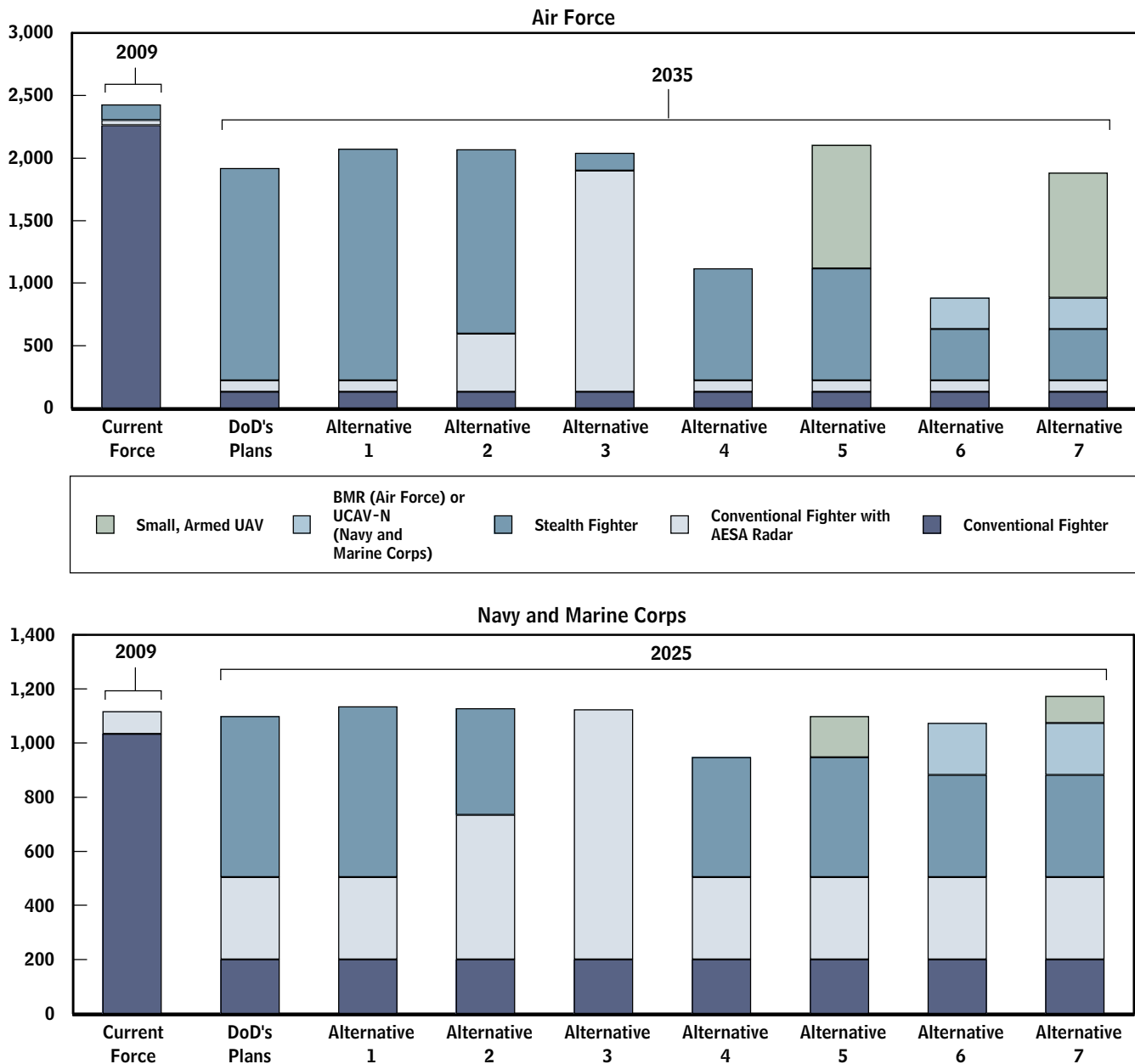
Alternatives that would result in smaller aircraft inventories would most likely have lower operation and support costs than forces that maintain today's inventory levels. CBO did not estimate operation and support costs for the alternatives examined because there is considerable uncertainty about how expensive it will be to maintain the new generation of manned and unmanned aircraft. Recent operational experience with the F-22 and projections for the JSF suggest that those aircraft will be more

17. With aircraft such as the EA-6B and EA-18G, DoD anticipates conducting specialized airborne electronic attack (AEA) operations against advanced air defenses even when operating with stealthy aircraft, and some additional investment in AEA forces might be needed if DoD were to purchase larger numbers of conventional aircraft. Considerations of AEA capabilities in the options presented here are excluded, however, for the sake of simplicity and because detailed survivability discussions are best carried out at a classified level.

18. Predator and Reaper operations could be constrained by air defenses, however, and thus might not be possible early in a conflict against an adversary with advanced defenses (before those defenses could be otherwise suppressed). To provide fighter forces with greater capability in the face of air defenses, General Atomics is developing a stealthier version of the Reaper that could be purchased instead (although probably at a higher cost).

Summary Figure 4.**Composition of Fighter Inventories Under DoD's Fiscal Year 2009 Modernization Plans and Seven Alternative Plans**

(Number of aircraft)



Source: Congressional Budget Office.

Notes: AESA = advanced electronically scanned array; BMR = medium-range bomber; DoD = Department of Defense; UAV = unmanned aerial vehicle; UCAV-N = carrier-capable unmanned combat aerial vehicle.

The years 2035 and 2025 correspond with the respective services' fiscal year 2009 plans for concluding production of the Joint Strike Fighter. After 2035 (or perhaps sooner), the Air Force will probably need to begin replacing or extending the service life of older F-22s. After 2025, the Navy will probably need to take similar measures for F/A-18E/Fs.

Today's inventories may be slightly different as a result of recent deliveries or retirements of aircraft.

expensive to operate and maintain than the aircraft they are replacing, however.¹⁹

The significantly longer unrefueled ranges achievable by the medium-range bombers and the UCAV-Ns envisioned for Alternatives 6 and 7 would help address DoD's concerns about so-called anti-access threats.²⁰ Access can be restricted not only by an adversary's air defenses (which stealth capability is designed to counter) but also under certain "denied-basing" scenarios—for instance, if local airbases are not made available for political reasons,

19. A brief discussion of operation and support costs can be found in the appendix.

20. The 2006 Quadrennial Defense Review explicitly called for reorienting joint air capabilities toward "...systems that have far greater range and persistence; larger and more flexible payloads for surveillance and strike; and the ability to penetrate and sustain operations in denied airspace."

if operations are conducted in remote areas that lack airbases, or if an adversary is able to attack bases used by U.S. forces or Navy carriers with long-range weapons. Longer-range aircraft can make it more practical to operate aircraft from bases outside the range of an adversary's weapons (or to keep aircraft carriers farther from shore where they are more difficult to locate and attack). Other advantages of long-range aircraft are that they offer the ability to attack targets farther into defended airspace where aerial refueling tankers are usually unable to operate and to loiter longer over target areas to provide persistent fire support. Purchases of the F-35B might also help address access limitations because those aircraft can be operated from large amphibious ships as well as from airbases that are smaller than needed by conventional land-based aircraft. That basing flexibility comes with the disadvantages of decreased mission range and payload capacity and increased costs, however.

The Department of Defense's Plans for Modernizing Fighter Forces

The U.S. military currently maintains a total active inventory of nearly 3,500 fighter and attack aircraft. The Air Force's fleet consists of about 2,400 land-based aircraft, and the Navy's and Marine Corps' fleets together comprise about 1,100 aircraft capable of operating from ships. (The Army does not operate fixed-wing fighter aircraft.) To maintain today's inventory levels and modernize this force, the Department of Defense (DoD) plans to extend the service life and improve the capabilities of selected aircraft and to purchase about 2,500 new aircraft over the next 25 years. In this chapter, the Congressional Budget Office (CBO) describes the composition of today's fighter forces and DoD's proposals (as laid out by the previous Administration in its fiscal year 2009 defense plans) for modernizing those forces. It then examines how fighter inventories could deviate from expected levels given prevailing uncertainty about the service life of existing aircraft and about the scheduling of new purchases. The implications of those possible inventory changes for the effectiveness of fighter forces are explored in Chapter 2.

While this report treats aircraft acquisition issues in terms of total aircraft inventories, combat operations are carried out only by that part of the inventory that is assigned to the combat element of the force (in other words, units that are manned, trained, and equipped for combat). The combat element of the force is often referred to as the "combat force structure" and typically accounts for about 60 percent of the total number of aircraft procured. The remainder of the inventory is used for flight training and ongoing testing and also allows for routine maintenance and for reserve aircraft to offset anticipated losses from peacetime mishaps. From time to time, policymakers and others have advocated and attempted to implement economies in those "overhead" factors, but DoD has sustained

the current general inventory planning concepts for roughly 50 years. Accordingly, those apportionments will be considered appropriate in all the alternatives developed in this paper.

Today's Fighter Forces

The Air Force's current fleet includes five types of fighter or attack aircraft (see Table 1-1). Although each was initially designed to fill a specific role—whether establishing air superiority, conducting long-range strikes against ground targets, or providing fire support to ground forces—upgrades to most of those aircraft have increased their versatility:

- The **A-10 Thunderbolt II** is a ground-attack aircraft that was designed primarily to destroy armored vehicles, although its capabilities have been broadened considerably over the years by increasing the types of weapons that the aircraft can deliver. (A-10As with upgraded precision engagement capabilities are designated as A-10Cs.) Although the A-10 is not capable of supersonic flight, it has long flight endurance and is the only fighter/attack aircraft in the U.S. inventory that is armored against gunfire from the ground.
- The **F-15 Eagle** was originally designed as an air-superiority fighter (intended for air-to-air combat and to enter and control enemy airspace), and the C/D models are equipped and used in that role.
- The **F-15E Strike Eagle** is a multirole version of the original F-15. It retains much of the air-to-air capability of earlier F-15s but includes substantial modifications for air-to-ground missions.

Table 1-1.

Configuration and Capabilities of Fighter Aircraft in the Air Force’s Current Inventory and Under DoD’s Modernization Plans

Parameter	Current Inventory					DoD's Plans
	A-10 Thunderbolt II	F-15 Eagle	F-15E Strike Eagle	F-16 Fighting Falcon	F-22 Raptor	F-35A JSF
Total Active Inventory (2009) ^a	350	470	220	1,200	135	0
Year First Fielded	1977	1975	1989	1979	2005	2013
Average Age (Years)	28	26	17	20	2	n.a.
Maximum Weight						
at Takeoff (Pounds)	51,000	68,000	81,000	48,000 ^b	83,500	~70,000
Supersonic Dash	No	Mach 2+	Mach 2+	Mach 2	Mach 2+	> Mach 1
Sustained Supersonic Cruise	No	No	No	No	Yes	No
Stealth Capability	No	No	No	No	Yes	Yes

Source: Congressional Budget Office based on data from the Department of Defense (DoD).

Notes: JSF = Joint Strike Fighter; n.a. =not applicable.

Mach number measures speed relative to the speed of sound (Mach 1).

- a. Inventories are approximate and may not reflect recent deliveries or retirements.
- b. Weight shown is for Block 50/52 F-16Cs.

- The **F-16 Fighting Falcon** is the most widely fielded Air Force aircraft. Originally conceived as a light-weight fighter for close-in maneuvering during air combat, current F-16 variants provide a wide range of air-to-air and air-to-ground capabilities, including “beyond visual range” air-to-air engagement and the capacity to deliver bombs weighing up to 2,000 pounds.
- The **F-22 Raptor** is the newest Air Force fighter in service. Like the early F-15s, the F-22 was designed primarily as an air-to-air fighter, but it is capable of launching some types of air-to-ground weapons as well. Since the retirement of the F-117 Nighthawk in 2007, the F-22 is the only stealthy fighter (able to elude detection by radar) currently in the Air Force inventory. As of February 2009, about 135 of the 187 F-22s that DoD plans to procure had been delivered.
- The **F/A-18A/B/C/D Hornet** has been flown by both the Navy and Marine Corps since the 1980s. It can operate from air bases on land and can also be catapulted from and recovered aboard aircraft carriers. This multirole fighter replaced several older types of aircraft whose functions were limited specifically to air-to-air or air-to-ground roles.
- The **F/A-18E/F Super Hornet** is a newer and substantially larger version of the F/A-18. In service since 2001, Super Hornets—the F/A-18E is a single-seat aircraft, and the F/A-18F is a two-seat aircraft—have greater flight range and greater payload capacity than do earlier versions of the F/A-18. They also include several design features that, under certain circumstances, make them more difficult to detect with radar than earlier-model F/A-18s.

The Department of the Navy’s (DoN’s) fighter inventory currently includes three types of fighters (see Table 1-2). Those naval fighters were designed from the outset as multirole aircraft.¹

1. This report does not consider tactical fighter aircraft specialized for airborne electronic attack—in particular, the EA-6B and its replacement, the EA-18G—in its discussion of inventory goals.

- The **AV-8B Harrier** is a short takeoff vertical landing (STOVL) attack aircraft operated by the Marine Corps. The Harrier has the flexibility to operate from tactical landing sites and amphibious ships. Although primarily intended as a ground-attack aircraft, under some circumstances, the Harrier can be used in an air-to-air role, as was demonstrated by the British during the Falkland Islands War in 1982.

Table 1-2.

Configuration and Capabilities of Fighter Aircraft in the Navy's and Marine Corps' Current Inventory and Under DoD's Modernization Plans

Parameter	Current Inventory			DoD's Plans	
	AV-8B	F/A-18A/B/C/D	F/A-18E/F	F-35B	F-35C
	Harrier	Hornet	Super Hornet	Joint Strike Fighter	Joint Strike Fighter
Total Active Inventory (2009) ^a	125	620	380	0	0
Year First Fielded	1985	1983	2001	2012	2015
Average Age (Years)	14	19	5	n.a.	n.a.
Maximum Weight at					
Takeoff (Pounds)	32,000 ^b	51,900	66,000	~60,000	~70,000
Supersonic Dash	No	Mach 1.7+	Mach 1.8+	> Mach 1	> Mach 1
Sustained Supersonic Cruise	No	No	No	No	No
Stealth Capability	No	No	Some	Yes	Yes

Source: Congressional Budget Office based on data from the Department of Defense (DoD).

Notes: n.a. = not applicable.

Mach number measures speed relative to the speed of sound (Mach 1).

a. Inventories are approximate and may not reflect recent deliveries or retirements.

b. Weight in table is for short takeoff roll. Maximum weight for vertical takeoff is about 21,000 pounds.

More-detailed descriptions of the functions and capabilities of these aircraft can be found on the services' Web sites.²

DoD's Fiscal Year 2009 Plans for Modernizing U.S. Fighter Forces

As articulated in the Fiscal Year 2009 Future Years Defense Program (FYDP) and longer-term documents such as the Selected Acquisition Reports (SARs), DoD's plans for fighter modernization would result in inventories close to those in existence today but would substantially improve force effectiveness.³ Improvements in effectiveness would be achieved by replacing existing aircraft, which are based primarily on 1970s-era airframe designs, with a more capable mix of new, more technologically advanced aircraft. To maintain inventories while new aircraft are being purchased, DoD's plans also include programs to extend the service life of selected portions of today's fleet.

2. For further information on aircraft in today's fighter fleets, see: www.af.mil/factsheets/; www.navy.mil/navydata/fact.asp, and <http://hqinet001.hqmc.usmc.mil/AVN/documents/aircraft/fixed-wing/fixedwing.htm>. A description of the JSF can be found at www.jsf.mil.

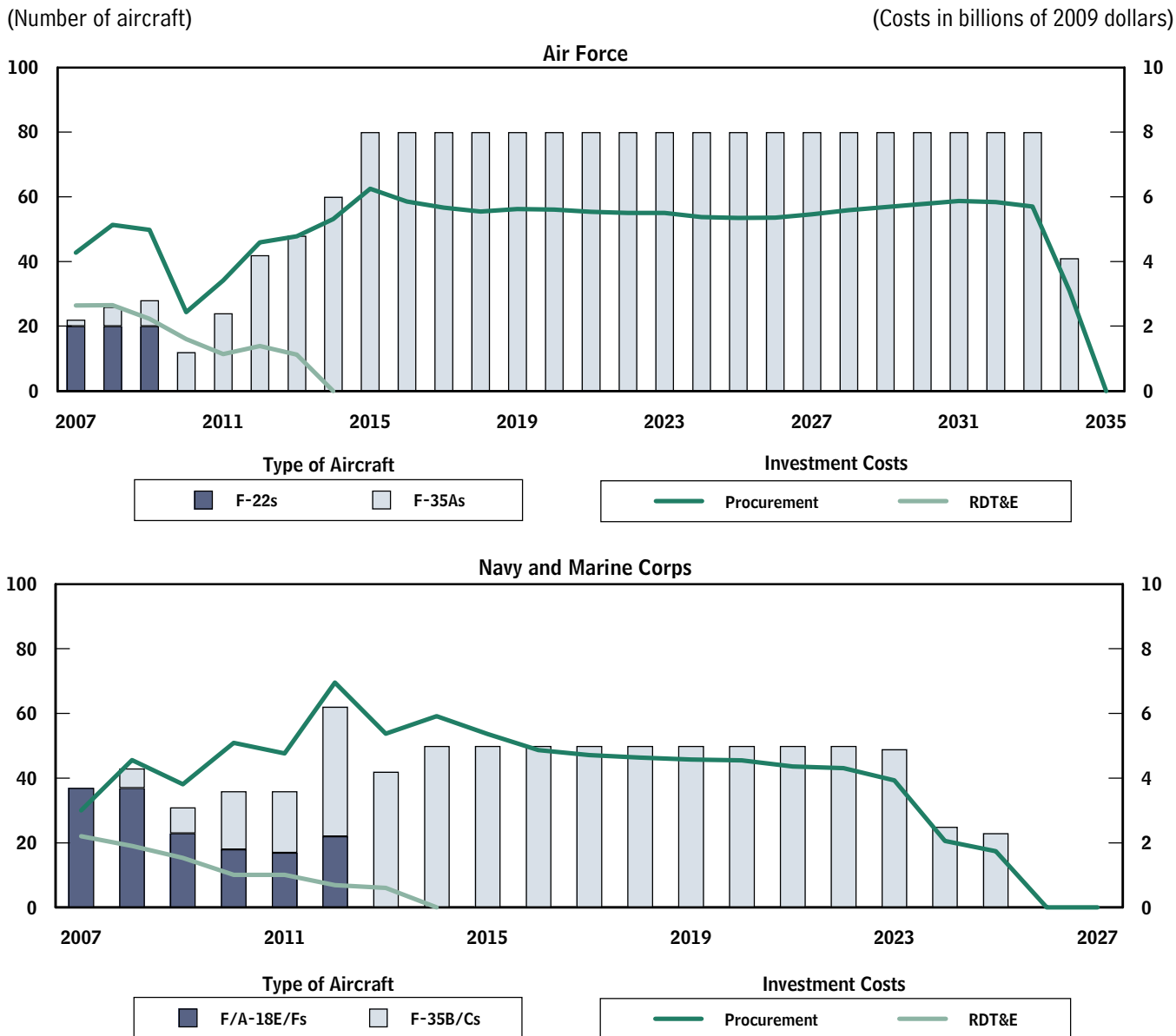
The Air Force plans to move toward an all-stealth fighter force by completing production of 187 F-22 Raptors over the next two years and by purchasing 1,763 F-35As, the land-based version (also referred to as the conventional takeoff and landing, or CTOL, version) of the Joint Strike Fighter (JSF) over the next 25 years. Both the F-22 and the F-35A incorporate advanced radars and avionics into stealthy airframes that are difficult to detect with radar.⁴ Although funding was provided in the 2009 budget for what were intended to be the final 20 F-22s purchased for the Air Force, that service branch has claimed in the past that it needs about 200 more—for a total of 381—to adequately equip its force. Although the new Administration has indicated its intention to end

3. The FYDP is a database that comprises a historical record of defense forces and funding as well as DoD's plans for future programs. The historical portion of the FYDP shows costs, forces, and personnel levels since 1962. The plan portion presents DoD's program budgets (estimates of funding needed for the next five or six years, based on the department's current plans for all of its programs). Selected Acquisition Reports are legally mandated reports that provide a summary of the status of major acquisition programs.

4. Avionics are the electronic systems and software that support various aircraft functions, including communications, navigation, flight control, collision avoidance, and so on.

Figure 1-1.

Number of Fighter Aircraft Scheduled for Purchase and Associated Investment Costs Under DoD's Fiscal Year 2009 Modernization Plans



Source: Congressional Budget Office based on the Department of Defense's (DoD's) fiscal year 2009 plans.

Note: RDT&E = research, development, test, and evaluation.

production of the F-22 at 187 aircraft, the number of F-22s ultimately procured may increase. The first production version of the F-35A was ordered in 2007, and the first F-35A squadron is expected to become operational in 2013. DoD's fiscal year 2009 plans call for purchases of the F-35A to reach 80 aircraft per year in 2015 and for the final F-35As to be procured in 2034 (see the top panel of Figure 1-1). According to DoD's estimates,

the Air Force's investment costs for F-35As would total \$128 billion (in 2009 dollars) from 2010 through 2034. Annual expenditures for the F-35A would average about \$5.6 billion during the years with the highest production rate.

To maintain inventory levels during the JSF's long production run, the Air Force, in its fiscal year 2009 plans,

included funding for programs to increase the service life of many existing fighters by making structural and technological upgrades. Notable among those efforts are wing replacement and the addition of precision munitions capabilities for over 200 A-10s and improved radars, avionics, and airframe structures for nearly 180 F-15Cs. Those F-15s have been dubbed “Golden Eagles” because, as a result of prospective upgrades, they are expected to reach nearly 50 years of service. (Historically, the typical service life of fighter jets has been about 20 years, depending on factors such as the number of flight hours logged and the number of takeoffs and landings experienced.) According to the Air Force’s projections, a number of A-10s, F-15Es, and F-15C Golden Eagles would remain in the fleet until the final JSFs were delivered after 2035. The 2009 FYDP indicates that the Air Force plans to spend about \$6 billion through 2013 on modifications to A-10s, F-15s, and F-16s. Additionally, DoD officials have indicated that about \$8 billion may be needed for modifications to bring all F-22s up to a common, highly capable configuration. (Alternatively, DoD has the option to leave about 100 of the F-22s in a less capable configuration.)

The Department of the Navy’s fiscal year 2009 modernization plans called for fielding a mix of F/A-18E/F Super Hornets and Joint Strike Fighters (F-35Bs and F-35Cs). Super Hornets incorporate today’s most advanced radars and avionics in a conventional airframe (although that airframe does include certain design features to help it avoid detection by an enemy’s radars). According to budget documents submitted by DoD in its fiscal year 2009 budget request, procurement of the F/A-18E/F will continue through 2012 for a total of 493 aircraft (see the bottom panel of Figure 1-1). An additional 13 F/A-18Fs have been procured as part of the 2008 wartime supplemental appropriation, however, and purchases of F/A-18E/Fs may be further increased in the future. Under current plans, F/A-18E/Fs will be used only in Navy squadrons.

DoN plans to purchase 680 JSFs both for the Marine Corps and to round out the Navy’s fighter fleet. The Navy plans to operate the carrier-capable F-35C, but the Marine Corps prefers the short takeoff vertical landing F-35B because it can be flown from amphibious ships and small airfields ashore. According to DoD’s fiscal year 2009 estimates, DoN’s procurement costs for the JSF would total \$75 billion (in 2009 dollars) over the 2010–2025 period, with procurement ending in 2025.

Annual procurement costs would average about \$4.9 billion during the years of highest F-35B/C production.

What portion of the 680 JSFs will be F-35Bs and what portion will be F-35Cs has not yet been decided. That mix will depend on the extent to which the Marine Corps will be responsible for providing squadrons to augment Navy squadrons aboard aircraft carriers (as part of DoN’s Tactical Aircraft Integration Plan) and whether F-35Bs will be suitable in that role. The Navy would prefer that the Marine Corps provide squadrons equipped with F-35Cs, arguing that the longer range and heavier payload offered by the C model would be critical when flying from aircraft carriers that might be far out at sea and that the B model would require additional logistics support and equipment aboard ship. The Marine Corps prefers the simplicity of operating only one type of aircraft. The Marine Corps’ inventory currently consists of about 380 fighters: 125 AV-8Bs and 255 F/A-18 Hornets.

Like the Air Force, the Navy is investing in extending the service life of existing aircraft until they can be replaced by the remaining complement of F/A-18E/Fs to be purchased and by JSFs. According to the 2009 FYDP, DoN plans to spend about \$5 billion on upgrades to the AV-8B and F/A-18 series of aircraft through 2013. Of particular concern is the service life of the A/B/C/D models of the F/A-18, which currently make up nearly 60 percent of DoN’s fighter force. By making a variety of structural repairs and closely monitoring how the aircraft are used, DoN hopes to achieve as many as 10,000 flight hours from aircraft in the Hornet fleet, a substantial increase over that aircraft’s original design of 6,000 flight hours. As part of that effort, DoN plans to spend over \$1 billion for structural repairs and modifications on 420 Hornets to enable them to reach an 8,000-hour service life. However, it is expected that much more costly repairs will be needed if those F/A-18s are to reach 10,000 hours. At the time of this report’s publication, emerging results from an ongoing Service Life Assessment Program (SLAP) of the F/A-18 were being reviewed by DoN.⁵ Uncertainties surrounding the success of that and other Service Life Extension Programs (SLEPs), and how fighter inventory levels might be affected, are discussed next.

5. Preliminary estimates indicate that about \$4.6 billion may be required to modify 300 Hornets—about half of the current fleet—to attain a service life 10,000 flight hours. (Those modifications are not currently funded.) The Navy anticipates final estimates of the scope and costs of such modifications late in 2010.

Future Fighter Inventories Under DoD's Fiscal Year 2009 Plans

The services' inventory goals call for maintaining fighter forces at roughly today's levels through at least 2030. Despite the planned investments in both new aircraft and service-life extensions for existing aircraft, however, both the Air Force and DoN are projecting inventory shortfalls in the next decade. The extent of those shortfalls depends primarily on projections of how long current aircraft can be kept in operational condition and on assumptions about when deliveries of the JSF will occur. Considerable uncertainties exist with regard to both of those factors.

The Air Force's and DoN's plans for maintaining their fighter forces include stretching the service life of existing aircraft beyond original designs by carefully monitoring the structural condition of the aircraft and implementing service-life extensions as necessary. As the structural failure of an F-15C over Missouri in November 2007 illustrated, however, problems can arise unexpectedly and force the grounding of large portions of a service's fleet. Changes in how aircraft are used as well as the services' efforts to operate aircraft well beyond what might have previously been considered viable have made it necessary to more carefully monitor the condition of their aircraft. For example, two structural repair packages—the so-called “Falcon Up” program of the late 1980s and the “Falcon Star” program of the late 1990s—were created to sustain the Air Force's F-16 fleet, which has been tasked with carrying heavier weapon loads than were anticipated when the aircraft was initially designed. The Navy's F/A-18C encountered structural issues during tests of the durability of its airframe and, as a result, those aircraft have been undergoing a series of analyses and upgrades to permit extended service life. The structural failure that led to the destruction of the F-15C in 2007 was the first serious incident associated with that aircraft type and also led to emergency surveys and repairs. Although repairing the structural component that failed in the F-15C proved to be both technically and economically feasible, that may not always be the case.

Further clouding inventory projections are uncertainties surrounding the production and delivery of the JSF. When approved for engineering development, the JSF was expected to reach initial operational capability, or IOC (the date at which a particular type of aircraft first enters service with a combat squadron), in the three service branches in 2010 (Marine Corps), 2011 (Air Force),

and 2012 (Navy). However, those IOC dates have been postponed to 2012, 2013, and 2015, respectively, because progress in the JSF's development program has been slower than anticipated. Additional developmental and production problems could further postpone initial fielding of new aircraft, and additional cost growth or budget constraints could necessitate reduced annual production quantities. Flight-testing delays in the program have been announced as recently as August 2008 (although program officials insist there will be no impact on delivery schedules), and the Government Accountability Office has reported on the potential for substantial future growth in production costs.⁶

Because of uncertainties such as those described above, CBO's analysis describes ranges of inventories for the Air Force and DoN that might result in the coming years as existing aircraft continue to age and as development and production of the JSF progresses. The inventory ranges do not reflect best-case or worst-case outcomes but rather illustrate how inventories could evolve as a result of different combinations of budgetary or technological factors.

Projecting Future Fighter Inventories

In the coming years, the fighter inventory that DoD will be able to maintain will depend on how long existing aircraft can be kept in service and how rapidly new aircraft can be purchased. A variety of factors contribute to the service life of an aircraft. During the Cold War, the life of a fighter was typically limited by the rate of technological advancement: Each side would field new and improved aircraft to counter improved aircraft fielded by the other. Sixteen new types of fighter or attack aircraft were fielded in the 1950s, six in the 1960s, and five in the 1970s. Between 1975 and 1990, no less than 5 percent and as much as 9 percent of the fighter/attack fleet was replaced each year. In recognition of that turnover, aircraft structures were designed with sufficient durability to last until the next aircraft was fielded. Consequently, fighters were strong enough and light enough to provide the desired performance (as reflected in speed, climb and turn rates, range, and payload capacity) and were designed to have enough structural durability to be able to withstand the wear and tear (as measured, for example, by the number of flight hours accrued and the number of takeoffs and

6. See Government Accountability Office, *Joint Strike Fighter: Recent Decisions by DoD Add to Program Risk*, GAO-08-388 (March 2008).

landings) that was expected over, at most, about 20 years of operation.

Since 1980, however, only four new fighter designs—the F-117 Nighthawk, the F/A-18 Hornet and Super Hornet, and the F-22 Raptor—have been fielded, and since the early 1990s the rate of replacement for fighters has dropped to about 1 percent per year. Although the annual replacement rate would increase to nearly 4 percent under current production plans for the JSF, most of today's aircraft are expected to fly until they reach the end of their structural design life or beyond—essentially until they wear out and become unsafe to operate and too costly to repair.⁷ To project how the wearing out of old aircraft might affect the Air Force's and DoN's fighter inventories over time, CBO estimated when existing aircraft would be forced to leave the inventory through retirement or other forms of loss and combined those results with DoD's projections for purchasing replacement aircraft. CBO's method for estimating retirement rates is described in Box 1-1.

The Air Force's Fighter Inventory

With the exception of the F-22, most of the fighters in service with the Air Force today were purchased at high rates during the late 1970s and the 1980s (see the top panel of Figure 1-2). Coupled with the reduction in force structure that came with the end of the Cold War—the Air Force's fighter inventory is about half what it was in the mid-1980s—those purchases resulted in little need for new aircraft immediately after 1990, and annual purchase quantities declined accordingly. As a consequence, however, the age of the Air Force's fighters has steadily increased from an average of about 10 years in the 1980s to over 20 years today. In addition to chronological age, about 80 percent of today's Air Force fighters have expended more than 50 percent of their service life as measured by hours flown (see the bottom panel of

Figure 1-2). Given the typical design life of fighter aircraft and past usage rates, aircraft purchased in the 1980s are expected to reach the end of their service life at increasing rates beginning in the near future.

Under CBO's base-case assumptions—that service life extension plans are successful, and that past operational tempos (average hours flown per aircraft each year) and loss rates accurately reflect future rates—the number of Air Force fighters that reach their maximum flight hours each year will steadily increase from about 10 to 20 in 2009 to a peak of about 180 in 2021. That rate of retirement for existing aircraft would exceed deliveries of the JSF called for under fiscal year 2009 plans and result in a net decrease in the Air Force's fighter inventory over time (see the left panel of Figure 1-3). Under CBO's base-case estimate, the total fighter inventory would drop below the Air Force's stated requirement of 2,200 aircraft in about 2015. The shortfall would peak at more than 400 aircraft—resulting in an inventory approximately 20 percent below the Air Force's goal—in about 2025. The shortfall would narrow at some point thereafter but would not close within the time horizon stated in current plans because combined purchases of F-22 and F-35A fighters would total slightly less than 2,000 aircraft. Fighters would need to be purchased in greater amounts than is stated in fiscal year 2009 plans if a fleet of 2,200 aircraft is to be maintained. (Indeed, with the delivery of the last F-35As in about 2036, the F-22s in service today could be approaching their maximum flight hours and would themselves soon be in need of replacement or refurbishment under a service life extension plan. The Air Force could choose to replace those F-22s with additional JSFs or with a newly designed aircraft. CBO's cost estimates do not consider the substantial resources that would be needed between roughly 2025 and 2035 for research and development to design a new fighter for fielding in about 2035.)

CBO's base-case inventory projection closely matches the Air Force's projections over the period considered in this study, although the Air Force projects a somewhat larger gap in the mid-2020s (see the left panel of Figure 1-3). However, as has been previously noted, considerable uncertainty surrounds many of the assumptions that contribute to inventory projections. To explore the range of

7. In recognition of that fact, today's aircraft are being designed to have a longer service life. For example, the JSF has been designed to achieve a service life of 8,000 flight hours. In contrast, the A/B/C/D models of the F/A-18 were designed for 6,000 flight hours, and some early-model F-16s were retired after 4,000 flight hours because of structural concerns. As was noted earlier, however, DoD has had success with efforts to extend the service life of tactical aircraft and might also be able to do so in the future with the JSF.

Box 1-1.**CBO's Method of Estimating the Retirement Rate of Fighter Aircraft**

In the Congressional Budget Office's (CBO's) analysis, aircraft were assumed to be retired or otherwise removed from fighter force inventories for one of three reasons:

- The aircraft's design usage limit had been met or exceeded;
- The aircraft was in poor material condition despite not having reached its design usage limit; or
- The aircraft was destroyed or damaged beyond repair in an accident.

Reaching one of several different usage limits can force the retirement of an aircraft. For example, aircraft usage limits as defined by the Navy include total flight hours, the number of catapults from and recoveries aboard aircraft carriers, and the number of land-based takeoffs and landings. Complicating matters, not all flight hours are comparable: aggressive maneuvering conducted during air-to-air training or combat and takeoffs in which the aircraft carry heavy bomb loads cause more structural stresses and wear than do straight and level flights and flights in which the aircraft carry light loads. Those issues notwithstanding, flight hours are a useful means of measuring service life because they are easily tracked and because design limits based on accrued flight hours incorporate assumptions about types of usage. Flight-hour limits can also be reestimated if actual usage differs significantly from design assumptions.

CBO used accrued flight hours to estimate when aircraft would reach their usage limits. Starting with the

number of flight hours that had been accrued by each aircraft in the services' inventories, CBO projected future flight-hour accruals on the basis of average usage rates over the past 10 years. Usage rates and usage limits are different for each service branch and each type of aircraft.

Experience with the operation and maintenance of older aircraft has shown that some wear out earlier than expected. It is not uncommon for severe problems such as structural cracking or corrosion to be uncovered when older aircraft undergo periodic maintenance. To capture that effect in its inventory projections, CBO assigned a small probability of early retirement to aircraft older than a certain age.

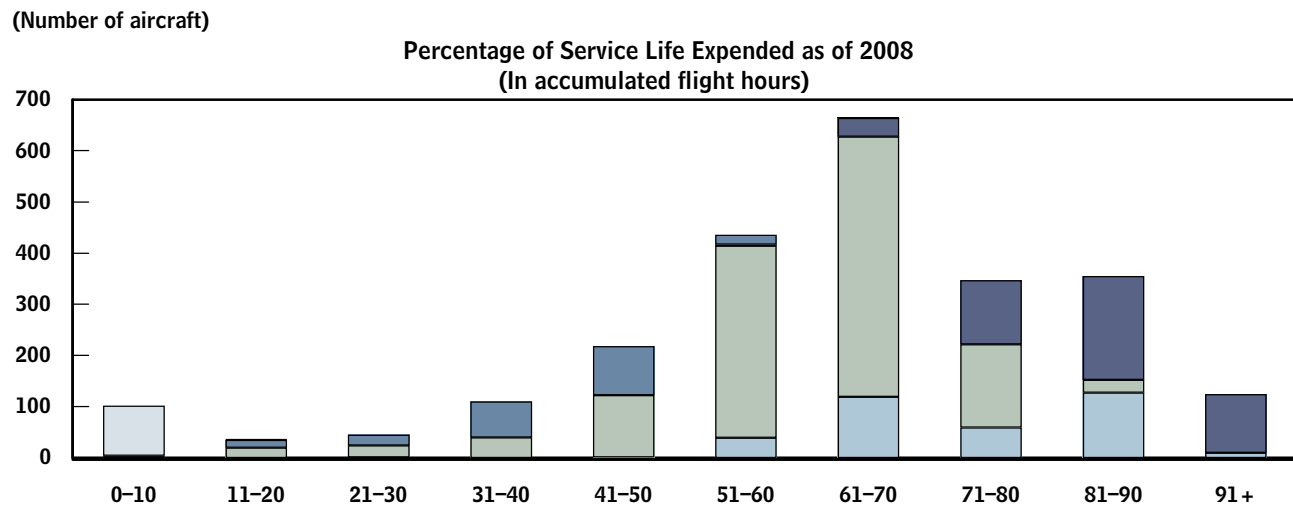
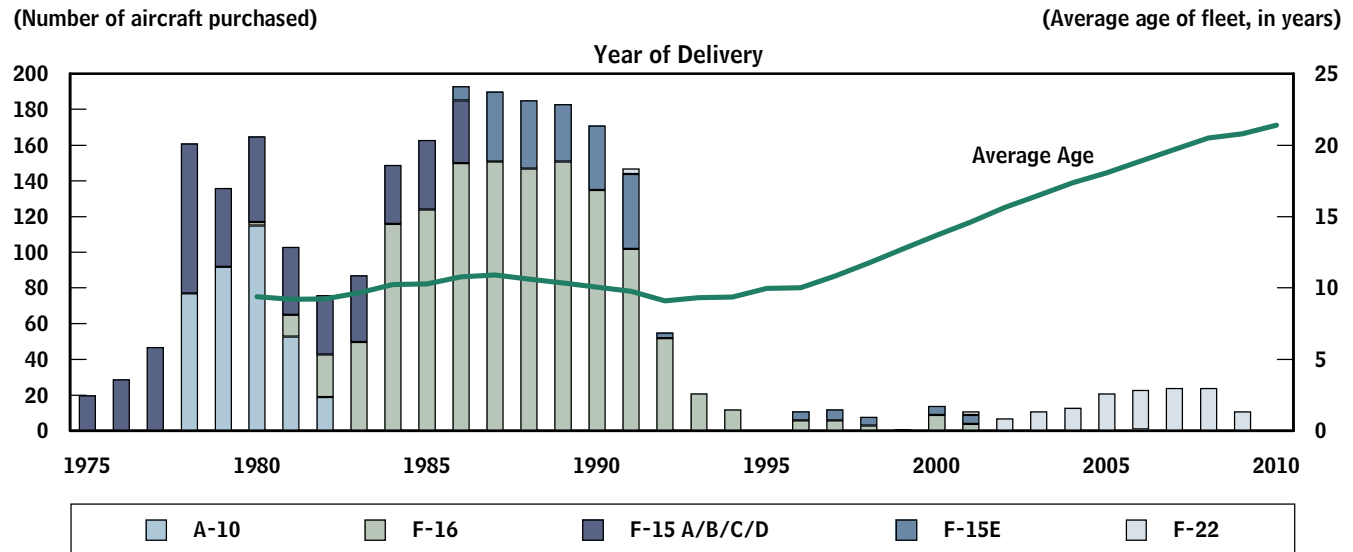
Finally, CBO used data based on the services' past experience to account for aircraft that crash or are otherwise damaged beyond repair. (Combat losses have not contributed significantly to overall attrition since the Vietnam War.) Those losses, which vary between about 1 percent and 2 percent per year, depending on the type of aircraft, are not limited to older aircraft but also erode the inventories of new aircraft entering the fleet. Consequently, although the Air Force plans to purchase 1,763 F-35As, those purchases will not yield an inventory of 1,763 because a certain percentage of the aircraft will be lost to accidents before the final one is produced. (To account for those losses, procurement plans sometimes include in advance "attrition reserve" aircraft in numbers above those needed for the force. Alternatively, the final purchase quantity can be increased as the end of production approaches to replace aircraft that have been lost.)

inventory shortfalls that might occur, CBO calculated two additional inventory projections—an optimistic case and a pessimistic case that would result in smaller and larger shortfalls, respectively. Those cases do not represent best-case or worst-case scenarios but rather reflect the way different sets of evolving circumstances could affect inventory levels. (Not considered at this stage of CBO's analysis are the possible effects of increasing the number

of new aircraft purchases or accelerating the pace of those purchases. Those factors are considered in three of the alternative scenarios examined in Chapter 3.) The two cases bound the shaded areas in Figure 1-3. The most significant feature of the pessimistic case is a two-year delay in fielding the F-35A (currently slated for 2011) and a lower peak production rate (64 aircraft per year instead of 80 as currently planned). CBO incorporated the

Figure 1-2.

The Air Force's Current Inventory of Fighter Aircraft, by Year of Delivery and Percentage of Service Life Expended



Source: Congressional Budget Office.

Notes: Historically, fighter jets have been operated for about 20 years before being replaced.

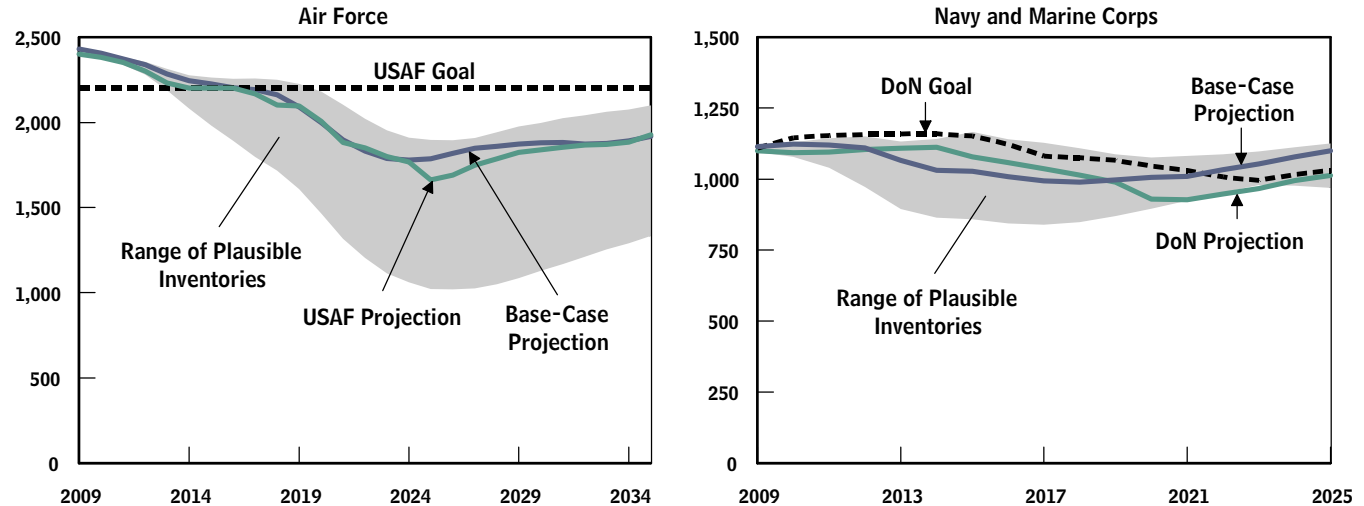
The estimates are based on the following service-life limits (as measured in total flight hours):

- A-10: 12,000
- F-16: 8,000
- F-15A/B/C/D: 8,000
- F-15E: 12,000
- F-22: 8,000

With structural monitoring and upgrades (including Service Life Extension Programs), the Air Force hopes to extend the service life of A-10s and some F-15Cs to 16,000 and 12,000 flight hours, respectively.

Figure 1-3.**Potential Fighter Inventories Under a Range of Projections**

(Total aircraft inventory)



Source: Congressional Budget Office based on the Department of Defense's fiscal year 2009 plans.

Notes: DoN = Department of the Navy; JSF = Joint Strike Fighter; SLEP = Service Life Extension Program; USAF = United States Air Force.

Air Force:*Base-Case Projection:*

- The A-10 and F-15 reach 16,000 and 12,000 flight hours, respectively
- Production and fielding of the F-35A JSF remain on schedule
- Average annual flight hours accrued per aircraft equal those of the past 10 years

Optimistic Case (Upper edge of shaded region):

- The A-10 and F-15 reach 16,000 and 12,000 flight hours, respectively
- Production and fielding of the F-35A remain on schedule
- Average annual flight hours accrued per aircraft are reduced by 10 percent (relative to the average of the past 10 years)

Pessimistic Case (Lower edge of shaded region):

- The A-10 and F-15 reach 12,000 and 8,000 flight hours, respectively
- Production of the F-35A slips by two years and peak production is reduced from 80 aircraft per year to 64
- Average annual flight hours accrued per aircraft equal those of the past 10 years

Navy and Marine Corps:*Base-Case Projection:*

- F/A-18A/B/C/Ds reach 8,500 flight hours
- Average annual flight hours accrued for F/A-18A/B/C/Ds equal 325 hours per aircraft
- AV-8B Harriers are retained through 9,500 flight hours
- Production of the F-35B/C JSF remains on schedule

Optimistic Case (Upper edge of shaded region):

- F/A-18C/Ds reach 10,000 flight hours (including an as-yet-unfunded SLEP)
- Average annual flight hours accrued for F/A-18A/B/C/Ds equal 325 hours per aircraft
- AV-8Bs are retained through 9,500 flight hours
- Production of the F-35B/C remains on schedule

Pessimistic Case (Lower edge of shaded region):

- F/A-18A/B/C/Ds reach 8,000 hours
- Annual flight hours accrued for F/A-18A/B/C/Ds equal 420 hours per aircraft
- AV-8Bs are retired as F-35Bs are delivered
- Production of the F-35B/C slips by two years

scheduling delay and a reduced production rate on the basis of a report released by the Government Accountability Office in March 2008 that cited three assessments from organizations within DoD predicting that the JSF “development schedule is likely to slip from 12 to 27 months” and that cost estimates for the JSF program could be significantly understated.⁸ A production rate of 64 aircraft per year would result if procurement costs for the JSF increased by 20 percent but funding for JSF procurement remained at planned levels.⁹ The pessimistic case also assumes that the A-10 Thunderbolt II, F-15E Strike Eagle, and F-15C Golden Eagle would have a service life that is more consistent with past experience: for the A-10, 12,000 hours instead of 16,000; and for the F-15s, 8,000 instead of 12,000. Under CBO’s pessimistic case, the Air Force’s fighter inventory could drop to as low as about 1,000 aircraft, less than half the current inventory requirement.

The optimistic case examined by CBO shows considerable improvements relative to the base-case assumptions. In the optimistic case, the A-10 would reach 16,000 flight hours, and the F-15 Strike Eagles and Golden Eagles would reach 12,000 flight hours. Additionally, aircraft would last somewhat longer because they are assumed to fly about 10 percent fewer hours each year than they have in the past. Indeed, the Air Force’s 2008 flight-hour program was reduced by that amount to free up operation and maintenance funds for other operations. Although the Air Force’s leadership expressed the hope that this would be a one-time reduction—because limiting flying hours can reduce pilots’ proficiency—the cost of fuel and the need to slow the rate of wear on older fighters may constrain the service’s options. The expanded use of advanced flight simulators for maintaining pilot proficiency might compensate partially for lost flying time, however.

The Navy’s and Marine Corps’ Fighter Inventories

Chronologically, the Navy’s and Marine Corps’ fighter fleets are substantially younger than the Air Force’s fleet. Unlike the Air Force, which saw very little fighter procurement during the 1990s, DoN continued production

of the AV-8B Harrier and the F/A-18 Hornet, and the transition from Hornets to Super Hornets proceeded without a break in production in about 2000 (see the top panel of Figure 1-4). Consequently, the ages of DoN’s fighters are more evenly distributed than those of the Air Force’s aircraft, and DoN’s fighter inventories are not expected to show as precipitous a drop as that projected for the Air Force. Nevertheless, DoN is projecting inventory shortfalls as the aircraft purchased at high rates after 1985 reach the end of their service life.

Under its base-case assumptions, CBO estimates that more than 550 older fighters (F/A-18A/B/C/Ds and AV-8Bs) will leave the Navy’s and Marine Corps’ inventories between 2009 and 2020 as a result of age-related wear and tear or accident. Under DoD’s fiscal year 2009 procurement plans, fewer than 500 new aircraft would be in DoN’s inventory by 2020.¹⁰ Consequently, the gap between the Navy’s and the Marine Corps’ fighter inventories and DoN’s stated requirement would grow from about 20 aircraft today to nearly 130 aircraft in 2014 (see the right panel of Figure 1-3). The gap would then begin to decrease, and inventories could begin to exceed requirements after 2020, although rather than maintain a surplus DoN would probably retire its older aircraft slightly earlier than would otherwise have been necessary. The reduction in the gap would partially result from a decrease in DoN’s stated inventory requirement after 2014. DoN’s requirement varies over time because squadron sizes for new aircraft are smaller than those for the aircraft they replace. For example, squadrons comprising 10 F-35Cs are expected to replace squadrons consisting of 12 F/A-18A/B/C/Ds. The number of squadrons and the number of Carrier Air Wings and Marine Air Wings to which most of those squadrons would be assigned would not change.

According to CBO’s estimates, until about 2018, the Navy and Marine Corps would experience somewhat greater inventory shortfalls than DoN projects because CBO assumed it would be practical to extend the service life of F/A-18A/B/C/Ds by only about 500 flight hours, for a total service life of 8,500 flight hours (see Figure 1-3). DoN’s projection assumes extensive structural modifications that would allow Hornets to

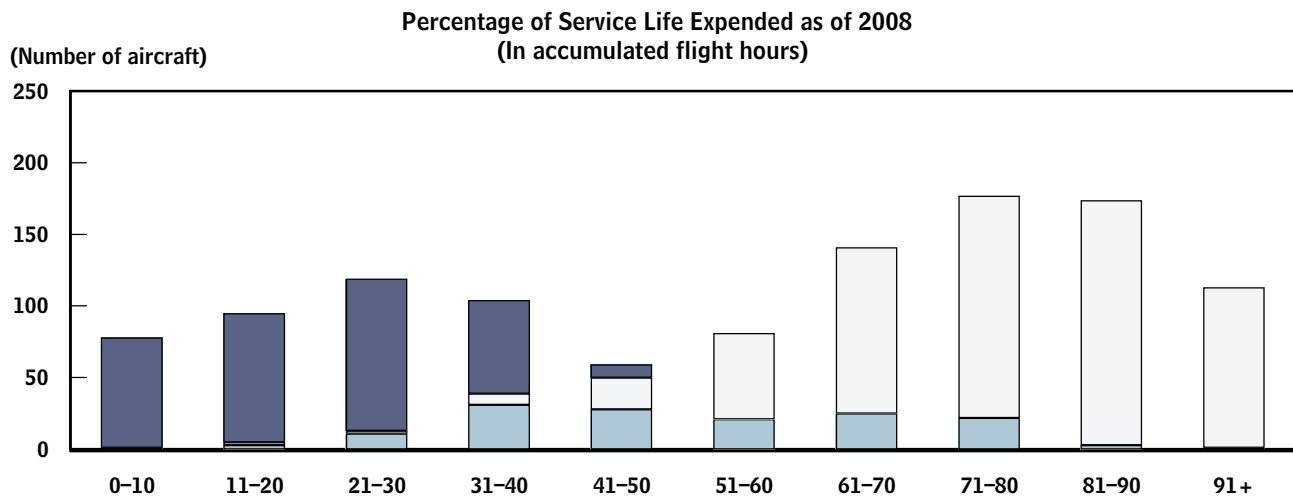
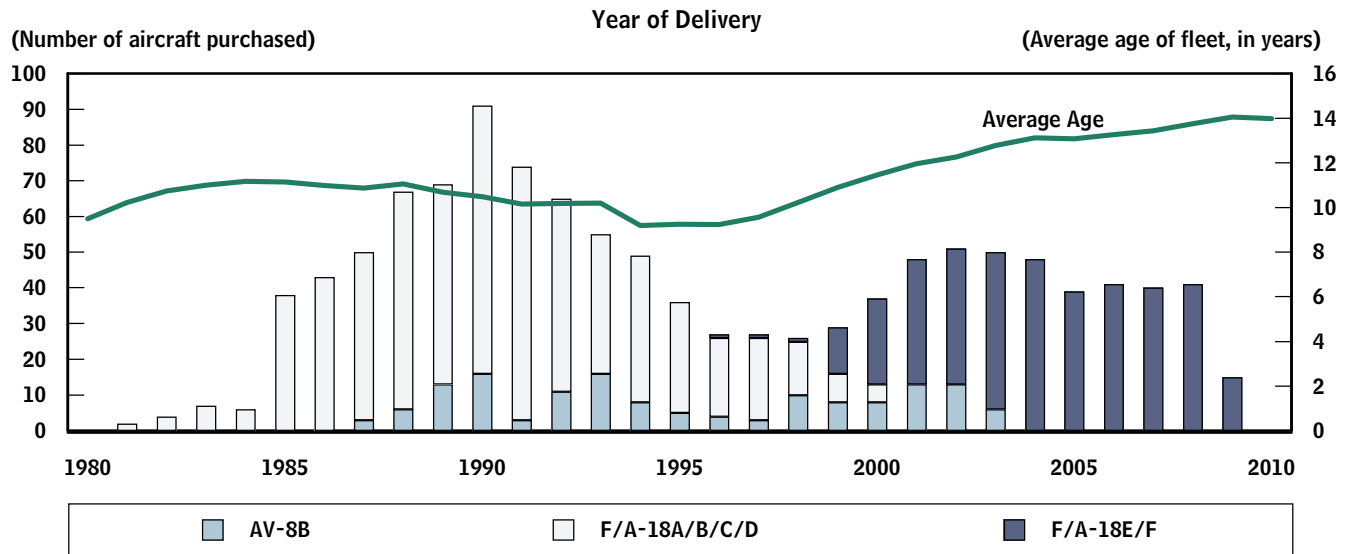
8. See Government Accountability Office, *Joint Strike Fighter*, p. 23.

9. Some Air Force projections assume that fiscal constraints would limit production of the F-35A to 48 aircraft per year instead of the planned rate of 80 per year. Larger shortfalls would result under that scenario.

10. About 540 aircraft would have been delivered, but on the basis of past attrition rates, CBO estimates that nearly 50 of those aircraft would have been lost to combat or mishaps by 2020 (see Box 1-1).

Figure 1-4.

The Navy's and Marine Corps' Current Inventory of Fighter Aircraft, by Year of Delivery and Percentage of Service Life Expended



Source: Congressional Budget Office.

Notes: Historically, fighter jets have been operated for about 20 years before being replaced.

The estimates are based on the following service-life limits (as measured in total flight hours):

- AV-8B: 9,500
- F/A-18A/B/C/D: 8,000
- F/A-18E/F: 8,000

With structural monitoring and upgrades (including Service Life Extension Programs), the Department of the Navy hopes to extend the service life of the F/A-18A/B/C/D to 10,000 flight hours.

be retained up to 10,000 flight hours.¹¹ Considerable uncertainty underlies the feasibility of that goal, however, because it would involve retaining carrier-based fighters far longer than has been done in the past. In DoN's projections, inventories would be lower than CBO's projections for the years following 2018, reaching a shortfall of over 100 aircraft by 2021 before recovering in about 2025. That disparity is primarily attributable to differing assumptions about the Marine Corps' inventory of AV-8Bs. In DoN's projection, AV-8Bs—regardless of the number of flight hours accrued—would be retired as the Marine Corps accepted delivery of F-35B aircraft. By contrast, in CBO's projection, AV-8Bs would be retained if they had service life remaining. Although the basic design of the AV-8B is older than the design of other fighters in DoN's inventory—the original Harrier entered Royal Air Force service in 1969—the Marine Corps' AV-8Bs were purchased (or remanufactured and upgraded) more recently than many F/A-18A/B/C/Ds of more modern design and, hence, have substantial remaining service life. That holds open the possibility of easing DoN's projected fighter shortfall by retaining AV-8Bs longer and shifting production of the F-35C to an earlier time frame and production of the F-35B to a later point. The Marine Corps argues, however, that the AV-8B's lesser capability—in particular, its limited ability to survive modern air defenses—would make it inadequate over future battlefields.

11. Preliminary estimates indicate a cost of \$4.6 billion to modify about 300 aircraft for a service life of 10,000 flight hours. Final estimates await further inspection of aircraft that have logged significant flight time and are anticipated near the end of 2010. Those modifications are not currently funded in DoN's budget plans, however.

As with its inventory projections for the Air Force, CBO also calculated a more optimistic case and a more pessimistic case to examine the potential effect of uncertainties underlying the base-case assumptions. In the pessimistic case, CBO assumed that efforts to extend the service life of the F/A-18A/B/C/D beyond 8,000 hours would be impractical, that usage rates would be higher, and that deliveries of the JSF would be delayed by two years. As in DoN's projection, CBO's pessimistic case incorporated the assumption that the AV-8B would retire early. Under those assumptions, DoN's shortfall would reach nearly 300 aircraft—about one-quarter of the stated requirement—in about 2014. Shortfalls would remain small or not be realized at all under the optimistic case, which assumes a successful service-life extension for models A/B/C/D of the F/A-18 and retention of AV-8Bs over a more extended period.

Although inventories under all four projections converge to points near the stated requirement in about 2025, after that year, F/A-18E/Fs are projected to begin reaching the end of their service life. At that time, DoN could continue purchases of the JSF, extend the service life of the Super Hornets, or begin fielding a new aircraft. Navy leaders, indicating plans to do the latter, have discussed developing and fielding a new aircraft—the so-called F/A-XX—to replace the Super Hornet. They have not described the characteristics of that aircraft, however. One candidate might be an unmanned combat aircraft. (The Navy is currently researching the feasibility of conducting operations using unmanned carrier aircraft with the X-47B demonstrator program.) The capabilities that might be offered by such an aircraft are examined in two of the alternative scenarios for fighter forces described in Chapter 3.

The Capabilities of Fighter Forces Under DoD's Plans for Modernization

Although the Department of Defense's plans for modernizing U.S. fighter forces could cause the Air Force's and the Department of the Navy's inventories to fall below the services' stated requirements over the next 25 years, the effectiveness of a fighter force depends on more than just the quantity of aircraft available to support military activities at a given time—it also depends on the quality of the aircraft and weapons used by that force and the proficiency of the people employing those systems. The Congressional Budget Office's analysis indicates that, notwithstanding projected inventory shortfalls, the improved capabilities offered by the newer aircraft currently scheduled for production would result in many of the U.S. fighter forces' capabilities remaining constant or actually increasing relative to today's capabilities.

This chapter describes how, in CBO's estimation, force capabilities would change as a result of the possible inventory changes described in Chapter 1. In most instances, projected capability improvements in the fighter force would result from the demonstrated superior performance of the F-22 Raptor and F/A-18E/F Super Hornet and from the anticipated superior performance of the F-35 Joint Strike Fighter, relative to the aircraft they are slated to replace. The potential capabilities of forces intentionally sized to be smaller than the forces called for in DoD's fiscal year 2009 plans are explored in Chapter 3, where CBO examines seven alternatives to DoD's fighter modernization plans.

To analyze the capabilities that would be provided by the modernized fighter force envisioned under DoD's fiscal year 2009 plans, CBO developed several performance metrics that allow comparisons between today's fighter fleets and future fleets. Those metrics include measures of fighters' capacity for carrying and launching air-to-ground and air-to-air weapons, as well as assessments of the survivability characteristics that are viewed as important advantages of the new F-22 and F-35. The

estimates of military capability described in this chapter are derived from CBO's base-case inventory projections, which in turn are based on DoD's fiscal year 2009 plans for producing the F/A-18E/F, F-22, and JSF.¹ (Uncertainties underlying the inventory projections described in Chapter 1 would result in corresponding uncertainties in estimates of capability.)

CBO's estimates of capability over time reflect changes only in inventory and in the performance of fighter aircraft. Additional capability improvements can be expected during the more than two-decade span of these projections as other aspects of DoD's arsenal improve. For example, the 250-pound GBU-39 Small Diameter Bomb (SDB) that has recently entered service is expected to significantly improve air-to-ground effectiveness by making it possible for fighters to destroy a greater number of targets per sortie than is possible with older weapons. Additionally, improvements in communications, reconnaissance, and targeting systems are expected to enhance the probability that fighters will successfully identify and destroy their targets. (However, improvements in forces fielded by potential adversaries might offset some of the improvements offered by planned U.S. systems.) Furthermore, the ultimate utility of a particular performance characteristic will depend on the circumstances in which the fighters might be needed. For example, only minimal air-to-air capability was needed against Iraq's air force in 2003, whereas air-to-air capability may

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1. CBO's base-case assumptions can be summarized as follows: For the Air Force, A-10s and F-15s reach 16,000 and 12,000 flight hours, respectively; production and fielding of F-35As remain on schedule; and average annual flight hours accrued per aircraft equal those of the past 10 years. For the Navy and Marine Corps, F/A-18A/B/C/Ds reach 8,500 flight hours; average annual flight hours accrued for F/A-18A/B/C/Ds equal 325 hours per aircraft; AV-8Bs are retained through 9,500 flight hours; and production of F-35B/Cs remains on schedule.

be crucial in a conflict against a stronger adversary that has fielded a sufficiently large, well-equipped, and proficiently trained air force.

Air-to-Ground Capabilities

Fighter and attack aircraft provide the preponderance of DoD's capability to strike targets on the ground with nonnuclear weapons. (Heavy bombers and cruise missiles provide most of the remainder of that capability.) The effectiveness of a fighter force in strike or ground-support roles rests primarily on its lethality (the ability to reach, locate and destroy targets) and survivability (the ability to execute missions in the presence of air defenses and return safely to base). To measure the air-to-ground lethality of fighter forces, CBO estimated the weapons payload capability and mission ranges of individual aircraft and summed those values into a fleet's aggregate capacity to "deliver" weapons—that is, to carry them, target them, and launch them—against targets on the ground. To measure relative survivability, CBO estimated what fraction of total air-to-ground capacity would be provided by stealthy aircraft (F-22s or F-35s carrying weapons only in their internal bomb bays). CBO also estimated the number of aircraft that will be equipped with new airborne radars that use advanced electronically scanned array (AESA) antennas in place of older, mechanically scanned antennas. Those AESA radars can provide improved air-to-ground lethality with their ability to create synthetic aperture radar images of ground targets through most weather conditions, increasing the likelihood that the correct target will be located and destroyed. The new radars also improve survivability by increasing the range at which a strike fighter can detect and engage an enemy's interceptor aircraft.

The aircraft used by the Air Force, Navy, and Marine Corps can deliver many different types of weapons. For a given aircraft, the specific types and quantities of weapons that can be carried depend on several factors, including the weapon's weight and dimensions (length, diameter, and size of fins); the number of hard points on the aircraft available for attaching weapons or weapon racks; and whether the weapon has been integrated with the aircraft's electronic systems so as to be able to receive target coordinates. As the length of a mission increases (either because an aircraft must travel greater distances or be able to orbit over a target area for an extended period), pay-

loads tend to decrease, especially if weapons have to be displaced by external fuel tanks.

For its analysis, CBO estimated maximum weapon loads for two representative types of munitions: heavy, 2,000-pound-class weapons typically used to attack large targets or "hard" targets that require direct penetration and powerful blast; and smaller, 250- to 500-pound-class weapons that are preferred when collateral damage—that is, injuries to friendly forces or civilian bystanders, or damage to structures or equipment other than the intended target—must be kept to a minimum. CBO based its loads of large weapons on the GBU-31 JDAM, which consists of a Global Positioning System (GPS) guidance package attached to a 2,000-pound Mk-84 or BLU-109 bomb. For small weapons, CBO estimated potential carriage capacity for the 250-pound SDB. The JDAM and SDB are two weapons that have been and continue to be purchased in large quantities and are likely to be among the predominant air-to-ground munitions used in future conflicts. When available, the configuration of specific aircraft loads was taken from data contained in the Air Force's and DoN's flight manuals.² CBO's estimates assume that all weapon carriage points are wired to allow targeting data to be transmitted to the weapon. Some existing aircraft may need to be modified to meet that condition. (For example, not all fighter aircraft can currently carry the SDB, but all could be modified to do so.) CBO's estimates of weapon loads are idealized because they reflect the maximum capability of the aircraft, not necessarily the way in which the aircraft is typically used. For example, the A-10 Thunderbolt II can carry weapons over long ranges, but it is not typically used for attack missions that occur deep in enemy territory.

The Air Force's Air-to-Ground Capabilities

All aircraft currently used and projected to be used by the Air Force, except for F-15A/C Eagles, can carry small air-to-ground weapons such as the SDB. The A-10 could potentially carry up to 24 SDBs and the F-16 Fighting Falcon up to 24 (see Table 2-1). The F-15E Strike Eagle can carry up to 28. The F-22 is expected to be able to carry eight SDBs in its internal weapons bay, and the F-35A has been designed to carry up to eight SDBs internally and as many as 16 more on racks hung on external

2. For example, T.O. 1F-16C-1: *Flight Manual, USAF Series Aircraft F-16C/D*, and A1-F18EA-NFM-000: *NATOPS Flight Manual, Navy Model F/A-18E/F 165333 and Up Aircraft*.

Table 2-1.

Weapons Capacity and Mission Range of the Air Force's Current and Future Fighter Aircraft

(Number of weapons)

	Current Fleet					Future Fleet	
	A-10 Thunderbolt II	F-15 Eagle	F-15E Strike Eagle	F-16 Fighting Falcon	F-22 Raptor	F-35A JSF	Medium- Range Bomber
Maximum Air-to-Ground Weapons Capacity							
Small munitions	24	0	28	16	8/8 ^a	8/24 ^a	40
Large munitions	6	0	5	4	0	2/6 ^a	10
Air-to-Ground Weapons Capacity for Large Munitions, Out to a Specified Mission Radius							
400 n. mi.	4	0	5	2	0	2/6 ^a	10
500 n. mi.	4	0	5	0	0	2/4 ^a	10
600 n. mi.	2	0	5	0	0	2/2 ^a	10
700 n. mi.	2	0	2	0	0	0	10
Air-to-Air Weapons Capacity	0	8	8	6	8/12 ^a	4/10 ^a	0

Source: Congressional Budget Office based on the Department of Defense's fiscal year 2009 plans.

Notes: JSF = Joint Strike Fighter; n. mi. = nautical miles.

Air-to-ground weapons capacity for large munitions is based on loads of 2,000-pound Joint Direct Attack Munitions; air-to-ground weapons capacity for small munitions is based on 250-pound Small Diameter Bombs. For air-to-air missions, weapons capacity is based on aircraft-specific loads of AIM-9 and AIM-120 missiles. Some modifications to the aircraft may be needed to reach those capacities.

- a. Stealth capacity/total capacity. (Stealth capacity indicates that weapons are carried exclusively in internal bays. Total capacity indicates that weapons are carried both in internal bays and on external racks.)

hard points under the wings. The notional medium bomber shown in Table 2-1 would be able to carry up to 40 small air-to-ground weapons in its internal weapons bay. (The capabilities offered by this aircraft are examined in the alternative forces described in Chapter 3.) For small-weapons capability, CBO examined only maximum payloads.

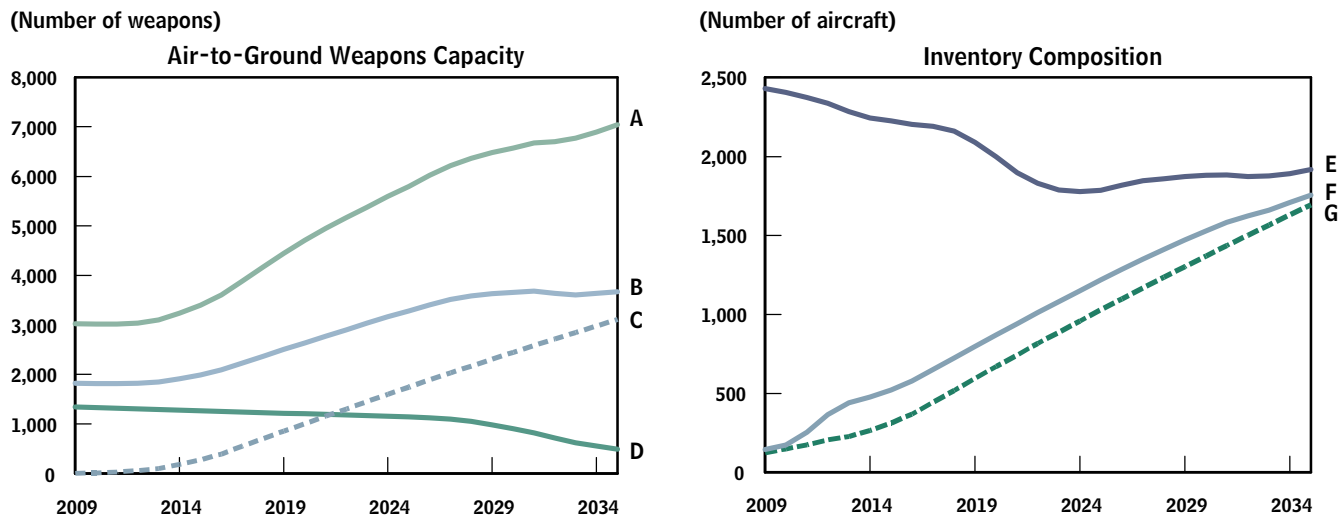
For large air-to-ground weapons such as the 2,000-pound JDAM, the A-10 can carry up to six, the F-15E can carry up to five, and the F-16 can carry up to four for missions of short duration. The number of those weapons that can be carried is smaller for longer ranges.³ The F-22 is not designed to carry 2,000-pound weapons; the largest air-to-ground weapon it can deliver is a 1,000-pound JDAM. The F-35A has been designed to carry two 2,000-pound JDAMs internally and up to four more on external hard points.

According to CBO's analysis of DoD's fiscal year 2009 plans, the Air Force's capacity to deliver air-to-ground munitions would, in many respects, increase or remain at about today's levels despite projected decreases in inventory (see the left panel of Figure 2-1). CBO estimates that air-to-ground munitions capacity would increase relative to today's capacity for both small and large weapons out to a radius of 600 nautical miles (n. mi.) without aircraft

- Unless otherwise noted, specific estimates of flight range and payload capacity reflect the distance a fighter could fly from an aerial refueling tanker to a designated target and back with a fuel reserve of 30 minutes. The distance from tanker to target can be roughly thought of as the depth into defended airspace that a fighter can reach. With multiple aerial refuelings, total mission distances can be much greater than those described here. The flight-range estimates also limited fighters to external fuel tanks typically used by the U.S. military. Longer ranges might be possible with larger tanks.

Figure 2-1.

Changes in the Air-to-Ground Weapons Capacity and Inventory Composition of the Air Force's Fighter Force Under DoD's Fiscal Year 2009 Plans



Source: Congressional Budget Office based on the Department of Defense's (DoD's) fiscal year 2009 plans.

Notes: AESA = active electronically scanned array; JDAM = Joint Direct Attack Munition; n. mi. = nautical miles.

Estimates of mission range are based on the distance a fighter could fly from an aerial refueling orbit.

Weapons capacity is based on loads of 2,000-pound JDAMs.

Stealth-only capacity (dashed lines) indicates that weapons are carried exclusively in internal bays. Total capacity (solid lines) indicates that weapons are carried both in internal bays and on external racks.

A = Total capacity out to a radius of 500 n. mi.

B = Total capacity out to a radius of 600 n. mi.

C = Stealth-only capacity out to a radius of 600 n. mi.

D = Total capacity out to a radius of 700 n. mi.

E = Total aircraft inventory

F = Inventory of aircraft equipped with AESA radar

G = Inventory of stealth aircraft

having to rely on aerial refueling. The most pronounced increase would be for 2,000-pound weapons carried on shorter-range missions. The reason for that increase is that the F-35A has been designed to offer range and payload advantages over the F-16s it is slated to replace. Only at ranges greater than about 650 n. mi. would capacity decrease in the out years because the F-35A would lack the range to replace the A-10 and F-15E as they are retired. (The A-10 would not typically be used for missions of that distance, however, because of its low cruise speed and vulnerability to air defenses.)

Under current plans, survivability in the air-to-ground role would also increase substantially relative to today's

Air Force fighters, although some of that improvement might be offset by improvements in the defensive capabilities of potential adversaries. At the present time, the Air Force has accepted delivery of about 135 stealthy F-22s.⁴ Under fiscal year 2009 plans, nearly the entire Air Force inventory of fighters will be stealthy by 2035 (see the right panel in Figure 2-1). Although the F-22 is primarily designed for air-to-air combat, it is also able to carry two 1,000-pound JDAMs and, as noted above, it is expected that the F-22 will be able to carry up to eight SDBs in its internal weapons bay. Internal carriage is necessary for

4. The last of the F-117A Nighthawk stealth fighters were recently retired. The Air Force also operates 20 B-2A stealth bombers.

stealth operation because bombs and bomb racks slung under an aircraft's wings can be easily detected by radar.⁵ The fielding of the F-35A will substantially increase the capacity of the Air Force's fleet to carry weapons when operating in a stealthy configuration (see the left panel of Figure 2-1). That increase in capacity will not be as pronounced as the increase for nonstealthy configurations, however, because the F-35A's under-wing weapons stations cannot be used. Nevertheless, as the dashed line in the left panel of Figure 2-1 illustrates, by 2030, the F-35A force operating in a stealth configuration would be able, in aggregate, to carry enough 2,000-pound JDAMs out to a radius of 600 n. mi. to equal today's entire capacity at that range.

The prevalence of AESA radar-equipped aircraft in the force—which improves both lethality and survivability—would also increase significantly under current plans (see the right panel of Figure 2-1). For the Air Force, most of that increase would follow the increase in the number of stealth aircraft because the F-22 and F-35 both carry AESA radars. In addition to those aircraft, however, the Air Force plans to retrofit its F-15E force with AESA radars. (In the figure, the line denoting AESA capability does not include AESA-equipped F-15C Golden Eagles because those aircraft will be used only in an air-to-air combat role.)

CBO's estimates of weapons capacity do not reflect other advantages that could be obtained with the JSF relative to today's aircraft. Of particular potential importance is the expectation that the JSF will be able to sustain higher sortie rates—that is, a greater number of missions per aircraft per day—than the aircraft it will replace. To achieve that goal, the JSF has been designed for better reliability and shorter “reload/rearm” and maintenance times between missions. Whether higher sortie rates can be achieved in practice, however, remains to be seen. Other constraints, such as the rate at which targets can be identified and assigned to individual squadrons, can limit the pace of strike operations.

The Navy's and Marine Corps' Air-to-Ground Capabilities

Of the aircraft currently being used by the Navy and Marine Corps, the AV-8B Harrier can carry eight small

air-to-ground weapons, and all models of the F/A-18 (both Hornets and Super Hornets) can carry up to 16 (see Table 2-2). The F-35B and F-35C Joint Strike Fighters are being designed to carry up to 24 SDB, with eight carried internally. The F/A-18 can carry up to four large air-to-ground weapons. (The AV-8B cannot carry 2,000-pound weapons.) The F-35B is being designed to carry up to four 2,000-pound weapons, although all of those weapons would be carried on external hard points; the F-35B's internal weapons bay is limited to two 1,000-pound JDAMs.⁶ The F-35C is being designed to carry two 2,000-pound JDAMs internally in a stealthy configuration and up to four more under the wings. (In estimating the planned force's 2,000-pound bomb capacity, CBO assumed that DoN would purchase 420 F-35Bs and 260 F-35Cs.)

In comparison with estimates of how the Air Force's air-to-ground capabilities will change under fiscal year 2009 plans, details of how the Navy's and Marine Corps' capabilities will evolve are more uncertain. That uncertainty centers on whether or not proposed service-life extensions of the F/A-18A/B/C/Ds will be entirely successful. If the Hornet fleet achieves an average service life of only 8,500 flight hours, as is assumed in CBO's base case, aggregate weapons capacity for shorter mission ranges would be roughly unchanged relative to current levels (because of the higher payloads that can be carried by newer aircraft) even during the period of greatest inventory shortfalls (see the left panel of Figure 2-2). Weapons capacity at longer ranges would increase even during periods of inventory shortfall because the new aircraft will be able to carry weapons farther than the aircraft they replace. The capacity increases shown in the figure are not as pronounced as those projected for the Air Force because any payload differences between the older aircraft used by the Navy and Marine Corps (primarily the F/A-18A/B/C/Ds) and the F-35s that are slated to replace them are not as great as those anticipated for fighters in the Air Force's fleet. In particular, the inability of the F-35B to carry 2,000-pound JDAMs in its internal weapons bay reduces its contribution to large-weapons capacity.

5. Although it is possible to reduce the signature of external weapons and racks, internal carriage is required to take full advantage of a stealth airframe.

6. Initial plans called for a common internal weapons bay for all three variants of the F-35. The capacity of the F-35B's weapons bay was reduced as a weight-saving measure needed to meet performance goals for short takeoff and vertical landing.

Table 2-2.

Weapons Capacity and Mission Range of the Navy's and Marine Corps' Current and Future Fighter Aircraft

(Number of weapons)

	Current Fleet			Future Fleet		
	AV-8B Harrier	F/A-18 Hornet	F/A-18E/F Super Hornet	F-35B JSF	F-35C JSF	UCAV-N
Maximum Air-to-Ground Weapons Capacity						
Small munitions	8	16	16	8/24 ^a	8/24 ^a	8/16 ^a
Large munitions	0	4	4	0/4 ^a	2/6 ^a	2/4 ^a
Air-to-Ground Weapons Capacity for Large Munitions Out to a Specified Mission Radius						
400 n. mi.	0	2	4	0/2 ^a	2/6 ^a	2/4 ^a
500 n. mi.	0	2	2	0/2 ^a	2/4 ^a	2/4 ^a
600 n. mi.	0	0	2	0	2/2 ^a	2/4 ^a
700 n. mi.	0	0	0	0	2/2 ^a	2/4 ^a
Air-to-Air Weapons Capacity	0	10	10	4/10 ^a	4/10 ^a	0

Source: Congressional Budget Office based on the Department of Defense's fiscal year 2009 plans.

Notes: n. mi. = nautical miles; JSF = Joint Strike Fighter; UCAV-N = carrier-capable unmanned combat aerial vehicle.

Air-to-ground weapons capacity for large munitions is based on loads of 2,000-pound Joint Direct Attack Munitions; air-to-ground weapons capacity for small munitions is based on 250-pound Small Diameter Bombs. For air-to-air missions, weapons capacity is based on aircraft-specific loads of AIM-9 and AIM-120 missiles. Some modifications to the aircraft may be needed to reach those capacities.

- a. Stealth capacity/total capacity. (Stealth capacity indicates that weapons are carried exclusively in internal bays. Total capacity indicates that weapons are carried both in internal bays and on external racks.)

With the fielding of the F-35B and F-35C, the number of stealthy and AESA-equipped aircraft in the Navy's and Marine Corps' fighter fleets would also increase under fiscal year 2009 plans (see the right panel of Figure 2-2). Unlike the Air Force, however, DoN does not plan to move toward an all-stealth force but rather to a mix of stealthy F-35s and conventional F/A-18E/Fs. Although the F/A-18E/Fs do incorporate design features such as modified engine inlets that reduce their radar signature relative to that of older aircraft, the level of signature reduction does not approach that of aircraft such as the JSF. Most of the F/A-18E/Fs will be equipped with AESA radars, however.⁷ The dashed lines in the left panel of Figure 2-2 show that the Navy and Marine Corps would acquire a stealthy air-to-ground strike capacity under

fiscal year 2009 plans. The lower dashed line illustrates the capacity to carry 2,000-pound weapons in a stealthy configuration out to a radius of 700 n. mi. That capacity would be provided entirely by the F-35C because the F-35B will not be able to carry 2,000-pound weapons in its internal weapons bay. If 1,000-pound JDAMs carried by the F-35B are counted as "large weapons," CBO's measure of stealth carriage capacity would increase substantially, although only to a radius of about 500 n. mi. because the F-35B will have less range than the F-35C.

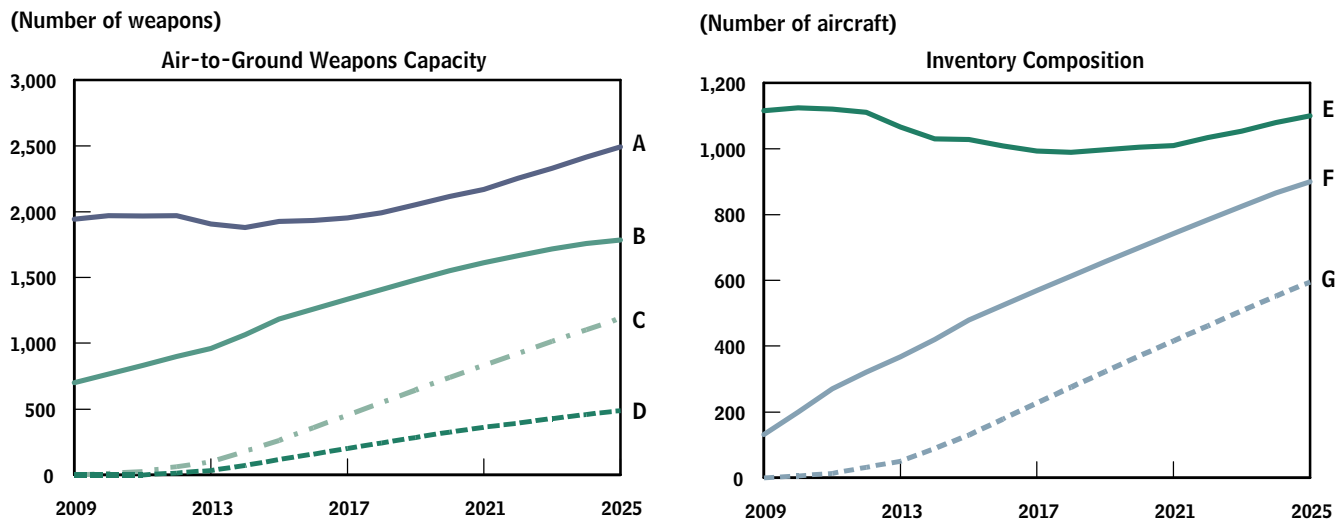
Air-to-Air Capabilities

Air-to-air effectiveness can be more difficult to estimate than air-to-ground effectiveness because targets, usually an adversary's fighters, are more active participants in the engagement. For example, the quality of an adversary's armored battalions and the skill of its troops usually have less impact on the effectiveness of an air attack against them than the quality of an adversary's fighters

7. The 137 Super Hornets with Block I configuration and the first 135 Block II Super Hornets were originally equipped with mechanically scanned radar antennas. The Navy plans to retrofit the 135 Block 2 aircraft with AESAs.

Figure 2-2.

Changes in the Air-to-Ground Weapons Capacity and Inventory Composition of the Navy's and Marine Corps' Fighter Force Under DoD's Fiscal Year 2009 Plans



Source: Congressional Budget Office based on the Department of Defense's (DoD's) fiscal year 2009 plans.

Notes: AESA = active electronically scanned array; JDAM = Joint Direct Attack Munition; n. mi. = nautical miles.

Estimates of weapons capacity and mission range reflect the distance a fighter could fly from an aerial refueling orbit.

Except where otherwise noted, weapons capacity is based on loads of 2,000-pound JDAMs.

Stealth-only capacity (dashed lines) indicates that weapons are carried exclusively in internal bays. Total capacity (solid lines) indicates that weapons are carried both in internal bays and on external racks.

A. Total capacity out to a radius of 500 n. mi.

B. Total capacity out to a radius of 600 n. mi.

C. Stealth-only capacity out to a radius of 500 n. mi. (including 1,000-pound JDAMs carried by the F-35B)

D. Stealth-only and total capacity out to a radius of 700 n. mi.

E. Total aircraft inventory

F. Inventory of aircraft equipped with AESA radar

G. Inventory of stealth aircraft

and the skill of its pilots during an air-to-air battle. Two of the contributors to air-to-air effectiveness that CBO considered are the ability to detect an adversary before being detected so as to fire the first shot, and the ability to carry enough weapons to sustain an engagement even if outnumbered.

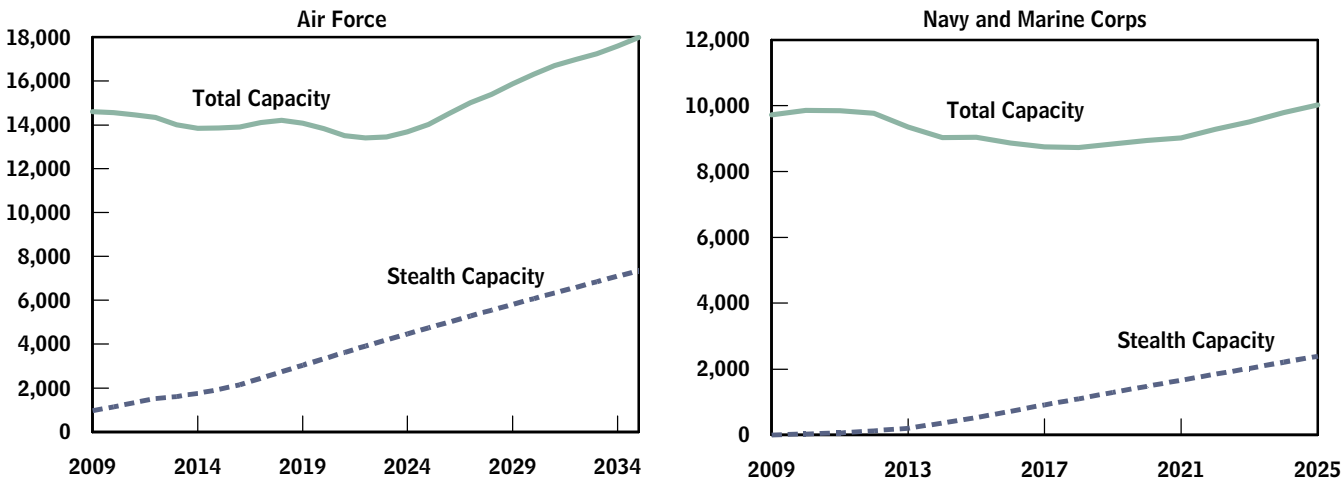
As specified in DoD's fiscal year 2009 modernization plans, the fielding of 2,443 JSFs and 187 F-22s would provide the U.S. military with many more stealthy aircraft capable of "first-shot/first-kill" engagements against any current or prospective adversary. Today's aircraft—especially those equipped with more-capable AESA radars and supported by airborne warning and control systems

(AWACS) aircraft—usually enjoy that advantage as well. As shown in Figures 2-1 and 2-2, the number of aircraft equipped with AESA radars would also increase substantially under current plans. The advantage offered by AESA radars may be less against the newest aircraft available to potential adversaries, however, because those aircraft can also be equipped with AESA radars as well as other advanced defensive systems.⁸ The stealthy F-22 and F-35 are expected to firmly reestablish the first-shot

8. The AESA radars carried on many aircraft that are marketed to potential adversaries are thought to be inferior to the AESAs that are or would be carried by U.S. aircraft, however.

Figure 2-3.
Changes in the Air-to-Air Weapons Capacity of Fighter Forces Under DoD’s Fiscal Year 2009 Modernization Plans

(Number of weapons)



Source: Congressional Budget Office based on the Department of Defense’s (DoD’s) fiscal year 2009 plans.

Note: Weapons capacity is based on aircraft-specific loads of AIM-9 and AIM-120 missiles.

capability. (Just when potential adversaries can be expected to field significant numbers of stealthy fighters is a topic of vigorous—and classified—debate in the defense community. As experience with the F-22 and JSF would indicate, developing and fielding such advanced aircraft is a long and costly endeavor.)

The large number of stealthy aircraft that would be fielded under fiscal year 2009 plans would be capable of carrying a significant number of air-to-air missiles (see Table 2-1 and Table 2-2). The F-22 and the F-35 have been designed to carry both medium-range, radar-guided AIM-120 missiles and short-range, infrared-guided AIM-9 missiles. The F-22 is designed to carry up to 12 (eight internally and four on external hard points), and the F-35A is designed to carry 10 (four internally and six under the wings).⁹ Under-wing carriage would be unusual, however, because external weapons would reduce the stealth advantages enjoyed by those aircraft.¹⁰ Under DoD’s fiscal year 2009 plans for procuring F-22s and F-35As, the Air Force’s stealthy air-to-air missile capacity would approach about half that of today’s total capacity (for both stealthy and nonstealthy aircraft). (See the left panel of Figure 2-3.) CBO estimates that if external carriage capacity is included, the Air Force’s capacity would decrease to about 93 percent of today’s capacity in

2022 before rebounding by 2026 and increasing thereafter until the final F-35As are delivered in about 2036.¹¹

Compared with the Air Force’s fighter aircraft, the Navy’s and Marine Corps’ fighters can carry fewer air-to-air

9. The F-22 has four external stations, each of which has the capacity to carry up to 5,000 pounds. Each station can carry two air-to-air missiles for a total of eight external missiles. The wiring and stores management system software required for launching air-to-air missiles from the external stations are currently incorporated in all F-22s. The launch of missiles from the external stations has not been certified, but air-to-air missiles were carried externally during developmental testing and evaluation. Certification of external missiles has not been an Air Force priority because of the large internal load of eight air-to-air missiles, implying that more than eight missiles would seldom be needed or that, in air-to-air combat, the F-22 would be likely to run out of fuel before missiles. For its calculations, CBO assumed that external fuel tanks would be carried on two of the external stations (in lieu of four missiles) to increase the aircraft’s endurance on nonstealthy missions.

10. With additional research and development, it might be possible to increase the number of air-to-air missiles carried internally by the JSF, especially for the A and C models, which have larger weapons bays.

11. These estimates of maximum missile capacity illustrate theoretical capabilities. Just as the F-22 and F-35 would probably rarely, if ever, carry external weapons for air-to-air missions, today’s fighters do not usually carry maximum air-to-air loads.

missiles in a stealth configuration because a large fraction of DoN's force—particularly the F/A-18E/Fs—will have larger radar signatures than the JSF. The stealthy air-to-air missile capacity of the F-35B/C would reach about 25 percent of today's total capacity (see the right panel of Figure 2-3). However, design features that reduce the F/A-18E/F's radar signature give it an advan-

tage relative to the aircraft it would replace, especially for the initial phases of a head-on air-to-air engagement (when the noses of the opposing aircraft are facing each other). In terms of total air-to-air missile carriage, the Navy's and Marine Corps' capacity would decrease to about 90 percent of current levels in 2018 and then rebound by 2024.

Alternatives to DoD's Plans for Modernizing Fighter Forces

In addition to its analysis of the Department of Defense's fiscal year 2009 plans for modernizing U.S. fighter forces, the Congressional Budget Office examined the implications—both for force effectiveness and for DoD's budget—of several possible alternatives to those plans. As detailed in Chapter 1, CBO's analysis of DoD's plans for fighter modernization indicated that those plans might not satisfy aircraft inventory objectives as currently defined by the military services. Shortfalls relative to the services' goals could be even larger than projected if, for example, the ability to extend the service life of certain existing aircraft turned out to be more limited than is hoped or the fielding of the Joint Strike Fighter was further delayed by technological challenges. Additional downward pressure on fighter inventories could be experienced if, as some observers expect, costs for producing the JSF grow and funding for fighter procurement became more constrained by competition from other priorities, such as providing pay and health care benefits for military personnel, enlarging the Army and Marine Corps, and implementing other modernization programs. The second portion of CBO's analysis, presented in Chapter 2, illustrated how, despite the potential for reduced inventories, the planned fighter force would nevertheless be more capable in many respects than today's force, which is already the most powerful tactical air force in the world.

That combination of characteristics—substantially improved effectiveness despite projected inventory shortfalls—has generated concern in different quarters about DoD's fiscal year 2009 plans for modernization. On the one hand, those who are unhappy with projected inventory shortfalls cite the need either to accelerate the fielding of the Joint Strike Fighter (if the development sched-

ule can be accelerated) or to augment purchases of the JSF with purchases of other fighters. (For example, the Navy could increase purchases of F/A-18E/F Super Hornets; and the Air Force could increase purchases of F-22s or resume purchasing F-16 Fighting Falcons and/or F-15E Strike Eagles, which are no longer being produced for U.S. forces but are still in production for foreign customers.) Conversely, those who think current capabilities will be adequate for years to come have proposed reducing purchases of JSFs and allowing inventories to shrink or, alternatively, canceling the JSF program altogether; purchasing new aircraft that are based on older designs—but incorporate technological upgrades—on an as-needed basis to maintain inventories; and working to develop new technologies that could be incorporated in future aircraft designs. (Some experts have argued that such advanced aircraft, which could be manned or unmanned, would be ready for fielding at a future date when the capabilities of potential adversaries might be formidable enough to make them necessary.)

To explore different approaches to fighter modernization, CBO developed seven alternative plans for replacing existing fighter fleets. Three of the alternatives would satisfy today's inventory requirements by increasing the number of fighters purchased and accelerating the timing of those purchases; two would preserve today's capabilities but would do so with fewer manned fighter aircraft; and the final two would offer capabilities comparable to those currently provided by manned tactical fighters but would do so with other types of systems that might also offer additional capabilities not provided by today's force or the force envisioned by DoD in its fiscal year 2009 modernization plans.

Alternatives 1 Through 3: Forces That Satisfy the Services' Inventory Requirements

CBO examined in detail three approaches to modernization that would maintain inventories of fighter aircraft at or near the services' stated goals through 2025 for the Navy and Marine Corps and through 2035 for the Air Force (see Table 3-1).¹ The three alternatives would offer varying levels of technological capability and require different (sometimes substantially different) levels of funding. Under Alternative 1, production of the JSF would increase; under Alternative 2, production of the JSF would be augmented in the near term with purchases of new aircraft that are based on older designs but that incorporate state-of-the-art technologies such as modern radars and electronic systems; and under Alternative 3, the JSF program would be canceled and the entire force would be recapitalized with new aircraft that are based on older designs but incorporate state-of-the-art technologies.

The purchases required under those three alternatives are based on the supposition that existing aircraft would achieve the service life projected under the base-case assumptions described in Chapter 1. Under Alternatives 1 through 3, the Air Force would purchase about 160 more aircraft than are called for under fiscal year 2009 plans. For the Navy and Marine Corps, the total number of aircraft purchased under Alternatives 1 through 3 would change little relative to current plans. For all three service branches, however, purchases would shift to earlier years relative to fiscal year 2009 plans to prevent the projected inventory shortfalls. In the case of the Navy and the Marine Corps, that shift would also be sufficient to avoid the expense of extending the service life of F/A-18 Hornets to 10,000 flight hours.

Purchase Quantities and Costs

Under **Alternative 1**, the Air Force would acquire 1,927 F-35s, 164 more than are called for under DoD plans (see Table 3-1). To eliminate projected shortfalls, however, purchases would also be shifted to earlier times relative

to DoD's fiscal year 2009 plans. Specifically, 415 more F-35As would be purchased from 2010 to 2025 and 251 fewer F-35As would be purchased from 2026 through 2034 (see Figure 3-1).² The total number of F/A-18E/Fs and F-35B/Cs designated for the Navy and Marine Corps—506 and 680, respectively—would not change under Alternative 1. Of those totals, 57 F/A-18E/Fs and 668 F-35B/Cs would be procured after 2009. As with the Air Force, production of the F-35B/Cs would shift to earlier years—from 2010 to 2014, the Navy and Marine Corps would acquire 107 more F-35B/C aircraft than were contained in the fiscal year 2009 plans. (For calculations of effectiveness, CBO assumed that 420 F-35Bs would be purchased for the Marine Corps and 260 F-35Cs would be purchased for the Navy.) According to CBO's estimates, total investment costs under Alternative 1 would be about \$208 billion (in 2009 dollars), or about \$5 billion more than is projected in DoD's fiscal year 2009 plans (see Table 3-1).³

Although DoN's total investment costs would remain about the same under Alternative 1, average annual funding for fighter purchases over the 2010–2014 period would be about \$2.2 billion more per year—about 35 percent higher than is projected in DoN's fiscal year 2009 plans—primarily to accommodate earlier production of F-35B/Cs. By contrast, funding requirements for the Navy and Marine Corps over the ensuing 10 years (2015 to 2024) would be about \$1 billion lower per year than would be the case under fiscal year 2009 plans. The Air Force would not require a significant increase in funding over the 2010–2014 period but would, on average, require an additional \$2 billion per year from 2015 to 2024, CBO estimates, an increase of 35 percent. Over the 2025–2034 period, the Air Force's average annual funding needs would be about \$3.4 billion per year, 30 percent lower than is projected in fiscal year 2009 plans. Although the total investment costs estimated for Alternative 1 would be only about 2 percent higher than DoD's fiscal year 2009 plans when measured in constant dollars, implementing Alternative 1 would be about

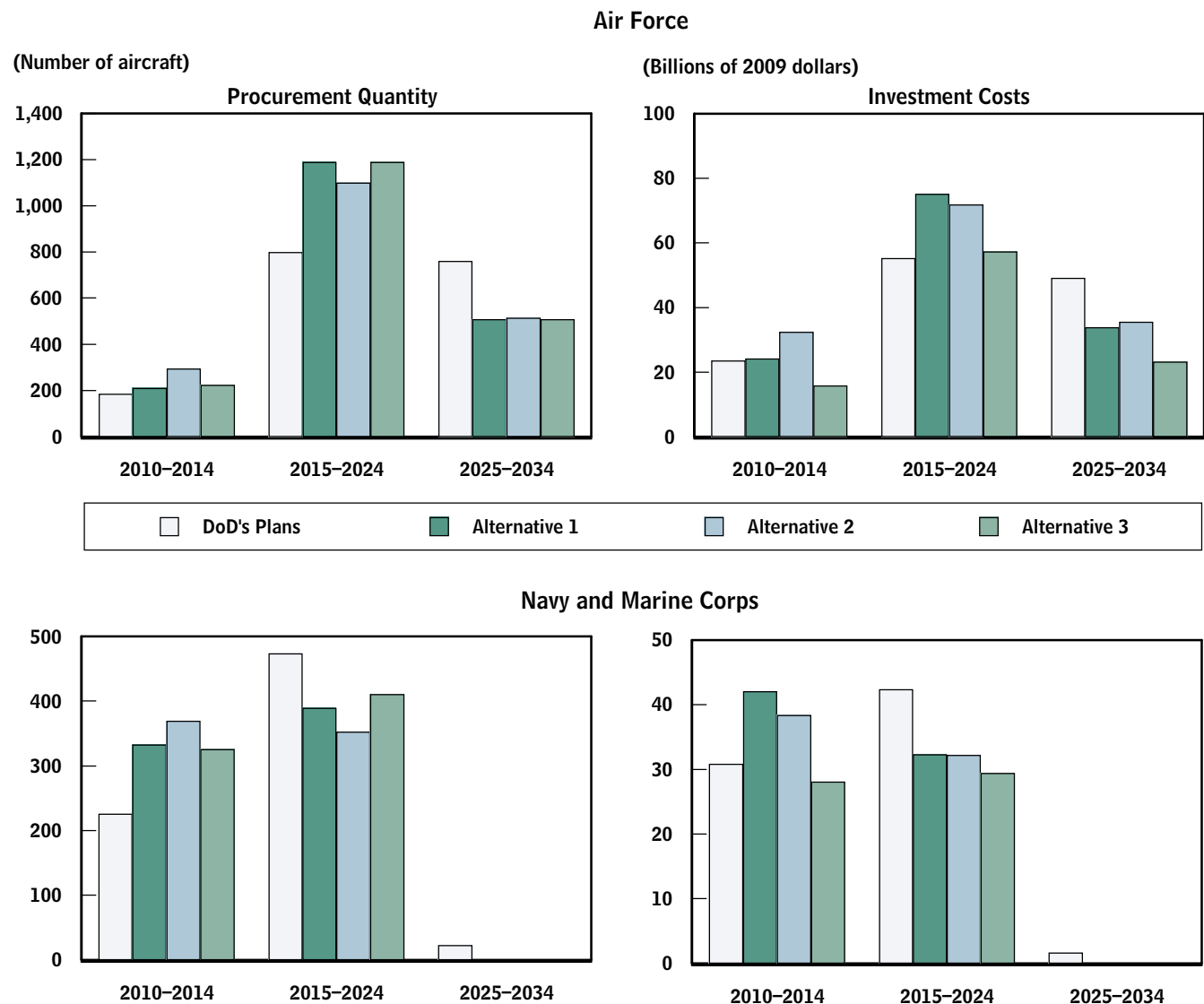
1. The years 2025 and 2035 correspond with the respective services' fiscal year 2009 plans for concluding production of the JSF. As was noted earlier, after 2025, the Navy will probably need to begin replacing or extending the service life of today's older F/A-18E/Fs, and after 2035 (or perhaps sooner) the Air Force will probably need to take similar measures for the F-22.

2. The Air Force could also decide to maintain higher production rates for F-35As after 2025 and complete purchases before 2034.

3. Investment costs include those for research, development, test, and evaluation (RDT&E) and for procurement of new aircraft. The figures cited do not include costs to modify and/or upgrade existing aircraft.

Figure 3-1.

Quantities and Costs of New Fighter Aircraft Under DoD's Fiscal Year 2009 Modernization Plans and Alternatives That Satisfy the Services' Inventory Requirements



Source: Congressional Budget Office.

Notes: DoD = Department of Defense.

Investment costs comprise expenses for research, development, test, and evaluation of new aircraft and for procurement of those aircraft.

Table 3-1.

Quantities and Costs of Fighter Aircraft Under DoD's Fiscal Year 2009 Modernization Plans and Seven Alternative Plans

Service Branch	Type of Aircraft	Total Purchase Quantity	Purchases Remaining After 2009	Remaining Investment Costs (Billions of 2009 dollars)		Remaining Investment Costs (Billions of dollars, net present value)	
				2010–2014	2010–2034	2010–2014	2010–2034
DoD's Fiscal Year 2009 Modernization Plans							
USAF	F-35A	1,763	1,749				
	F-22	187	0				
DoN	F-35B/C	680	668				
	F/A-18E/F	506	57				
Total		3,136	2,474	54	203	49	147
Alternative 1: Satisfy Inventory Requirements by Accelerating/Increasing Purchases of JSFs							
USAF	F-35A	1,927	1,913				
	F-22	187	0				
DoN	F-35B/C	680	668				
	F/A-18E/F	57	57				
Total		2,851	2,638	66	208	59	157
Alternative 2: Satisfy Inventory Requirements by Purchasing JSFs and Improved Legacy Aircraft							
USAF	F-35A	1,493	1,479				
	F-22	187	0				
	F-16E	435	435				
DoN	F-35B/C	420	408				
	F/A-18E/F	766	317				
Total		3,301	2,639	71	211	64	160
Alternative 3: Cancel the JSF Program and Satisfy Inventory Requirements by Purchasing Improved Legacy Aircraft							
USAF	F-16E	1,925	1,925				
	F-22	187	0				
DoN	F/A-18E/F	1,186	737				
Total		3,298	2,662	44	154	39	117
Alternative 4: Purchase JSFs in Quantities to Match Weapons Capacity in 2009							
USAF	F-35A	850	836				
	F-22	187	0				
DoN	F-35B/C	480	468				
	F/A-18E/F	506	57				
Total		2,023	1,361	53	136	48	105

Continued

Quantities and Costs of Fighter Aircraft Under DoD's Fiscal Year 2009 Modernization Plans and Seven Alternative Plans

Service Branch	Type of Aircraft	Total Purchase Quantity	Purchases Remaining After 2009	Remaining Investment Costs (Billions of 2009 dollars)		Remaining Investment Costs (Billions of dollars, net present value)	
				2010–2014	2010–2034	2010–2014	2010–2034
Alternative 5: Purchase Enough JSFs to Match Weapons Capacity in 2009 and Satisfy Inventory Requirements by Purchasing Small, Armed UAVs							
USAF	F-35A	850	836				
	F-22	187	0				
	MQ-9	987	987				
DoN	F-35B/C	480	468				
	F/A-18E/F	506	57				
	MQ-9	151	151				
Total		3,161	2,499	57	156	51	119
Alternative 6: Replace Some Fighter Aircraft with BMRs or UAVs to Improve Mission Range							
USAF	F-35A	325	311				
	F-22	187	0				
	BMR	250	250				
DoN	F-35B/C	410	398				
	F/A-18E/F	506	57				
	UCAV-N	275	275				
Total		1,953	1,291	64	200	58	153
Alternative 7: Replace Some Fighter Aircraft with BMRs or UAVs to Improve Mission Range and Augment Fleets with Small, Armed UAVs to Satisfy Inventory Requirements							
USAF	F-35A	325	311				
	F-22	187	0				
	BMR	250	250				
DoN	MQ-9	1,000	1,000				
	F-35B/C	410	398				
	F/A-18E/F	506	57				
	UCAV-N	275	275				
	MQ-9	100	100				
Total		3,053	2,391	67	220	61	165

Source: Congressional Budget Office.

Notes: BMR = medium-range bomber; DoD = Department of Defense; DoN = Department of the Navy; JSF = Joint Strike Fighter (F-35A/B/C); MQ-9 = Reaper small, armed UAV; UAV = unmanned aerial vehicle; UCAV-N = carrier-capable unmanned combat aerial vehicle; USAF = United States Air Force.

Legacy aircraft are upgraded versions of fighters, such as the F-16 and F-15E, that are still in production but based on older designs.

7 percent more costly when measured on a net-present-value basis (with a real discount rate of 3 percent) because of the substantial shift in funding to earlier years.

Those cost estimates are based on the assumption that the fielding of the JSF could be accelerated without substantial cost growth. (Although costs might be incurred sooner, net costs would not increase substantially for a fixed number of aircraft.) However, accelerating the production of the JSF, as is postulated in Alternative 1, would raise the risk of increased costs. Developing three aircraft around a common airframe has proved to be technically challenging, and, as a result, the JSF program has experienced several delays and significant cost growth. To minimize the risk of increased development costs, increases in production quantities relative to fiscal year 2009 plans would not occur under Alternative 1 until after the 50th F-35B/C was ordered for the Navy and Marine Corps and after the 200th F-35A was ordered for the Air Force. The higher production rates envisioned for the JSF under Alternative 1 would not exceed the capacity planned for the facility in Fort Worth, Texas, where Lockheed Martin assembles JSFs. However, some modifications to the notional production schedule that CBO assumed for Alternative 1 might be necessary depending on how international customers' production requirements for the JSF evolve.

Under **Alternative 2**, the inventory shortfall that CBO projects for the Air Force under fiscal year 2009 plans would be eliminated by purchasing 435 F-16Es through 2021.⁴ At the same time, total purchases of the F-35A would be reduced by 270, for a net increase of 165 aircraft. For the Navy and Marine Corps, 260 more F/A-18E/F Super Hornets than were included in fiscal year 2009 plans would be purchased, and purchases of F-35B/Cs would be reduced by 260 aircraft. (For calculations of force effectiveness, CBO assumed that the Marine Corps would acquire 150 F-35Bs, roughly replacing today's Harrier force, and that the Navy would acquire 270 F-35Cs. The Navy's and Marine Corps'

fighter fleets would be rounded out with F/A-18E/Fs.) In the near term, production of F-16Es and additional F/A-18E/Fs would supplement planned production rates of the JSF to eliminate projected inventory shortfalls; reductions in the total number of JSFs would be taken near the end of the production run. CBO assumed that procurement of F-16Es under Alternative 2 would begin in 2010 to ensure that the production line for the fighter remained active. Although that would be earlier than necessary to meet the Air Force's projected shortfall, such a strategy would give the service the flexibility to retire aircraft that are experiencing maintenance problems sooner than would be possible under fiscal year 2009 plans. Total investment costs under Alternative 2 would be about \$211 billion, CBO estimates, about \$8 billion more than is projected in DoD's fiscal year 2009 plans (or about 4 percent higher in constant dollars and 9 percent higher on a net-present-value basis). Relative to the costs projected under Alternative 1, total investment costs under Alternative 2 would be about \$3 billion higher.

DoN's costs would be about \$4 billion lower than is projected under fiscal year 2009 plans because there would be no net change in the number of aircraft purchased and the unit recurring flyaway cost of the F/A-18E/F would be low enough relative to the F-35B/Cs it replaced to more than offset an increase in F-35B/C unit costs that would result from decreased production quantities.⁵ As with Alternative 1, however, costs would be higher over the next five years (see Figure 3-1). The Air Force's costs under Alternative 2 would be about \$12 billion more than is indicated in fiscal year 2009 plans, primarily because of the net increase in the number of aircraft purchased and the costs for RDT&E that CBO estimated would be required to integrate the F-16E into U.S. service (the Air Force operates F-16Cs today). Additionally, the savings realized by purchasing lower-cost F-16Es would largely be offset by an increase in F-35A unit costs that would result from reduced production of the JSF. (The effect of increased unit costs for the JSF that would arise with decreased production is particularly evident in the higher cost of Alternative 2 relative to Alternative 1.)

Under **Alternative 3**, the final alternative that would satisfy the services' inventory requirements, the Air Force would purchase a total of 1,925 F-16Es in lieu of the

4. Two land-based fighters currently in production domestically for foreign customers—Lockheed Martin's F-16E and Boeing's F-15E—could fill that role. The calculations for cost and performance that are cited in this report assume that the substitute for the F-35A Joint Strike Fighter would be the F-16E. The F-15E would provide greater range and payload performance but at a higher (unit recurring flyaway) cost: about \$43 million for the F-16E versus more than \$70 million for the F-15E.

5. The unit recurring flyaway cost is for the aircraft itself. The total unit procurement cost incurred by the government is higher because it includes initial spares and program support costs.

1,763 F-35As in the fiscal year 2009 plan. The 680 F-35B/Cs designated for the Navy and Marine Corps would be replaced one-for-one with additional purchases of F/A-18E/Fs. CBO estimates that total investment costs under Alternative 3 would amount to approximately \$154 billion, about 25 percent lower than is projected for DoD's fiscal year 2009 plans. The Air Force's expenditures would drop by about \$31 billion, and DoN's expenditures would drop by about \$17 billion (or 24 percent less in constant dollars and 21 percent less on a net-present-value basis for the three services). Spending over the 2010–2014 period would decrease by about \$8 billion for the Air Force and by about \$3 billion for the Navy and Marine Corps.

If the United States were to cancel procurement of the JSF, the international participants in the program—the United Kingdom, Norway, Denmark, the Netherlands, Canada, Italy, and Turkey—would most likely be forced to withdraw as well because the aircraft would be significantly more expensive if produced in lower quantities. Collectively, those U.S. allies have thus far contributed about \$5 billion to the JSF's research and development. Depending on the details of the contractual arrangements underlying that participation, the United States could decide to take some action (for instance, providing financial compensation) to mitigate the adverse effect that canceling the JSF program would have on the program's other participants. CBO's cost estimate for Alternative 3 includes approximately \$5 billion that would be returned to those international partners over the next five years.

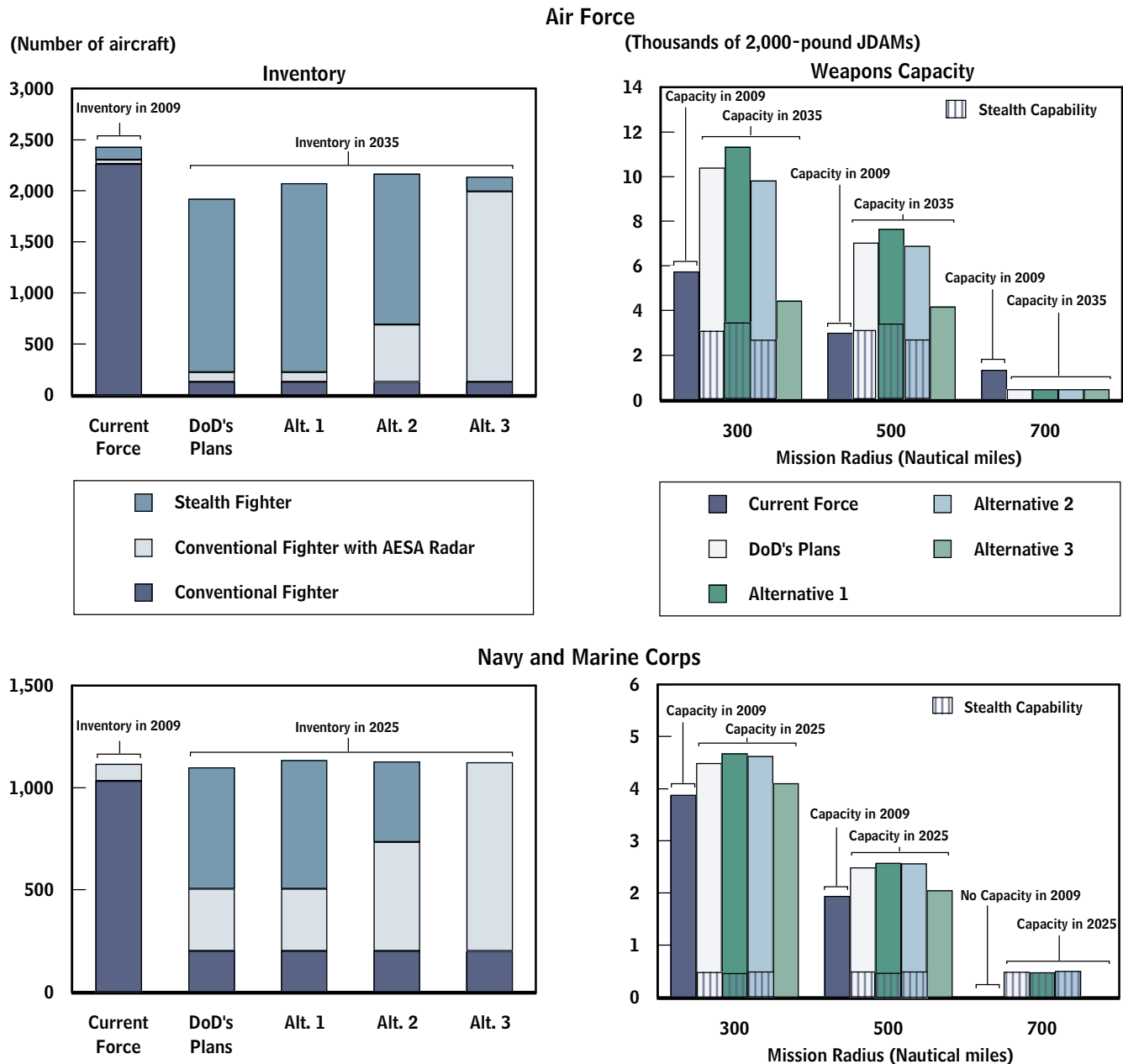
Force Capabilities

In Chapter 2, CBO compared the capabilities offered by today's fighter force with those that would be provided by the modernized fighter force envisioned under DoD's fiscal year 2009 plans. To do so, CBO developed several performance metrics that allowed the quantification of air-to-ground and air-to-air capabilities. This chapter focuses on a subset of those capabilities. Specifically, CBO analyzed and compared the following indicators of force effectiveness:

- **Number of stealth aircraft.** That amount illustrates the relative ability of a force to operate in the presence of air defenses, such as an adversary's fighter aircraft and surface-to-air missile systems;
 - **Number of conventional aircraft with active electronically scanned array radar.** That figure is a measure of the relative effectiveness of a force's aircraft against airborne adversaries, as well as against ground targets if the radar includes a surface imaging capability (note that all stealth aircraft are AESA-equipped);
 - **Total bomb-carriage capacity versus flight range.** That measure denotes the relative rate at which a force can destroy targets and the distance into defended airspace to which it can do so; and,
 - **Stealth bomb-carriage capacity versus flight range.** That measure reflects a force's relative ability to attack ground targets without first suppressing air defenses and the distance it can penetrate into defended airspace to do so.
- Chapter 2 includes descriptions of the derivations of those measures and additional discussion about how those capabilities contribute to overall force effectiveness.
- Modernization plans that satisfied the services' inventory goals would result in total force sizes that are essentially the same as today's force (see Figure 3-2). As a result, under Alternatives 1 through 3, the Air Force's, Navy's, and Marine Corps' force structures would remain relatively unchanged. The number of air wings and squadrons and the number of aircraft in each squadron could remain constant, as could the timing of force deployment cycles (as experienced by the people assigned to such missions). Consequently, the ability to dispatch forces to operations around the world, and to maintain those operations for extended periods of time, would remain similar to today's capabilities.
- Although the size of the inventories postulated for Alternatives 1 through 3 would be similar, the capabilities of the varying aircraft would differ substantially. The composition of fighter forces under Alternatives 1 and 2 would be quite similar to those of DoD's planned force in many respects. Alternative 1 would feature higher stealth inventories and slightly larger bomb-carriage capacities for both stealthy and conventional aircraft because more JSFs would be purchased under that scenario. For the

Figure 3-2.

Configuration and Capabilities of Fighter Forces Under DoD's Fiscal Year 2009 Modernization Plans and Alternatives That Satisfy the Services' Inventory Requirements



Source: Congressional Budget Office.

Notes: AESA = advanced electronically scanned array; DoD = Department of Defense; JDAM = Joint Direct Attack Munition.

Specific estimates of mission range reflect the distance an aircraft could fly from an aerial refueling tanker to a designated target and back with a fuel reserve of 30 minutes.

The years 2035 and 2025 correspond with the respective services' fiscal year 2009 plans for concluding production of the Joint Strike Fighter. After 2035 (or perhaps sooner), the Air Force will probably need to begin replacing or extending the service life of older F-22s. After 2025, the Navy will probably need to take similar measures for F/A-18E/Fs.

Air Force, Alternative 2 would offer slightly lower bomb-carriage capacity out to a radius of 500 nautical miles because some JSFs would be replaced with F-16Es, which have lower payload capacity. Alternative 2 would feature a somewhat lower fraction of stealth aircraft than called for under DoD's fiscal year 2009 plans—70 percent of the Air Force's fleet would be stealthy in 2035 (versus 84 percent under CBO's projection of DoD's plans), and 37 percent of the combined Navy and Marine Corps fleet would be stealthy (versus 57 percent under DoD's plans). The number of stealthy aircraft would still be substantial under both alternatives, however, and would provide considerable capability for attacking targets early in a conflict before an adversary's air defenses could be suppressed.

The potential cost savings afforded by Alternative 3 would come with substantially reduced capability relative to DoD's fiscal year 2009 plans for fighter modernization. The number of stealth fighters would be minimal—fewer than 200 F-22 Raptors for the Air Force and none for the Navy and Marine Corps. Bomb-carriage capacities would be lower than under Alternatives 1 and 2 and DoD's plans, especially for the Air Force, because of the payload disparity between the F-35A and the F-16E. The longer flight range offered by the carrier-based F-35C under DoD's fiscal year 2009 plans and under Alternatives 1 and 2—out to a radius of 700 n. mi.—would be lost under Alternative 3, although today's carrier-based fighters lack that flight range as well (see Figure 3-2). Additionally, under Alternative 3, the Marine Corps would lose the ability to operate fighters from amphibious ships or tactical landing sites because the F-35B would not be available to replace the Harrier.

The lack of stealth aircraft that would result under Alternative 3 would be viewed by some observers as a significant shortcoming. The F-16Es and F/A-18E/Fs that would predominate under Alternative 3, coupled with the superior training provided to U.S. aircrews, would be very capable against air threats, and the AESA radars with which they would be equipped would probably provide an improved electronic warfare capability to help defeat surface defenses. However, those aircraft would not enjoy the survivability advantages conveyed by stealth technology. Although such a shortcoming would probably not be critical against lesser adversaries, against stronger, more technologically advanced foes the loss of tactical flexibility that stealth technology offers could result in the need for more extensive operations to roll back an adversary's air defenses, slowing the overall pace of air operations and

increasing the likelihood of incurring losses. Increased investment in electronic warfare capabilities would probably be necessary to help mitigate the loss of stealthy strike capability that would result under Alternative 3. Even with a stealthy strike aircraft force, the Department of Defense anticipates conducting specialized airborne electronic attack (AEA) operations against advanced air defenses. Current acquisition programs for equipping aircraft with specialized AEA systems include the EA-18G Growler, a variant of the F/A-18E/F, and the Miniature Air-Launched Decoy, a small expendable air vehicle that resembles a small cruise missile. Other survivable systems, such as the F-22 Raptor, the B-2 Spirit bomber, or a new manned or unmanned strike aircraft could also be relied upon more heavily early in a conflict against an adversary with strong air defenses.⁶

Although the force fielded under Alternative 3 would be less capable than the forces envisioned under DoD's fiscal year 2009 modernization plans and under Alternatives 1 and 2, all three alternatives would be significantly more capable than today's force. Under those alternatives, almost the entire force would consist of aircraft that were either stealthy or equipped with an AESA radar (versus less than 10 percent today for the Air Force, Navy, and Marine Corps); and in most circumstances, the resulting modernized forces would offer greater bomb-carriage capacity than does today's force. Two exceptions would be the short-range and long-range capacity of Air Force aircraft under Alternative 3 (out to a radius of 300 n. mi. and a radius of 700 n. mi., respectively), which would be lower than the capacity afforded by today's force because some retiring A-10s and F-15Es would be replaced with F-16Es (which have lower payload capacity). At 500 n. mi., that effect would be reversed because the loss of the A-10's and F-15E's payload capacity would be more than countered by the fact that F-16Es have a higher payload at that range than the F-16Cs in today's force. (The payload capacity of the F-16C and F-16E is the same for missions out to a radius of 300 n. mi., and neither aircraft could reach 700 n. mi. under the assumed mission profile.)

The forces envisioned under DoD's fiscal year 2009 plans and under Alternatives 1 and 2 would also provide

6. Discussion of the AEA capabilities inherent in the fighter force options presented here is excluded for the sake of simplicity and because detailed survivability assessments are best carried out at a classified level.

substantial capacity for stealth carriage of air-to-ground weapons (see Figure 3-2). The only fighter in today's force with the internal weapons bay necessary for stealth carriage is the F-22. However, the F-22's weapons bay is limited to two 1,000-pound Joint Direct Attack Munitions or, on the basis of planned future modifications, up to eight Small Diameter Bombs. Purchases under DoD's fiscal year 2009 plans and under Alternatives 1 and 2 would add large numbers of F-35As and F-35Cs, which could each carry two 2,000-pound JDAMs internally. (Because Figure 3-2 depicts stealth carriage as the capacity to carry 2,000-pound JDAMs only, today's fighter force is shown as having no stealth carriage capability. Since the recent retirement of the F-117A Nighthawk, only the B-2A Spirit bomber provides stealth carriage for 2,000-pound weapons.) For missions out to a radius of 500 n. mi., the Air Force's stealthy bomb-carriage capacity under DoD's fiscal year 2009 plans and under Alternatives 1 and 2 would be comparable to today's total capacity at that range. The Navy and Marine Corps would have a less substantial stealthy bomb-carriage capacity for 2,000-pound weapons because F/A-18F/Fs do not have internal weapons bays, and the F-35B will be limited to 1,000-pound weapons in its internal weapons bay.

Alternatives 4 and 5: Forces That Maintain Current Air-to-Ground Weapons Capacity

Under Alternatives 4 and 5, DoD would field a force with fewer fighters but with at least the same bomb-carriage capacity (for weapons up to 2,000 pounds) provided by today's force. The analysis in Chapter 2 showed that DoD's planned fighter force would have substantially greater bomb-carriage capacity for missions up to a radius of about 600 n. mi. from an aerial refueling tanker.⁷ For example, the Air Force's capacity to deliver 2,000-pound-class weapons on missions up to 500 n. mi. from an aerial refueling tanker would increase nearly threefold relative to DoD's current capacity, and the aggregate capacity of the Navy and Marine Corps would increase by 30 percent. The Air Force's stealth-only capacity would be higher than today's total capacity

under DoD's fiscal year 2009 plans at that unrefueled radius. The Navy's and Marine Corps' capacity increase would be smaller because a smaller portion of the fleet remains to be replaced (most of the planned number of F/A-18E/Fs have already been fielded) and also because the F-35B cannot carry 2,000-pound weapons in its internal bay. If the two 1,000-pound weapons in the internal bay were counted as "large weapons," the Navy's and Marine Corps' capacity would exceed that of today's force by 60 percent. (According to those rules, the Air Force's increase in capacity would rise as well because the F-22's ability to carry 1,000-pound weapons would be counted.)

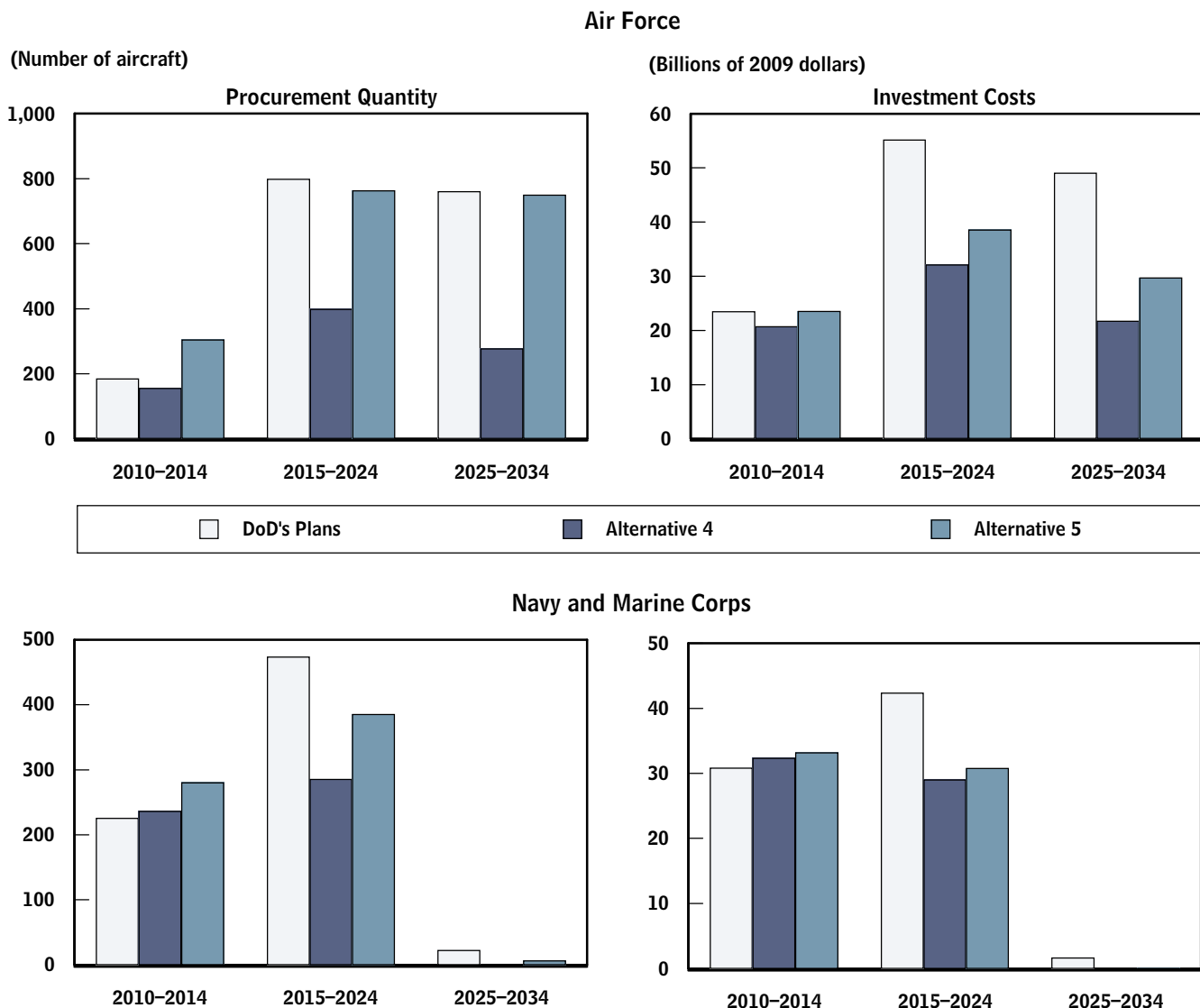
Under **Alternative 4**, procurement of the F-35A for the Air Force would be cut approximately in half, to 850 aircraft, and the Air Force's fighter inventory would, as a consequence, drop to about 1,200 aircraft (see Figure 3-3 and Figure 3-4). For the Navy and Marine Corps, 150 F-35Bs and 330 F-35Cs would be purchased under Alternative 4, and the fighter inventory would drop to about 900 aircraft. Smaller purchases would result in significantly lower procurement costs as well. Investment costs for Alternative 4 would total about \$136 billion, CBO estimates, or about \$67 billion less than was projected for DoD's fiscal year 2009 modernization plans (or 33 percent less in constant dollars and 29 percent less on a net-present-value basis). Savings would be small over the next five years because CBO assumed that production of the JSF would initially ramp up as currently planned but that Air Force production would level off at a lower rate—40 aircraft per year versus a planned 80 per year. Production for the Navy and Marine Corps would level off at the scheduled rate of 50 F-35B/Cs per year, but the production run would be shorter.

Under Alternative 4, the Air Force, Navy, and Marine Corps would field a force with significantly more stealth aircraft and AESA-equipped conventional aircraft than exist in today's force (see Figure 3-4). The capacity to deliver 2,000-pound bombs would be comparable to that of today's force, although variations in payload relative to flight range precluded exactly matching capacities at all ranges. For example, the Air Force's fleet under Alternative 4 would have similar capacity at 300 n. mi., better capacity at 500 n. mi. (because the F-35A has better range than the F-16C), but reduced capacity at 700 n. mi. (because the F-35A has less range than the F-15E).

7. The mission radii cited in this report represent distances from an aerial refueling orbit. Mission radii from a land base, aircraft carrier, or amphibious ship would be shorter because fuel is consumed during taxi, takeoff, and the climb to altitude.

Figure 3-3.

Quantities and Costs of New Fighter Aircraft Under DoD's Fiscal Year 2009 Modernization Plans and Alternatives That Maintain Today's Weapons Capacity



Source: Congressional Budget Office.

Notes: DoD = Department of Defense.

Investment costs comprise expenses for research, development, test, and evaluation of new aircraft and for procurement of those aircraft.

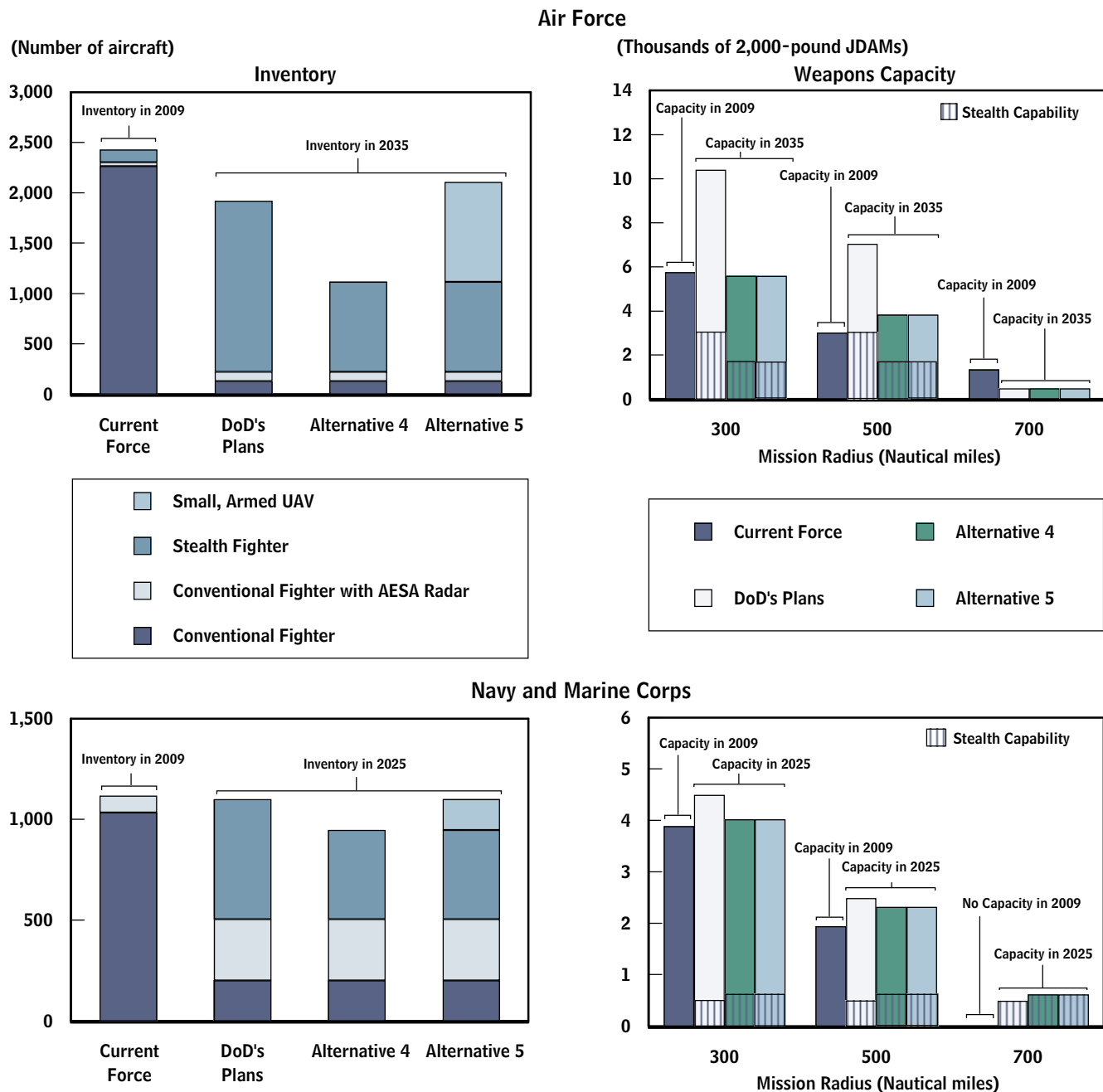
A significant difference between the force envisioned under Alternative 4 and both today's force and the force envisioned under DoD's fiscal year 2009 modernization plans, is the number of aircraft: Under Alternative 4, the DoD-wide inventory of fighters would fall to about 2,100 aircraft. By comparison, today's fleet contains about 3,500 aircraft, and DoD's inventory goal is about

3,300 aircraft. A force of 2,100 aircraft would be roughly the size of the forces currently fielded by Russia and China—the two countries, behind the United States, with the largest fighter forces in the world.

It is unclear what the relative situation would be 20 years from now after the inventory reductions called for under

Figure 3-4.

Configuration and Capabilities of Fighter Forces Under DoD's Fiscal Year 2009 Modernization Plans and Alternatives That Maintain Today's Weapons Capacity



Source: Congressional Budget Office.

Notes: AESA = advanced electronically scanned array; DoD = Department of Defense; JDAM = Joint Direct Attack Munition.

Specific estimates of mission range reflect the distance an aircraft could fly from an aerial refueling tanker to a designated target and back with a fuel reserve of 30 minutes.

The years 2035 and 2025 correspond with the respective services' fiscal year 2009 plans for concluding production of the Joint Strike Fighter. After 2035 (or perhaps sooner), the Air Force will probably need to begin replacing or extending the service life of older F-22s. After 2025, the Navy will probably need to take similar measures for F/A-18E/Fs.

Alternative 4 had been realized. At that time, the tactical aircraft force envisioned under Alternative 4 would still include large numbers of stealthy fighters. Within DoD and the broader defense community as well, disagreement exists as to the likely speed with which stealthy fighters will proliferate to nations other than those slated to buy the JSF. Again, using the world's next-two-largest fighter forces as an example, China has only just recently begun fielding indigenously produced fighters on a par with the older aircraft in DoD's fleet and still has many even older aircraft to replace. Many of China's most modern aircraft are based on Russian designs dating from the 1980s. China's efforts to build more-advanced fighters have been hampered by the difficulties inherent in producing high-performance fighter engines. Russia is working on a stealthy fighter, but some observers doubt it will be fielded by 2020. Even Japan, which has a very advanced aerospace industry and is committed to fielding stealthy tactical aircraft, is not expected to be able to field an indigenous stealth fighter for at least a decade. (Japan has stated that it would like to buy F-22s and has also expressed interest in the JSF.)⁸

Of course, a concerted national effort by a technologically capable country could be made to increase its fighter inventory and possibly advance the technological sophistication of its fighters. For example, China's rapid economic growth and Russia's income from energy exports have been cited as making such advancements possible. Nevertheless, under Alternative 4, the United States would have the flexibility to respond to such efforts by increasing inventories of the JSF. That flexibility might be lacking under Alternative 3 because production of the JSF would be completely halted. Under that scenario, DoD would be faced with the expense of restarting production of the JSF (or, for the Air Force, the F-22) if an aircraft based on some future design, perhaps an unmanned aircraft, was not yet ready for fielding.

The smaller inventory called for under Alternative 4 would result in DoD's being less able to conduct simultaneous operations around the world and could also make it more difficult to sustain large operations for extended periods of time. It is unclear, however, that the ability to conduct one or more major air campaigns of limited

duration would be seriously hampered because air power in those scenarios is frequently limited by the rate at which forces can be moved into the theater and the availability of facilities from which they can operate. Carrier air wings, which are frequently the first tactical air power on the scene, would probably consist of fewer aircraft, although it should be possible to rapidly augment smaller peacetime carrier air wings by flying over as many additional aircraft as an aircraft carrier could support. Moreover, the greater capability of each aircraft fielded relative to today's aircraft, as well as improvements in weapons effectiveness, could enable future operations to be conducted successfully using fewer aircraft than current operational plans would require.

Alternative 5 would address the potentially reduced ability of the forces envisioned under Alternative 4 to sustain long-term operations, particularly those requiring strike aircraft to orbit overhead for extended periods of time in order to be ready to provide support to forces on the ground. Fighters are not ideally suited for such missions because they are designed for speed and agility rather than endurance. In Operations Enduring Freedom and Iraqi Freedom, both of which have seen high demand for quick-response missions, fighters have been effectively augmented by bombers and by unmanned reconnaissance aircraft—in particular, the MQ-1 Predator and its larger cousin, the MQ-9 Reaper—that have been modified to carry weapons. Following that example, under Alternative 5, the fighter force envisioned in Alternative 4 would be augmented with unmanned aircraft such as the MQ-9. Under Alternative 5, about 1,000 Reapers would be purchased for the Air Force, and 225 (modified for carrier operations) would be purchased by the Navy.⁹ (Those aircraft could be operated by the Marine Corps as well.) If Alternative 5 was implemented, the procurement of those unmanned aircraft would add about \$20 billion—\$17 billion for the Air Force and \$3 billion for the Navy—to the costs CBO estimated for Alternative 4, for a total investment cost of \$156 billion (or about 23 percent less in constant dollars and 19 percent less on

8. See, for example, *Aviation Week & Space Technology* (November 3, 2008), pp. 44 and 66.

9. Although a carrier-capable MQ-9 has not been produced, its manufacturer, General Atomics Corporation, has conducted preliminary design work on such a capability as part of its contract bid for the Navy's Broad-Area Maritime Surveillance (BAMS) program. Northrop Grumman won that competition with its proposal for an aircraft based on the RQ-4 Global Hawk.

a net-present-value basis than is projected for DoD's fiscal year 2009 plans).¹⁰

Although the MQ-9 offers a payload capacity of nearly 4,000 pounds, its current armament typically consists of smaller weapons, such as the GBU-12 Paveway II, a 500-pound laser-guided bomb; the GBU-38 JDAM, a 500-pound version of the satellite-guided JDAM; and the AGM-114 Hellfire, a laser-guided missile that was developed for use on attack helicopters. Consequently, CBO did not consider the force fielded under Alternative 5 to have an aggregate capacity for carrying 2,000-pound weapons that was larger than that available under Alternative 4. That conservative assumption probably understates the bomb-carriage capabilities afforded by Alternative 5, however, because the MQ-9 should also be able to carry at least four SDBs. The MQ-9 would not add air-to-air capability, although its availability would mitigate a loss of air-to-ground capability if F-35s were needed for air-to-air missions.¹¹

The Reaper would add the ability to keep aircraft armed with bombs in the air ready to respond on short notice to calls to attack fleeting targets. According to the Air Force, the Reaper has a range greater than 3,000 n. mi. and would therefore offer considerable endurance in orbits several hundred nautical miles from bases in-theater. With that endurance, fewer unmanned aerial vehicles than fighters would be needed to sustain an air-support orbit. However, fighters can reach targets from more distant orbits in the same amount of time as a closer but slower unmanned aerial vehicle. Therefore, in some cases, a larger number of orbit locations might be required to ensure MQ-9's were close enough to areas where they might be needed. Although the MQ-9's payload is

smaller than that of a fighter, attacks from such orbits typically require only a small number of weapons. Another advantage to Alternative 5 is that the use of unmanned aircraft in lieu of fighters would reduce the rate at which fighters would be consuming airframe life. As a consequence, the addition of UAVs for loitering missions could help extend the service life of the fighters they augment, postponing the date at which replacements would be needed. Of course, the magnitude of that effect would depend on the extent to which the United States remained involved in combat operations around the world, such as those that have been conducted in Iraq and Afghanistan.

Although the low cost of the MQ-9 (relative to that of fighters) is an advantage offered by Alternative 5, that aircraft's lesser performance would pose operational limitations. Because the MQ-9's lack of stealth design features could make it vulnerable, it would probably be of limited use early in a conflict against an adversary with effective air defenses. However, General Atomics is currently testing a stealthier variant of the Predator family of unmanned aircraft (called the Avenger or Predator C) that could overcome that disadvantage, albeit probably at a higher cost than that of the MQ-9. Additionally, its low speed would limit its ability to be rapidly repositioned to areas of unexpected need. (The Reaper's ability to rapidly respond to calls for fire support lies in its ability to loiter in the general vicinity.) Instead of relying on Reapers, the services could develop a more capable aircraft to augment a smaller fighter force. For example, a mix of MQ-9s and a more fighter-like unmanned aircraft could be developed and fielded, although at greater cost. (Such an aircraft is illustrated in Alternatives 6 and 7.)

The smaller fighter inventories envisioned under Alternatives 4 and 5 would result not only in lower procurement costs relative to those projected under DoD's fiscal year 2009 modernization plans, but most likely in lower operation and support costs as well. However, the extent to which those costs would scale with aircraft inventory would depend on the ratio of variable to fixed costs for sustaining the force. Considerable uncertainty surrounds how a reduced force would be structured and how costly it would be to operate the JSF and large numbers of unmanned aircraft. For example, depending on how many UAVs would be in the air at any given time and the extent to which future armed UAVs could be designed for autonomous operation, additional investments in satellite communications capability might be required. For those

10. That estimate is based on a cost of \$57 million for four aircraft and a ground station taken from an Air Force fact sheet. Unit costs under Alternative 5 could be lower because a much larger number of aircraft would be purchased than is specified under current plans, potentially reducing unit costs and also allowing a greater number of aircraft per ground station.

11. Cruise missiles might be used instead of unmanned aircraft to offset reductions in the size of fighter forces. However, because one aircraft can attack many different targets throughout a conflict as it flies multiple sorties over many days, it would take many missiles (of a number that cannot be projected without assuming, among other unknowns, the number of combat missions an aircraft might be tasked to conduct over its life) to substitute for one aircraft. Thus, there is no definitive way to calculate how many missiles might substitute for an aircraft.

reasons, CBO did not estimate total O&S costs for its individual alternatives. A brief discussion of O&S costs appears in the appendix.

Alternatives 6 and 7: Forces That Provide Longer Flight Range

The preceding analysis demonstrates that the modernized fighter force envisioned under DoD's fiscal year 2009 plans would be substantially more capable than the fighter force currently in service. A notable exception to that improved capability, however, would be aircraft flight range. Although the bomb-carriage capacity of the planned force would be greater than today's bomb-carriage capacity out to unrefueled radii that the force can already reach, the new fighters would not extend the unrefueled reach of the fighter force much beyond current limits. (The F-35C would extend the Navy's reach somewhat, to about 700 n. mi., but the Air Force would lose capability beyond 650 n. mi. as the A-10 and F-15E are retired.) That lack of improvement in flight range is in contrast to the 2006 Quadrennial Defense Review's call for reorienting joint air capabilities toward "...systems that have far greater range and persistence; larger and more flexible payloads for surveillance and strike; and the ability to penetrate and sustain operations in denied airspace."¹² The Air Force and Navy have considered plans for developing aircraft capable of accessing targets from even greater distances than the JSF is designed to reach—for the Air Force, the so-called Next-Generation Long Range Strike System (NGLRS); and, for the Navy, unmanned combat aircraft that could be fielded in about 2025—but those plans appear to be proceeding independently of DoD's fighter modernization plans.¹³ Alternatives 6 and 7 would reduce purchases of fighters (specifically, the Joint Strike Fighter) and, instead, purchase those aircraft with longer-range capability.

Under **Alternative 6**, the Air Force would procure 325 F-35As and 250 medium-range bombers rather than the planned 1,763 F-35As; and the Navy and Marine Corps would purchase 410 JSFs (150 F-35Bs and 260 F-35Cs) and 275 unmanned combat aircraft (UCAV-N) instead

of the planned 680 F-35B/Cs (see Figure 3-5). Investment costs under Alternative 6 would be \$200 billion, CBO estimates, or about 2 percent less in constant dollars but 4 percent more on a net-present-value basis than the projected cost of DoD's fiscal year 2009 plans. (The higher net-present-value cost reflects the substantial RDT&E investment needed in the near-term.) CBO estimated that the average unit cost (including support and initial spares) for 250 medium-range bombers and 275 UCAV-Ns would be \$205 million and \$105 million, respectively.¹⁴ The lower aircraft inventories envisioned under Alternative 6 would be mitigated under **Alternative 7** by the services' purchasing unmanned Reapers—an additional 1,000 for the Air Force and 100 for the Navy and Marine Corps—to augment fighters. (Alternatively, the Air Force could purchase a mix of Reapers and more-capable aircraft like the UCAV-N.) Total costs under Alternative 7 would be about \$20 billion higher than is projected for Alternative 6, or about 7 percent higher in constant dollars and 13 percent higher on a net-present-value basis than is projected for DoD's fiscal year 2009 plans. The costs described above include expenses for RDT&E, which CBO estimates could be on the order of \$20 billion for a medium-range bomber and \$10 billion for a UCAV-N.

Alternatives 6 and 7 would provide forces with bomb-carriage capacities comparable to or greater than those existing today out to a radius of 1,500 n. mi. from an aerial refueling tanker (see Figure 3-6). For the Air Force, the alternative forces would offer less total bomb-carriage capacity than DoD's planned force (for an unrefueled radius out to about 600 n. mi.) but comparable stealthy bomb-carriage capacity for those ranges and greater stealthy and total capacity for even longer ranges. For the Navy and Marine Corps, total bomb-carriage capacity would be comparable to the planned force out to a radius of about 600 n. mi. and greater than the planned force for longer ranges. Stealthy carrying capacity would be substantially greater at all ranges.

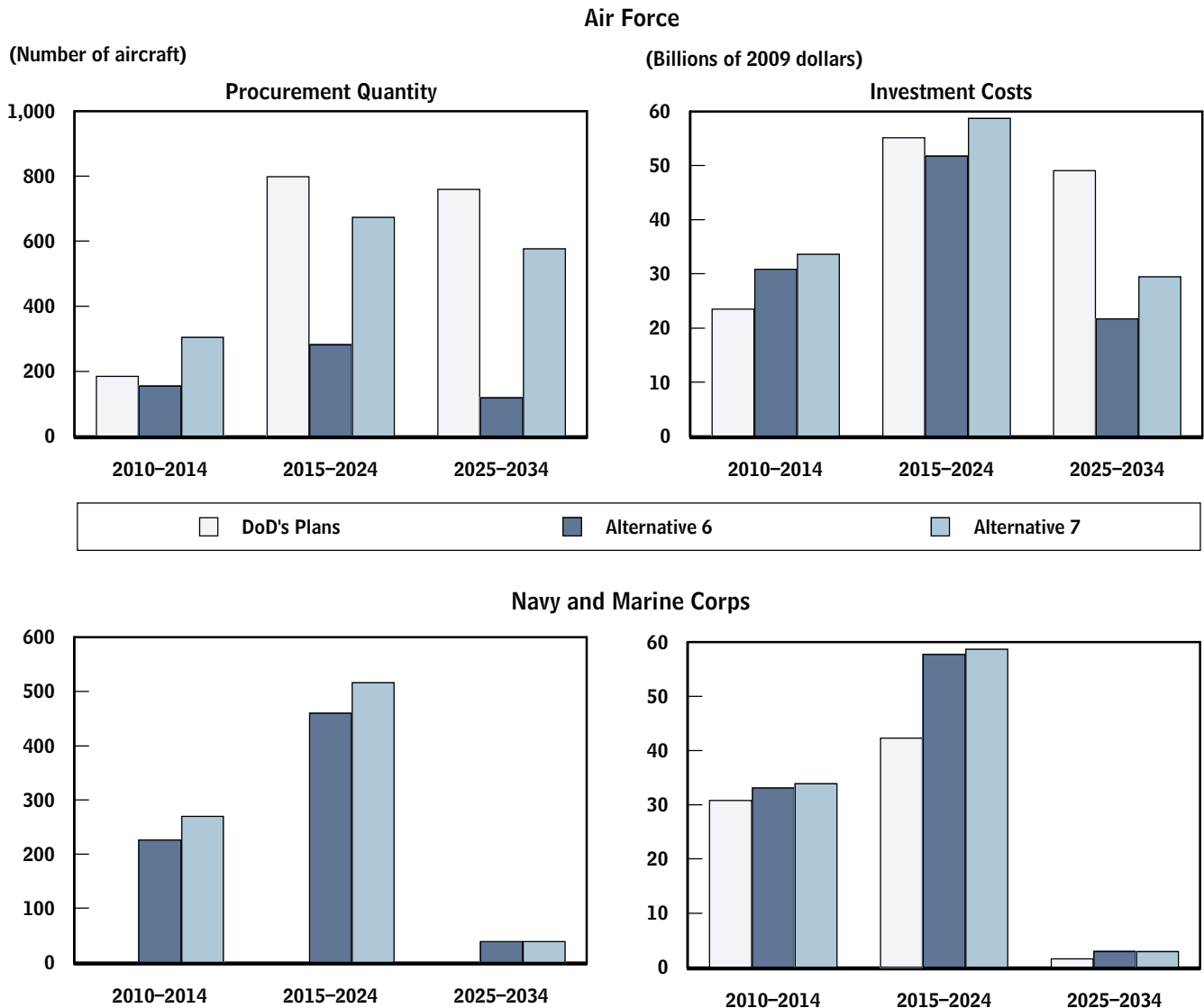
12. See Department of Defense, *Quadrennial Defense Review Report* (February 2006).

13. In April 2009, the Secretary of Defense indicated DoD's intention to postpone work on the NGLRS until a review of requirements and available technologies could be completed. Prior plans had called for fielding the NGLRS around 2018.

14. The cost estimate for the medium-range bomber is based on a CBO study of alternative long-range strike systems. See Congressional Budget Office, *Alternatives for Long-Range Ground-Attack Systems* (March 2006). CBO estimated the cost of the UCAV-N by analogy to the JSF. For a study of potential UCAV-N operations see Thomas P. Ehrhard and Robert O. Work, *Range, Persistence, Stealth, and Networking: The Case for a Carrier-Based Unmanned Combat Air System* (Washington, D.C.: Center for Strategic and Budgetary Assessments, 2008).

Figure 3-5.

Quantities and Costs of New Fighter Aircraft Under DoD's Fiscal Year 2009 Modernization Plans and Alternatives That Expand Mission Range



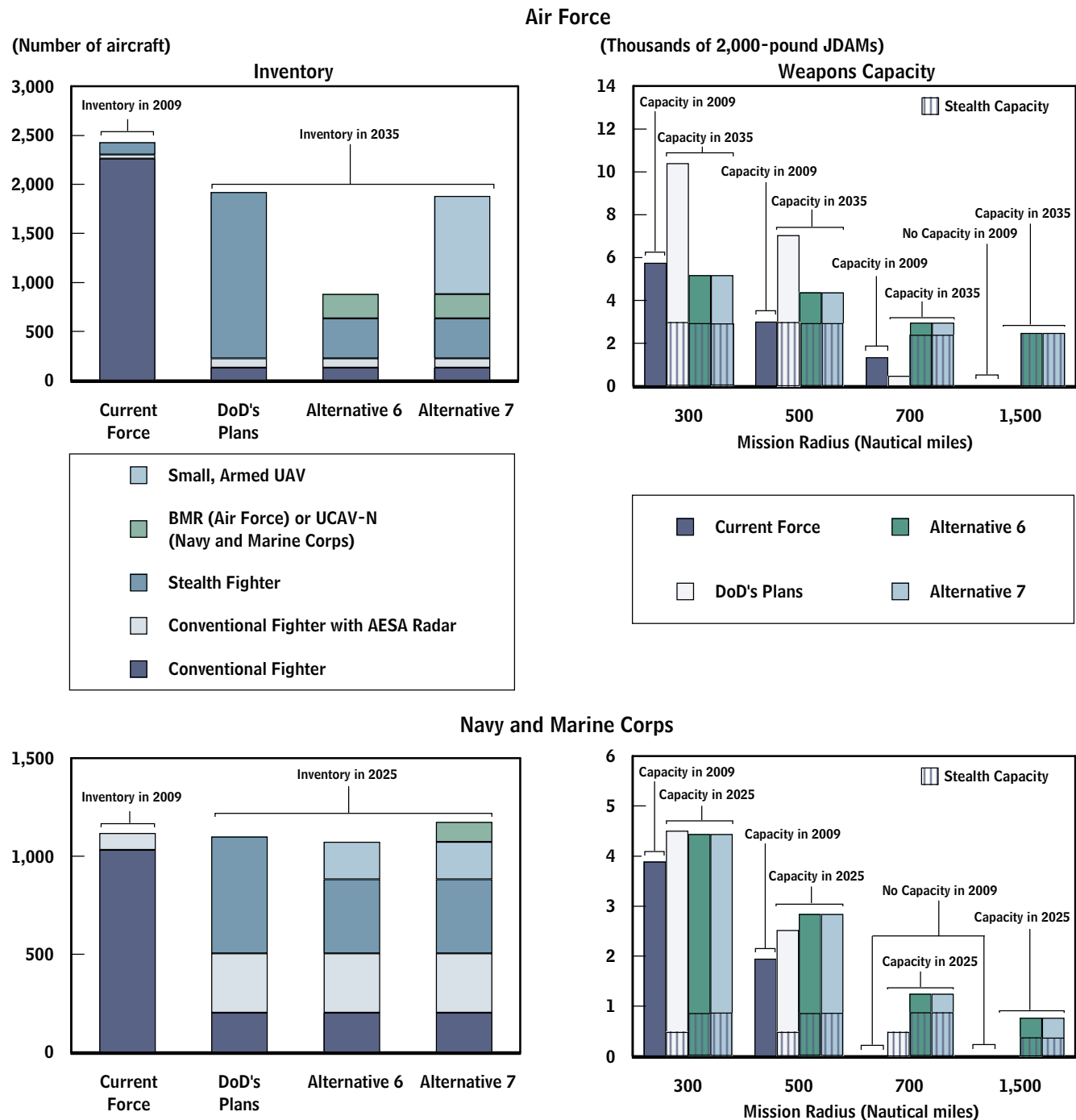
Source: Congressional Budget Office.

Notes: DoD = Department of Defense.

Investment costs comprise expenses for research, development, test, and evaluation of new aircraft and for procurement of those aircraft.

Figure 3-6.

Configuration and Capabilities of Fighter Forces Under DoD's Fiscal Year 2009 Modernization Plans and Alternatives That Expand Mission Range



Source: Congressional Budget Office.

Notes: AESA = advanced electronically scanned array; BMR = medium-range bomber; DoD = Department of Defense; JDAM = Joint Direct Attack Munition; UAV = unmanned aerial vehicle, UCAV-N = carrier-capable unmanned combat aerial vehicle.

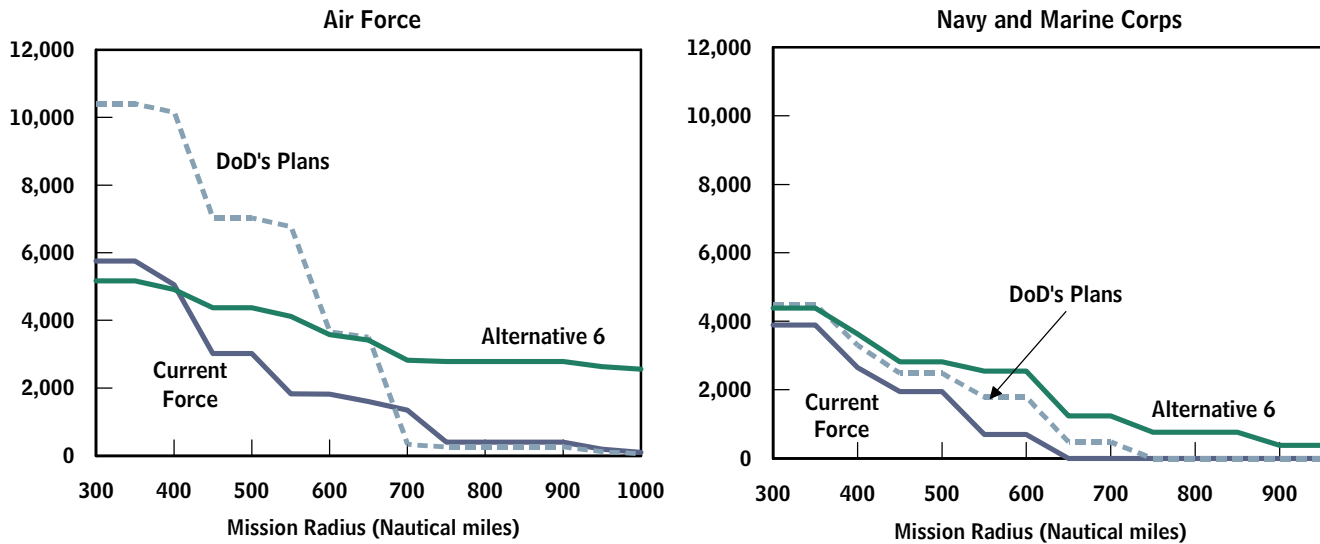
Specific estimates of mission range reflect the distance an aircraft could fly from an aerial refueling tanker to a designated target and back with a fuel reserve of 30 minutes.

The years 2035 and 2025 correspond with the respective services' fiscal year 2009 plans for concluding production of the Joint Strike Fighter. After 2035 (or perhaps sooner), the Air Force will probably need to begin replacing or extending the service life of older F-22s. After 2025, the Navy will probably need to take similar measures for F/A-18E/Fs.

Figure 3-7.

Weapons Capacity and Mission Range of Today's Fighter Forces Under DoD's Fiscal Year 2009 Modernization Plans and Under an Alternative Plan

(Number of weapons)



Source: Congressional Budget Office.

Notes: DoD = Department of Defense.

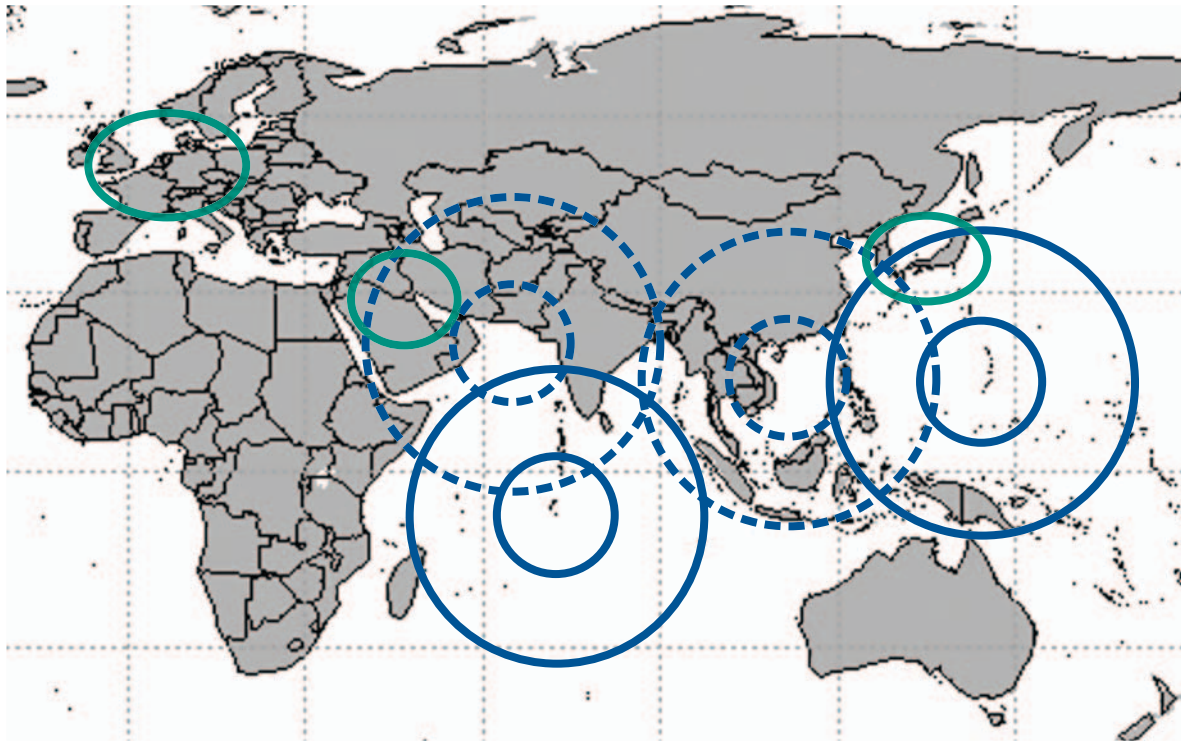
Specific estimates of mission range reflect the distance an aircraft could fly from an aerial refueling tanker to a designated target and back with a fuel reserve of 30 minutes.

Although air-to-ground weapons capacity would remain the same or even improve, reduced inventories of fighter aircraft could limit the Air Force's ability to sustain operations in several theaters at once or over long periods of time. Those limitations could be particularly significant in situations (such as air-to-air combat patrols and loitering air-to-ground support orbits) in which the success of a mission relied as much or more on the presence of sheer numbers of aircraft than on their weapons capacity. To establish a floor for air-to-air capability, Alternative 6 calls for the purchase of 512 stealthy fighters (including the 187 F-22s already procured plus 325 F-35As), a quantity greater than the 381 F-22s that the Air Force has stated it needs for air-superiority missions. For loitering air-to-ground missions, the lower number of Air Force aircraft in Alternative 6 would be countered somewhat by the medium-range bomber's higher endurance, a capability that allows aircraft to orbit longer over a specific area. Under Alternative 7, Reapers would be added to the aircraft available for ground attack. Those aircraft would most likely be limited to permissive air-defense environments, however, unless a more survivable armed UAV was purchased. Although the Navy's and the Marine Corps'

inventories under Alternative 6 would not be significantly lower than the inventories envisioned under DoD's fiscal year 2009 plans, air-to-air capabilities would be reduced because the UCAV-N would lack the air-to-air capability of the JSFs it would replace.¹⁵

Forces under Alternatives 6 and 7 would pay the price of lower fighter inventories to gain the advantage of improved endurance for strike aircraft. Although short-range fighter aircraft were used to great effect during the first Gulf War in 1991, planners recognized that U.S. airpower could be severely limited if local airbases, such as those provided by Saudi Arabia, were unavailable, a situation that could occur if nations in a region were reluctant to host U.S. military forces, if operations were in an

15. Some proponents think that unmanned aircraft will eventually be able to engage in air-to-air combat. Although it is unlikely that the intricacies of dog fighting could be completely automated in the near future, a stealthy unmanned fighter equipped with air-to-air radar and weapons could detect and shoot at other aircraft. Therefore, unmanned strike aircraft might eventually be equipped with a limited air-to-air capability for self-defense.

Figure 3-8.**Mission Ranges of Aircraft from Selected Locations**

Source: Congressional Budget Office.

Notes: Smaller rings represent mission ranges out to a radius of 500 nautical miles; larger rings represent mission ranges out to a radius of 1,500 nautical miles.

Solid rings represent mission ranges from land bases; dashed rings represent mission ranges from potential aircraft carrier locations.

undeveloped part of the world that lacked airbases (or proximity to the sea for aircraft carriers), or if an adversary were able to attack local bases with long-range weapons. Those “denied-basing” scenarios, coupled with the potential proliferation of air-defense systems much more advanced than those used by Iraq in 1991, constitute what DoD planners have called the anti-access threat to military air operations. Plans to modernize the fighter force with a preponderance of stealthy aircraft would help address the air-defense piece of the anti-access threat. However, the improvement in flight range that the JSF would offer over current aircraft would not remedy a situation in which the United States had limited access to local bases. (The Air Force currently operates about 140 long-range bombers—the B-52H Stratofortress, the B-1B Lancer, and the B-2A Spirit—that can be used to conduct conventional strikes over intercontinental distances. Their use in the conventional strike role can be constrained, however, by their commitment to other roles, such as nuclear deterrence. Consequently, CBO did

not include the conventional capabilities of those aircraft in its comparison of potential fighter force capabilities under alternative modernization plans.¹⁶)

Like today’s force, DoD’s planned fighter force would have considerable flight-range and payload capabilities out to a radius of about 600 n. mi., but the medium-range bombers and UCAV-Ns included in Alternatives 6 and 7 would extend that range substantially (see Figure 3-7 on page 42). The shorter mission ranges of current fighters have provided significant capability in the scenarios that have dominated past planning (see Figure 3-8). For scenarios involving war in Korea, Central Europe, and Iraq, aircraft with a combat radius of 500 n. mi. (the green rings in the figure) could reach most potential targets because those scenarios assumed

16. Today’s bombers, especially the B-52s, are already quite old and pose modernization decisions for the Air Force over the period considered in this paper.

bases would be made available by nearby nations with a strong interest in supporting U.S. operations. The figure shows that aircraft limited to operating within a radius of 500 n. mi. from two sample bases often used by U.S. forces—Diego Garcia, a British territory in the Indian Ocean, and Guam, a U.S. territory in the western Pacific Ocean (the solid blue rings in the figure)—would require many in-flight refuelings to reach locations of potential conflict. The longer range of the medium bombers procured under Alternatives 6 and 7 would allow those aircraft to reach potential targets from those secure bases with less (or possibly no) airborne tanker support.

Although short-range naval fighters operating from aircraft carriers are less constrained by political basing limitations, longer-range carrier aircraft would offer advantages as well (see the dashed rings in Figure 3-8). For one, naval air operations can be limited by geography; targets need to be fairly close to the sea if land-based airborne tankers are not available to support operations

far inland. Additionally, if an adversary possesses effective antiship weapons, such as submarines or cruise missiles, it is advantageous to keep carriers as far out to sea as possible. The increased range offered by the UCAV-N in Alternatives 6 and 7 would make that possible.

Despite its range limitations, the F-35B could also help address access limitations because those aircraft can be operated from large amphibious ships as well as from smaller airbases than are needed by conventional takeoff and landing aircraft. When he was Air Force Chief of Staff, General John Jumper proposed substituting some F-35Bs for F-35As to provide just that flexibility for his land-based fighter force. That basing flexibility would come with the penalties of decreased flight range and payload capacity, however, and increased costs. Additionally, given the logistical demands imposed by fighter operations—specifically, for fuel, maintenance, and munitions—it might prove difficult to generate significant levels of effort from small airfields.

Details Underlying CBO's Cost Analysis

The life-cycle costs of an aircraft consist primarily of two components: costs that are incurred to develop and produce an aircraft (investment costs) and those that are incurred to operate and maintain the aircraft over its service life (operation and support, or O&S, costs). The cost comparisons that the Congressional Budget Office (CBO) presented in this study are based strictly on investment costs. CBO did not include O&S costs in its comparisons for several reasons, including the uncertainty surrounding how fighter forces will be used in future decades and what O&S costs will actually be for new aircraft just entering the force. Nonetheless, a brief discussion of issues related to O&S costs for fighter forces is included at the end of this appendix. The primary purpose of the appendix is to describe the sources of information on which CBO based its cost estimates and the methodology used to develop those estimates. All of the cost estimates presented in this analysis are expressed in constant 2009 dollars.

Investment Costs

Investment costs include those incurred for research, development, test, and evaluation (RDT&E) and for procurement. Expenses for RDT&E include the cost to design and build prototypes of system components; the cost to test those components to ensure they meet performance requirements; and the cost to integrate the aircraft into the military's infrastructure and support systems. Expenses for procurement can include the cost of special tools and equipment to manufacture system components; the cost of hardware, raw materials, and fabrication of finished components; and the cost to assemble the final product.

For aircraft that are currently in production—the F/A-18E/F Super Hornet, the F-16E (the latest variant of the F-16 Fighting Falcon), the MQ-9 Reaper, and, in the very early stages, the F-35 Joint Strike Fighter (JSF)—

CBO used cost estimates prepared by the Department of Defense (DoD) or industry analysts and modified them to account for changes in the timing of purchases and for changes in the quantity of aircraft purchased. Those adjusted estimates then served as the basis for calculating the investment costs of each of the seven alternative plans CBO developed for modernizing U.S. fighter forces (as described in Chapter 3). In conducting its analysis, CBO noted situations for which the potential for significant cost growth exists, relative to DoD's estimates, but did not perform detailed bottom-up cost estimates for those aircraft.¹ The cost estimates for the notional medium-range bomber that the Air Force would purchase under Alternatives 6 and 7 and estimates for the carrier-capable unmanned combat aerial vehicle (UCAV-N) that the Navy would purchase under the same alternatives include more of a bottom-up cost analysis. The following paragraphs describe important features of the methodology and assumptions used to estimate costs for each aircraft considered in CBO's analysis.

Joint Strike Fighter

The JSF has entered low-rate production. As of 2009, 14 F-35As and 12 F-35Bs had been funded for the Air Force and Marine Corps, respectively, with the first operational JSF squadrons expected to enter service in 2013 (Air Force) and 2012 (Marine Corps). To arrive at its estimates of the cost of the F-35 under the modernization alternatives, CBO used cost estimates from the December 31, 2007, Selected Acquisition Report prepared by the JSF Program Office and adjusted those estimates to reflect changes in production quantities.² The cost for each alternative that contains F-35s (all but Alternative 3) includes the remaining RDT&E funding cited in that report—\$3.6 billion for the Air Force and \$3.5 billion

1. See Government Accountability Office, *Joint Strike Fighter: Recent Decisions by DoD Add to Program Risk*, GAO-08-388 (March 2008).

for the Department of the Navy (DoN) over the 2010–2013 period. The average unit procurement cost for each variant of the F-35 is different in each alternative.³ Among the alternatives that CBO examined, the lowest average unit procurement costs for the JSF—\$67 million for the F-35A and \$97 million for the F-35B/C—would be realized under Alternative 1. The highest average unit procurement costs—\$90 million for the F-35A and \$116 million for the F-35B/C—would occur under Alternatives 6 and 7.⁴

Although explored as an option in Alternative 3, canceling the JSF would be complicated given the commitment of international partners to the program. To reflect that somewhat intangible factor, CBO assumed that the United States would reimburse its international partners for the approximately \$5 billion they have provided so far for development of the F-35. Alternatives to the F-35 for those nations could include advanced fighters such as the Eurofighter Typhoon, the Saab Gripen, and the Dassault Rafale, as well as the Boeing F-15 (Eagle or Strike Eagle), the Lockheed Martin F-16C Fighting Falcon (or the newer F-16E), and the Boeing F/A-18E/F Super Hornet. Cancellation of the JSF would be most problematic for the British military, which needs aircraft with short take-off vertical landing (STOVL) capability, such as that provided by the F-35B, to operate from the Royal Navy's small Invincible class of aircraft carriers. However, the Royal Navy currently has plans for purchasing two much

larger replacement aircraft carriers (each displacing about 65,000 tons versus 22,000 tons for the Invincible class), which would enter service between 2014 and 2018. Although they would initially carry F-35Bs, those larger ships are being designed to accommodate the addition of catapult and arresting equipment for conventional carrier aircraft that might be fielded after the F-35B is retired. (The carriers are expected to be in the fleet for 50 years.) If the JSF is canceled, that equipment could be installed as the ships are built.

F-22

The Lockheed Martin F-22 Raptor is currently in production for the Air Force. All of CBO's alternative plans for modernizing U.S. fighter forces include a total of 187 F-22s. However, the cost estimates for the alternatives examined by CBO do not include any future funding for F-22s because those estimates are for fiscal year 2010 and beyond and the final F-22s were to be ordered in 2009. (As noted in the report, however, funds could be provided for additional F-22s.) Recent statements by DoD officials indicate that about \$8 billion may be needed to improve the capabilities of the first 100 F-22s produced. CBO did not include such ongoing plans for aircraft improvement (which can be expected for other fighters as well) in its costs estimates.

F/A-18E/F

The F/A-18E/F Super Hornet is currently in production for the Navy, and its manufacturer, Boeing, is marketing it to foreign governments. CBO based its estimates for procuring the F/A-18E/F on what the Navy is currently paying for those aircraft. According to CBO's estimates, the total average unit procurement cost would range from about \$75 million to \$90 million for each aircraft, depending on the production quantity and rate of production.

F-16E

The F-16E is in production for the United Arab Emirates (UAE), and Lockheed Martin is marketing it to other foreign governments as well. For Alternatives 2 and 3, CBO based its estimates of total average unit procurement costs for a U.S. variant of the F-16E—\$48 million to \$50 million—on the costs of the aircraft being produced for the UAE. To account for additional RDT&E that might be needed to integrate U.S. equipment or subsystems into the F-16E, CBO added about \$2 billion to its estimate of the cost of those alternatives. That estimate

2. Production quantities can affect costs in two primary ways: First, unit costs tend to decrease (rapidly at first before reaching a more steady state) as the cumulative quantity produced increases because improvements in manufacturing efficiency are usually realized as the manufacturer gains greater experience with a system's fabrication and assembly and because the costs to establish production facilities are incurred early in production. Second, higher annual production rates tend to result in lower unit costs because fixed (or nearly fixed) overhead expenses such as engineering and management support can be spread across a greater number of units.
3. The total average unit procurement cost includes items such as initial spare parts and support equipment. It is greater than the frequently cited unit recurring flyaway cost, which includes only the aircraft itself.
4. Data in the Selected Acquisition Report did not permit CBO to distinguish between the cost of the F-35B and the F-35C. Other sources have indicated that the F-35B will have a slightly higher unit cost, but the difference that is actually realized will depend on the relative quantities that are produced both for the Department of the Navy and for international partners.

is based by analogy on the RDT&E funding that was needed by the Navy for the EA-18G Growler program. Research and development funding for the EA-18G covered integrating more advanced systems—in this case airborne electronic attack equipment and avionics—into the existing F/A-18F Super Hornet.

MQ-9

The MQ-9 Reaper is currently in production for the Air Force, and its manufacturer, General Atomics, has investigated modifications that could make the aircraft capable of operating from aircraft carriers. CBO based its estimate of unit procurement costs for the MQ-9—about \$14 million per aircraft including one ground station per four aircraft—on data provided by the Air Force.

UCAV-N

The X-47B Pegasus, a flyable demonstrator for exploring technologies that could lead to an operational UCAV-N, was rolled out by Northrop Grumman in December 2008. Its purpose is to demonstrate the feasibility of operating unmanned strike aircraft from aircraft carriers. Its first flight is expected to take place in 2009, and fiscal year 2009 plans called for demonstrating carrier takeoff and landing in 2012. In the absence of a detailed design—the X-47B is a demonstrator, not necessarily a prototype of an operational system—CBO generated a procurement cost estimate for the UCAV-N by scaling the cost versus quantity curve for the F-35B/C to account for the lower expected weight of that aircraft. Although possessed with great range, the UCAV-N as envisioned in Alternatives 6 and 7 would probably have a lower empty weight than the JSF because it would have a smaller payload and would not carry a cockpit, pilot, and the associated support systems. Additionally, the UCAV-N's structure could be built lighter than the JSF's because it would not need the strength to withstand high-stress air-to-air combat maneuvers nor would it need the durability to accommodate large numbers of flight hours for pilot training. For its analysis of Alternatives 6 and 7, CBO estimated an average unit cost (including support and initial spares) of about \$105 million each for 275 UCAV-Ns. CBO estimated the RDT&E costs of about \$10 billion for the UCAV-N by analogy to previous fighter and attack aircraft programs. CBO assumed that the availability of technologies developed for the JSF and for the X-47B demonstrator would help reduce RDT&E costs for the UCAV-N.

Medium-Range Bomber

CBO based its estimates of the cost (and performance) of the medium-range bombers that would be purchased by the Air Force under Alternatives 6 and 7 on a notional medium-range bomber that would operate at subsonic speeds; that bomber was described by CBO in its March 2006 study of alternatives for long-range ground-attack systems.⁵ In the absence of even a demonstrator, CBO based its estimates of the costs of that aircraft on a technical analysis of the weight, dimensions, and propulsion systems that would be needed to provide an aircraft with the specified performance characteristics. For the 250 medium-range bombers included in Alternatives 6 and 7, CBO estimated an average unit cost (including support and initial spares) of about \$205 million per aircraft. CBO estimated RDT&E costs of about \$21 billion for the medium-range bomber by analogy to previous fighter and bomber programs.

Operation and Support Costs

This study focuses on investment costs; it does not address operation and support costs for the alternatives considered. O&S costs include those for the personnel to man fighter units, aircraft maintenance, the training establishment and other infrastructure associated with the fighter force, fuel, spare parts, and other supplies. Estimating O&S costs for the current force and for alternative modernization plans would involve consideration of a number of issues, including the following:

- Determining the variable and fixed components of the fighter fleet's O&S costs in the face of uncertainty as to how the significantly different alternative forces might be organized. (Those component costs would include costs that vary about linearly with the size of the fleet, such as costs for pilots, versus those costs that must be borne as long as there is a fleet of any size, such as those for certain elements of the supply and depot establishments.)
- Uncertainties surrounding current and future fuel costs. (That volatility is illustrated by recent changes in DoD's guidance on fuel prices: The standard fuel price used for planning purposes in 2009 is nearly 40 percent lower than that used for 2008.)

5. See Congressional Budget Office, *Alternatives for Long-Range Ground-Attack Systems* (March 2006).

- Uncertainties surrounding the O&S costs associated with the use of unmanned aerial vehicles.
- Uncertainties attached to the development of more advanced ground trainers, which might reduce the need to fly actual training sorties.
- Uncertainties about the O&S costs of new aircraft for which there is little or no operational experience. For example, estimates of the O&S costs for the F-22 and F-35A have changed substantially relative to the aircraft they are slated to replace.

Although a detailed treatment of O&S costs is not included in this report, those costs, in CBO's estimation,

would not change the conclusions drawn about the relative merits of the seven alternatives examined in the study. CBO's analysis of investment costs indicated, not surprisingly, that larger inventories and more advanced and capable aircraft would tend to result in higher investment costs. A qualitative inspection of the alternatives suggested that, with the possible exception of Alternative 2, O&S costs would trend in the same direction. A detailed analysis of Alternative 2 would be needed to determine whether replacing some F-35As with F-16Es (which could have lower operating costs) would be offset by the increased costs associated with maintaining an additional type of aircraft (and its separate support infrastructure) in the force.

