

The F-22 Acquisition Program

Consequences for the US Air Force's Fighter Fleet

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The majority of US Air Force fighter aircraft in service today are F-15s, F-16s, and A-10s acquired in the 1980s. During that decade, the service had a fighter strength of approximately 36 fighter wing equivalents, with the average aircraft in the fleet about 10 years old. Since then the number of fielded fighters has steadily decreased, the Quadrennial Defense Review (QDR) of 2010 having established a requirement for 16–17 fighter wing equivalents.¹ Additionally, the Air Force has acquired very limited numbers of new fighters since the early 1990s, causing the fighter fleet's average age to increase steadily. Acquisition of the F-22 slowed but did not stop this trend (fig. 1). By 2011 the average age of fighters was 21.3 years.²

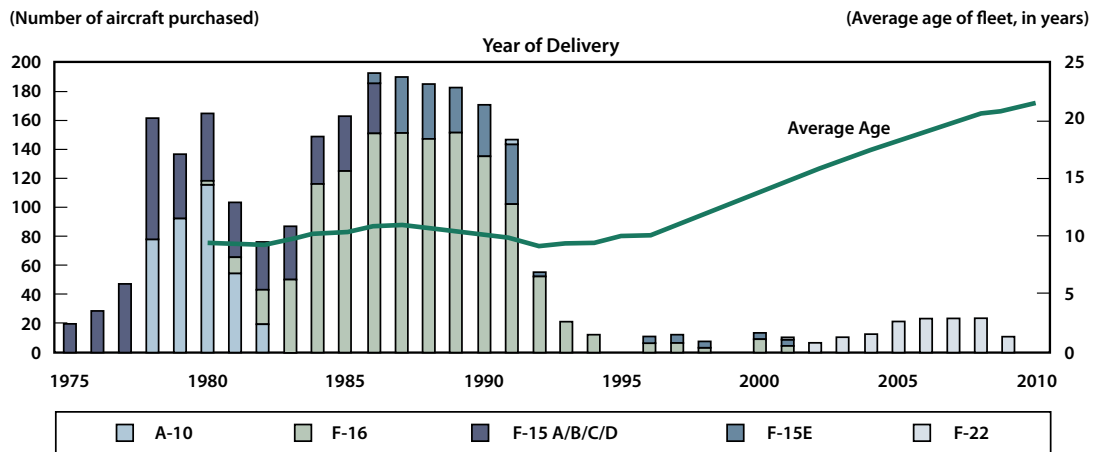


Figure 1. The Air Force's current inventory of fighter aircraft, by year of delivery.

(From Congressional Budget Office, *Alternatives for Modernizing U.S. Fighter Forces* [Washington, DC: Congressional Budget Office, May 2009], 9, <http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/101xx/doc10113/05-13-fighterforces.pdf>.)

More importantly, the corresponding percentage of planned service life “used” has markedly increased (fig. 2). By 2009, 80 percent of the fleet's aircraft had used more than 50 percent of their originally planned service life. Clearly, the Air Force's fighter fleet is wearing out.

This sustained decline in fighter inventory coincided with the development and acquisition of the F-22. Originally, the Air Force intended to obtain 750 F-22s, primarily as replacements for air superiority F-15s acquired through the 1980s. As late as 2008, Air Force Chief of Staff T. Michael Moseley stated that the service needed at least 381 F-22s to meet operational requirements.³ Nonetheless, in 2009 Secretary of Defense Robert Gates announced that F-22 production would end at 187.⁴

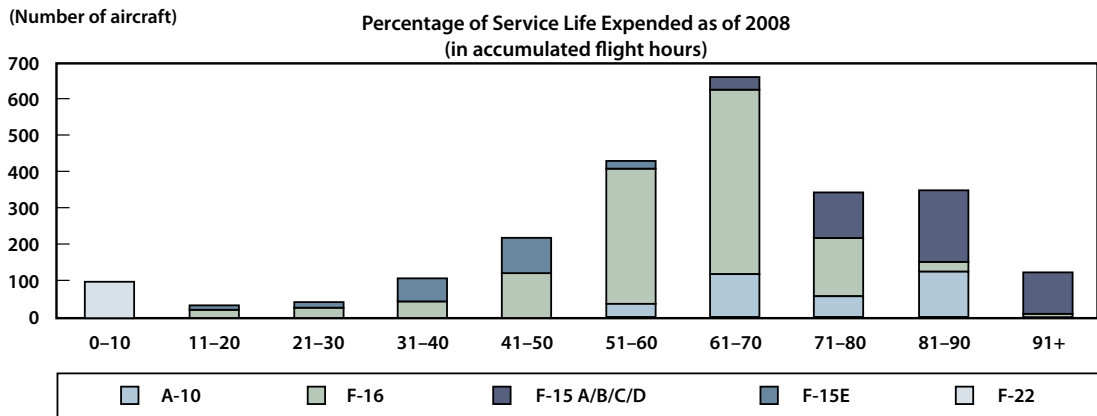


Figure 2. The Air Force’s current inventory of fighter aircraft, by percentage of service life expended. (From Congressional Budget Office, *Alternatives for Modernizing U.S. Fighter Forces* [Washington, DC: Congressional Budget Office, May, 2009], 9, <http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/101xx/doc10113/05-13-fighterforces.pdf>.)

In consideration of this decision, this article examines the F-22 program in an attempt to answer two questions. First, given the clear need to recapitalize its fleet, why did the Air Force acquire just 25 percent of the F-22s originally planned? Second, could it have realized a better result by making alternative decisions during F-22 development? Finally, the article briefly addresses current fighter acquisition efforts in the context of the Air Force’s experience with the F-22.

History of the F-22 Program

Originally, the Advanced Tactical Fighter (ATF) program sought to counter a Soviet threat during the Cold War. The ATF’s mission—air superiority—included finding and destroying high-priority enemy interceptors, standoff jammers, and large, offensive attack formations.⁵ Plans did not call for air-to-ground attack, reconnaissance, or other “multirole” missions. Advancements in Soviet weapons, especially the MiG-29 and Su-27 aircraft, during the 1980s heavily influenced the

ATF's design. Developed about a decade after the F-15, these platforms possessed similar aerodynamic performance although their avionics and long-range weapons remained inferior. Nonetheless, these Soviet advancements led Air Force leaders to believe that the F-15's decisive air superiority advantage was fading. They wanted the ATF to preserve the technological advantage needed to battle superior Soviet numbers without incurring unacceptable losses.⁶

Seven companies presented proposals to the Air Force during the concept-exploration phase. The service subsequently decided to incorporate a demonstration/evaluation phase with two contractors competing in a flight-test competition using full-scale prototypes, selecting Lockheed Martin and Northrop Grumman to lead the two teams in developing the YF-22 and YF-23, respectively. In 1991 Secretary of the Air Force Donald Rice announced that although both designs met requirements, the Lockheed Martin proposal was superior because it offered "better capability at lower cost."⁷ The Air Force considered the Lockheed Martin / Boeing / General Dynamics team more likely to deliver on its promises than the Northrop / McDonnell Douglas team, whose reputation was tarnished by B-2 problems and the A-12 cancellation.⁸ Thus, the ATF became the Lockheed Martin F-22.

The demonstration/evaluation phase transitioned to the engineering, manufacturing, and development (EMD) phase in 1991. At that time, the Air Force forecast that the new fighter would reach initial operational capability (IOC) 10 years later—in 2001.⁹ Although the service intended to replace approximately 790 air superiority F-15s with F-22s, early post-Cold War cuts reduced planned production from 750 to 648 in 1991.¹⁰ At that time, it estimated the total cost of the program at \$99.1 billion in "then-year dollars."¹¹ Of that amount, \$19.5 billion was dedicated to development (including \$3.7 billion already spent during demonstration/evaluation).¹² The remaining \$79.6 billion went to production, making the average production unit cost (APUC) \$122.8 million.¹³

Early Engineering, Manufacturing, and Development

In the early 1990s, the overall Department of Defense (DOD) budget came under increasing pressure in anticipation of a post-Cold War “peace dividend.” By fiscal year (FY) 1997, the DOD budget had decreased 38 percent from its FY 1985 peak while the procurement portion of the budget was simultaneously reduced by two-thirds (both figures in constant-year dollars).¹⁴ The dwindling budget created an exceedingly difficult environment for F-22 development.

The Air Force’s post-Cold War sustainment strategy entailed sacrificing force structure and preserving modernization programs.¹⁵ Implementation of this strategy called for decreasing active duty manning by more than 40 percent—from 602,582 to 351,375 personnel between FY 1987 and FY 2000—while the service aggressively retired older tactical aircraft like the F-4, F-111, and A-7.¹⁶ Consequently, by 1993 the Air Force’s force structure had shrunk from 36 to 27 fighter wing equivalents, well ahead of the post-Cold War drawdown identified in the outgoing Bush administration’s base force.¹⁷ However, the new Clinton administration, determined to reduce the growing federal deficit, soon planned a second major restructuring of the military.

The Air Force believed that simultaneously funding multiple development programs for tactical aircraft probably was not tenable.¹⁸ Furthermore, senior Air Force leaders strongly supported the F-22. For example, Gen Michael Loh, commander of Tactical Air Command in the early 1990s and author of the original ATF Statement of Need in 1981, remained “closely, and continuously involved with the ATF program” throughout his active duty career.¹⁹ Gen Merrill McPeak, then the Air Force chief of staff, declared in 1994 that the F-22 “is probably the single most important [acquisition] program” in the entire Air Force.²⁰ After retiring, he continued to testify on the need to procure additional F-22s. As a result of this widespread support, other developmental programs such as the A/F-X (a joint Air Force and Navy strike fighter) and the Multirole Fighter (an F-16 replacement) were sacri-

ficed for the F-22 during the Bottom-Up Review (BUR) negotiations.²¹ The F-22 program survived, but the aircraft needed to do more.

Undersecretary of Defense for Acquisition John Deutch was initially undecided on the F-22. He advocated that the initial operational aircraft incorporate an air-to-ground strike capability, enabling the F-22 to eventually replace the F-117.²² In response, the Air Force moved to broaden the F-22's capabilities by formalizing limited air-to-ground strike—a capability under consideration for some time. The modified F-22 design carried two 1,000-pound Joint Direct Attack Munitions (JDAM) guided by the Global Positioning System in its internal weapon bays. Lockheed Martin incorporated this “add-on” capability for the relatively modest sum of \$6.5 million.²³ For the first time, the Air Force had modified the F-22's design to incorporate an additional capability other than air-to-air.

The BUR, released in 1993, further reduced the Air Force's fighter strength to 20 fighter wing equivalents.²⁴ Planned F-22 production also decreased to 442 jets, a roughly proportional cut consistent with the new, smaller force structure. Although disappointed, the Air Force was relieved that the F-22's projected IOC date did not slip further beyond 2003 (since 1991 it had already slipped two years).²⁵

What Is the Threat?

Throughout its history, the primary criticism directed against the F-22 program was that the post-Cold War threat environment did not justify its cost. The 1993 BUR identified the DOD's responsibilities after the Cold War: deter major regional conflict, maintain overseas presence, conduct small-scale intervention operations, and prevent attacks involving weapons of mass destruction.²⁶ Air Force senior leaders continued to focus on advanced airborne threats of the future. They believed that although Russia was less likely to present a direct threat to America, its advanced aircraft (or even Western developmental programs such as the French Rafale) still justified continuation of the F-22 program.²⁷ Additionally, General McPeak established a commitment to

stealth that strongly influenced the Air Force's acquisition policy for the next 20 years: "As we field combat air forces for the future, stealth and precision must be first-order requirements."²⁸ His testimony to Congress provided the most plausible F-22 justification, arguing that the F-15C's replacement must preserve the ability to operate over enemy territory: "If we want to defend United States airspace, the F-15 will work fine. But I do not know where we are going to have to go in the year 2010 and have this fight. What I do know is I want to fight over *his* guys—not over *my* guys—and that is what air superiority means to us, and that is really why we need the F-22" (emphasis in original).²⁹ However, General McPeak also argued that we needed the F-22 for lower-threat environments, noting that Bosnian air operations also justified the aircraft even though pilots did not face advanced threats there.³⁰ The Air Force's support for the F-22 remained consistent and unified, but others were not convinced.

In December 1993, the General Accounting Office (GAO) presented a classified F-22 report to Congress. An unclassified version, along with public testimony, followed in early 1994.³¹ The report assessed the F-15 as superior to projected air threats in four of five performance categories (flight performance, radar, long-range missiles, short-range missiles, and range). Additionally, the report analyzed seven countries whose air forces represented potential threats to future air superiority missions. It concluded that (except for China) each of those air forces possessed between 188 and 460 fighter aircraft, far fewer than the number of US air superiority F-15s in service at that time. Furthermore none of them had more than a handful of advanced fighter aircraft with performance in the F-15's class. Finally, the report predicted that high costs likely would prevent proliferation of these aircraft. In short the GAO recognized that the F-22 greatly improved air superiority capabilities but contended that the F-15 could adequately meet air superiority requirements through at least 2014. Based on this assessment, it recommended that the Air Force delay IOC for seven years.

The service aggressively countered the GAO report, arguing that it underestimated the threat while overestimating the F-15's capabilities. The Air Force's own analysis projected that the F-15 was inferior to the future threat in "range" and "short-range missiles," equal in "radar" and "long-range missiles," and superior only in the "flight-performance" category. Ironically, today's F-22 fails to deliver improved performance in those areas in which the Air Force assessed the F-15 as most deficient: range and short-range missiles.³² Nonetheless, the service reinforced its F-22 argument with thousands of simulations modeling the F-15 against the *Mnogofunksionalni Frontovoy Istrebitel* (Multifunctional Frontline Fighter), a Soviet developmental project that never entered production. Scenarios pitted two F-15s against eight of these fighters, based on the BUR requirement to fight two major regional conflicts simultaneously. According to Air Force models, the F-22 would establish air superiority in seven days while the F-15 needed 22–25 days—and only after experiencing 4.8 times the losses.³³ In effect, the Air Force had defended the F-22 by using its own assumptions about future threats without addressing the GAO's fundamental allegation—the implausibility of the Air Force's threat assumption.

The 1997 Quadrennial Defense Review

Just a year after the BUR, the F-22 program again came under pressure. Deputy Secretary of Defense Deutch sent a memo to the services on 18 August 1994, calling for a review of several major acquisition programs. Deutch himself noted that the reduced threat made the F-22 program vulnerable.³⁴ He asked the Air Force to comment on the possibility of delaying F-22 production by up to four years.³⁵ Shortly afterwards, Lockheed Martin set up a "derivatives team" to explore further expansion of the F-22's mission set.³⁶ The team looked into a suppression of enemy air defenses (SEAD) variant (providing a follow-on capability to the Block 50/52 F-16) and an electronic surveillance version that could collect electronic emissions deep in enemy territory. However, neither of the two variants got off the drawing board, and the derivatives team stood down in 1997 to focus on the original design.³⁷

Nonetheless, the Air Force felt more pressure to demonstrate that the F-22 could fulfill additional requirements. One anonymous congressional staffer remarked, “I hope the Air Force is ready to unveil some new improved, better version.”³⁸ Recognizing that significant design changes were cost prohibitive, the Air Force turned to adapting the baseline F-22 to other missions. For example, *Aviation Week and Space Technology* reported that the F-22 would “collect electronic intercepts and thereby pinpoint the location of enemy headquarters for Navy Tomahawk cruise missile or Army artillery rocket attacks.” Moreover, Air Force officials hinted at a strategic electronic-intelligence collection capability similar to that of the RC-135 Rivet Joint.³⁹ However, these capabilities were not part of the F-22 design criteria, and currently fielded F-22s cannot conduct these missions effectively.⁴⁰

Other examples revealed the Air Force's struggle to defend the F-22. For example, one anonymous Air Force official noted that the F-22 offered “good connectivity with off-board sources, a sensor suite that collects a lot of information on its own, plus an electronically scanned radar that has good sensitivity against low RCS [radar cross section] cruise missiles, and a good combination of missiles.”⁴¹ In fact, upgraded F-15Cs are equal or superior to the F-22 in these areas (except for its sensor suite, where the F-22 enjoys marked superiority). Furthermore, this argument ignored both the F-22's greatest advantage (stealth) and the availability of upgraded F-15Cs years before F-22 IOC at much lower cost.⁴² One finds another example in Gen Ronald Fogleman's defense of the requirement for 442 F-22s, claiming that it would reduce territory lost by 18 percent as well as lower ground casualties by 28 percent and armor losses by 15 percent in future land battles—claims largely undermined by the wars in Iraq, Afghanistan, and Libya.⁴³

Despite the Air Force's objections, the May 1997 QDR imposed further cuts in the planned production of F-22s to 339 aircraft. This QDR noted that, unlike previous reductions which mirrored overall force cuts, a reduction to 339 was “consistent with its much greater capability compared to the F-15, as well as our overall affordability concerns and

force structure decisions.”⁴⁴ The only silver lining was that the Air Force had received a “promise to support production of two wings of F-22 strike aircraft,” which would restore total F-22 production to the 400–500 range—a promise never kept.⁴⁵

Later Engineering, Manufacturing, and Development

By 1996 rising program costs led the assistant secretary of the Air Force for acquisition to charter a joint estimating team (JET) to approximate the program’s future costs and determine ways to control the growth of such expenses. The JET estimated that the EMD would cost \$18.7 billion (this figure does not include \$3.7 billion spent during demonstration/evaluation). Congress subsequently adopted this number to establish an EMD limit in the National Defense Authorization Act for Fiscal Year 1998. It also implemented a \$43.4 billion limit for production.⁴⁶ This marked a significant change for the F-22: a requirements-driven program had now become budget-driven. Under this “buy-to-budget” acquisition strategy, decreased production numbers would fund additional production costs.⁴⁷ Air Force and Lockheed Martin officials initially expressed confidence in their ability to keep costs below the new congressional limits without reducing production. However, expenses continued to rise.

In the wake of the 1997 QDR, the Air Force implemented a new construct for its deployable forces. By 2000 all operational fighter squadrons had been grouped into one of 10 air and space expeditionary forces (AEF) packages that could deploy to meet deterrence, contingency, or war-fighting requirements. Meanwhile, it was becoming clear that producing 339 F-22s would cost significantly more than \$43.4 billion, a situation that demanded a new acquisition strategy to secure additional funding support and stop the erosion of production numbers. The AEF construct became the fundamental justification for F-22 numbers. The Air Force argued that since each AEF had an air superiority F-15C squadron (each including 24 aircraft) assigned to it, the service needed 10 operational F-22 squadrons.⁴⁸ Secretary of the Air Force

James Roche later quantified the exact requirement at 381, after including training, test, and attrition F-22s in the total.⁴⁹ The AEF requirement formed the foundation of the Air Force's F-22 acquisition argument throughout production years.

In 2001 President George W. Bush appointed Donald Rumsfeld secretary of defense with a mandate to reform the DOD. Secretary Rumsfeld used the word *transformation* to describe the process of preparing the department for new and different threats in the post-Cold War world. During early testimony to the House Appropriations Committee, he also made clear the need for recapitalization: "The Tomahawk cruise missile program, the F-15, F-18 and the F-16 aircraft flying today, were developed in the 1970s. . . . Because of the long procurement holiday of the 1990s, we have been left a poor hand. We must resolve to leave a better hand to our successors."⁵⁰ The only question concerned which acquisition programs supported transformation. Even at this early point, Secretary Rumsfeld appeared skeptical about the F-22 program; in fact, he did not mention the Air Force's highest acquisition priority a single time during his testimony.

By late 2004, Secretary Rumsfeld had concluded that additional F-22s did not support his transformation vision, so he sought additional production cuts. Massive cost overruns, combined with a high-profile acquisition scandal involving senior acquisition executive Darleen Druyun, undermined the Air Force's ability to defend the program.⁵¹ Late in 2004, Presidential Budget Directive 753 removed production funding after FY 2008, effectively ending production at 183 F-22s.⁵² The Air Force spent the next five years trying to overturn this decision but ultimately secured support for only four additional F-22s

Performance and Cost

To understand the production limitation of 187 F-22s, one must further examine the aircraft's performance and cost. Simply put, does the F-22's performance meet expectations and, if so, at what cost? In terms of performance, the initial operational test and evaluation in 2004

found the F-22 “overwhelmingly effective.”⁵³ Air Force analysts reinforced this evaluation recently, estimating that the F-22 exchange ratio is up to 30 times better than that for F-15s, F-16s, or F/A-18s in similar high-threat scenarios.⁵⁴ Although fourth-generation pilots are used to “seeing” nonstealth fighters 50 miles or more away with their radars, they typically fail to detect F-22s with their radar, visually or otherwise. Today’s F-22 clearly excels at its originally designed air-to-air mission, reinforcing the fact that stealth enables tremendous advantages in the radar-dominated environment of modern aerial combat.

Further, the F-22 has demonstrated a capability to conduct air-to-ground attack in high-threat environments where fourth-generation fighters simply cannot survive. Advanced surface-to-air-missile systems such as the Russian S-300 (North Atlantic Treaty Organization [NATO] designations SA-10 and SA-20) are the deciding factor in these environments. The S-300, similar to the American Patriot surface-to-air missile, has been operational since 1980. Although no Middle Eastern country currently possesses S-300s, Iran has expressed interest, and both China and Russia have fielded large numbers of them. This system can engage fourth-generation fighters at ranges exceeding 100 miles.⁵⁵ A single S-300 battalion has the potential to render F-15Es, F-16s, and F/A-18s incapable of striking targets within a circle approximately 200 miles across.⁵⁶ Additionally, the follow-on S-400 (NATO designation SA-21) further improves maximum engagement range. Fortunately, F-22s can utilize their stealth to operate effectively well inside the maximum engagement ranges of these systems.⁵⁷

However, F-22 performance is not without shortcomings, the two most substantial of which include limited range and high maintenance requirements. The aircraft’s maximum range is slightly superior to that of the F-16 but significantly inferior to that of the F-15C, which it was designed to replace.⁵⁸ This fact has three important consequences: operational missions need more air-to-air tanker support, the F-22 has a limited ability to deeply penetrate hostile airspace, and pilots cannot take full advantage of the F-22’s supercruise capability. The aircraft has

also proven more difficult to maintain than originally anticipated. The Air Force acknowledged that the F-22's "radar-absorbing metallic skin is the principal cause of its maintenance troubles, with unexpected shortcomings."⁵⁹ The service needs to maintain these coatings continuously to ensure the combat readiness of F-22s, thereby significantly increasing the necessary maintenance manpower (and cost). Moreover, even traditional (non-stealth-related) maintenance rates proved initially higher with the F-22 compared to those of older fighters. However, rates have improved vastly as maintenance personnel have acquired more experience. For example, the mean time between maintenance amounted to .97 flight hours in 2004, but that for newer F-22s has recently increased to 3.22 flight hours.⁶⁰

Another important consideration has to do with specialization. Air-to-air performance demands drove highly specialized requirements, with heavy emphasis on countering advanced airborne threats. This led to a highly specialized design with an integrated avionics architecture that has proven costly to modify in response to evolving needs. Consequently, the F-22 remains inferior to older fourth-generation fighters in some scenarios. For example, the F-22 will never have the capability of an air-to-ground platform like the A-10, F-15E, F-16, or F/A-18 in low-threat environments. Those fighters employ a much wider variety of air-to-ground munitions, can more easily incorporate emerging technologies (e.g., new-generation targeting pods), generally have greater range and loiter time, and are less expensive to procure and operate. These factors, combined with the absence of any airborne threat in Afghanistan, Iraq (since 2003), and Libya, largely explain why the F-22 did not participate in those conflicts. Nonetheless, critics were quick to charge that the F-22 lacked a viable mission when the Air Force's newest fighter didn't deploy to those countries.

In sum the F-22 performs as designed and, for the most part, meets expectations. It is a superb air-to-air fighter whose stealth, advanced avionics, and maneuverability offer immense advantages in modern combat. The aircraft also boasts significant air-to-ground capabilities.

However, the F-22's utility for these missions depends very much on the threat. In the absence of radar-dependent surface threats, it offers no advantage over older fourth-generation aircraft in air-to-ground missions. The next question addresses how much this performance cost.

The F-22 program embraced many leading-edge technologies. It was the first operational air-to-air fighter to incorporate stealth, integrated avionics, thrust vectoring, and supercruise. Congress, especially the House of Representatives, expressed concern about the F-22 from the beginning because members believed that the Air Force had a “highly unrealistic assumption of outyear funding levels.”⁶¹ By 1993 the GAO, Congressional Budget Office (CBO), and Defense Science Board had expressed concern about the discontinuity between the DOD's projected funding levels and projected program costs.⁶² Continuing perturbations due to technical challenges and funding instability forced the Air Force to restructure the F-22 program in 1993, 1994, 1996, and 1997—while developmental cost simultaneously increased by \$5 billion.⁶³

Diminished congressional confidence in the Air Force's ability to control program costs led to the FY 1998 cost caps. When those caps were originally set, near-unanimous consensus existed regarding projected developmental costs among the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG), JET, Air Force, and CBO. All of them estimated the EMD cost at \$18.7 billion and the total research, development, testing, and evaluation (RDT&E) cost at approximately \$22.4 billion.⁶⁴ Unanticipated technical problems that came to light a few years later prevented the four independent estimates from predicting the later cost overruns. By 2007 the cost of total RDT&E had ballooned to approximately \$30.4 billion, about 36 percent more than the FY 1998 congressional limit and 56 percent more than planned at the beginning of EMD.⁶⁵

Unlike forecasts of developmental expenses, estimates of production costs varied widely in 1997. The Air Force had the lowest estimate but still expected production to cost billions more than the \$43.4 billion limit imposed by Congress. The CBO, OSD CAIG, and JET predicted

higher production costs although all estimates were lower than the actual costs.⁶⁶ The author could find no explanation for why Congress set the production cap at \$43.4 billion, a level inadequate to fund 339 F-22s under the best of circumstances. By FY 2009, Congress had adjusted the original \$43.4 billion production limit to \$37.6 billion since inflation was in fact lower than assumed in the original FY 1998 legislation.⁶⁷ As production drew to a close, an estimate for the total cost for mass producing 179 aircraft (EMD money funded eight “preproduction” aircraft conforming to production standards) came to \$34.1 billion—about 90 percent of the total allocated for 339 F-22s in the FY 1998 legislation. The F-22’s APUC was \$191.6 million—56 percent higher than the \$122.8 million planned at the beginning of EMD.⁶⁸

Figure 3 compares these cost performance numbers to those of other fighter developmental programs. It depicts the total growth of program cost throughout EMD (except for the F-35, which will not complete EMD for many years) and demonstrates that despite the F-22’s unprecedented cost increases, they remained roughly consistent with those of other cutting-edge technology defense programs. For example, F-14 program costs increased 45 percent during its EMD.⁶⁹ Furthermore, since beginning EMD, the F-35 program has experienced a 58 percent growth in the cost of RDT&E and an 81 percent growth in projected APUC, already exceeding the total growth of the F-22 program.⁷⁰ Since the F-35 EMD will continue for many years, additional developmental problems (and cost increases) will almost certainly emerge. Nonetheless, total planned production thus far has been only modestly affected because the Air Force, Navy, and Marines (along with the services of several partner nations) desperately need the F-35 to recapitalize thousands of aging fighters. Thus, the F-22’s cost overruns, though substantial, were not the primary factor in curtailing production.

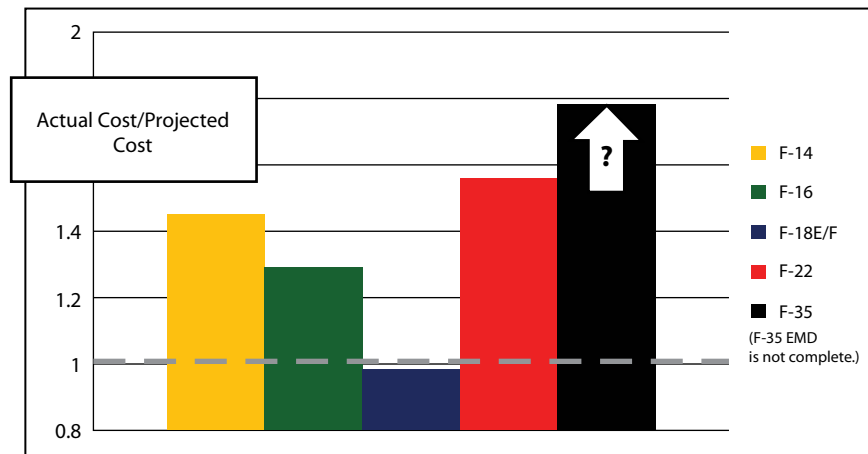


Figure 3. Cost increase during engineering, manufacturing, and development. (Cost data for the F-14, F-16, and F/A-18E/F from Obaid Younossi et al., *Lessons Learned from the F/A-22 and F/A-18E/F Development Programs* [Santa Monica, CA: RAND, 2005], 10, http://www.rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG276.pdf.)

Why 187?

The ATF was designed for a specific mission—countering the Soviet Union’s advanced fighter aircraft. The dissolution of that state effectively eliminated this threat and simultaneously undermined the Air Force’s threat-based argument. The service continued to argue vigorously that fighting large numbers of advanced fighters remained a valid requirement, even as the post-Soviet development of Russian advanced fighters slowed to a crawl. The failure of potential adversaries such as Iraq, North Korea, or Iran to acquire significant numbers of advanced air-to-air fighters further undermined the Air Force’s argument.

Against this backdrop, two factors further weakened the service’s position. First, as described in the earlier historical analysis, Air Force officials made overly optimistic claims about F-22 capabilities. Although intended to convince congressional and DOD skeptics that the F-22 was a good investment, these claims significantly damaged the Air

Force's credibility and ultimately limited its ability to defend the program. Second, the Air Force (and Lockheed Martin) repeatedly demonstrated that they could not accurately predict the program's total cost or timeline—a fact made clear by multiple cost overruns and program restructurings. By the late 1990s, these factors, in combination with a limited air-to-air threat, exacerbated the Air Force's difficulty in securing additional program funding. However, the F-22 retained strong congressional support, particularly from those districts and states directly involved with production. The FY 1998 cost caps enabled Congress to limit total expenditures without alienating these influential constituencies.

In 2003 planned production decreased to 276 under the FY 1998 program's cost caps as cost overruns continued to mount. The AEF argument proved no more effective than the threat-based one from the decade prior; therefore, the cost cap remained the de facto limit. Clearly, Congress could have repealed the production cap (as it had done with the developmental cap in FY 2002) but did not support additional production. In the end, the Air Force could not have fought harder for the F-22: the dogmatic support for the program by General Moseley and Secretary of the Air Force Michael Wynne evidently played a key role in their unprecedented dismissal.⁷¹

Primarily, the Air Force acquired only 187 F-22s because they were both too expensive *and* too specialized. The aircraft could have executed combat missions any time after attaining IOC in 2005, but the nation simply did not need its unique capabilities in those conflicts. Since becoming operational, the F-22 has conducted only deterrence deployments and homeland defense intercepts—missions hardly worthy of its unmatched prowess and cost. Meanwhile, F-15Es, F-16s, F/A-18s, and A-10s continued to prove their utility, flying combat in Iraq, Afghanistan, and Libya. Furthermore, F-15Cs updated with new, advanced radars, avionics, and weapons remain competitive with all air-to-air platforms currently fielded by potential adversaries.

As production began to wind down, the Air Force could not convince Congress to raise total program funding, despite the exceptional performance demonstrated by the F-22. Figure 4 depicts how decreased production (after the 1997 QDR) offset increased developmental and production costs, keeping total outlay under the FY 1998 cap. In the end, the Air Force fielded just 25 percent of the F-22s originally planned and less than half of its long-standing requirement of 381. The service must consider this disparity between required and actual production numbers in future acquisition programs.

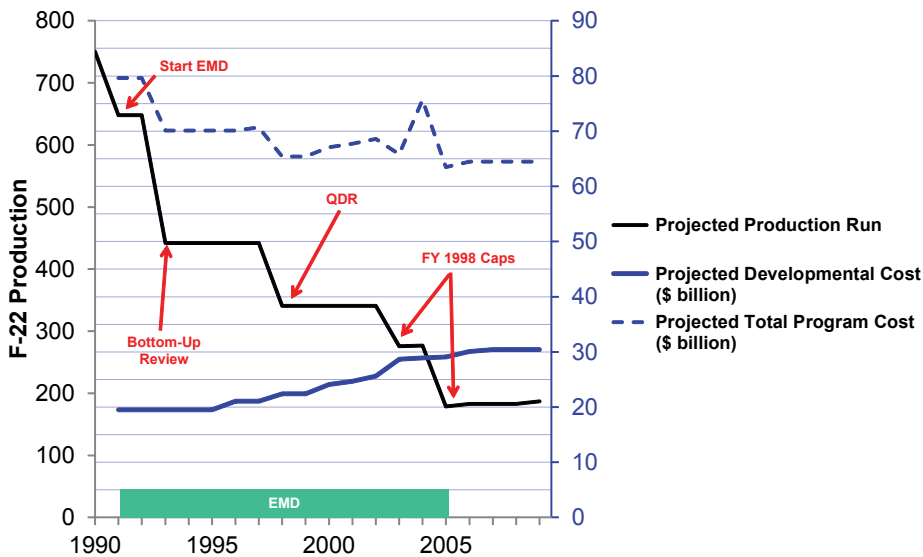


Figure 4. Cost versus production.

Alternative Possibilities

The F-22 acquisition program adversely affected recapitalization of the fighter fleet in two ways. First, 187 F-22s cannot recapitalize the entire air superiority F-15 fleet as originally planned; F-15Cs will need to remain in service for many years to supplement the F-22s.⁷² Second, and more significantly, the Air Force delayed multirole, close air support, and SEAD fighter recapitalization during the F-22 acquisition. As

a consequence, today's average age for Air Force fighters is twice the historical norms, and the service will not field significant numbers of new fighter aircraft for many years. Could the Air Force have avoided this predicament? It missed two key opportunities. First, the Air Force could have delayed the start of EMD, reassessed ATF requirements, and modified the F-22 design to broaden its capabilities. Second, it could have acquired additional fourth-generation aircraft to mitigate developmental risk with the F-35.

Delaying Engineering, Manufacturing, and Development

By the time the Air Force had awarded the F-22 EMD contracts in August 1991, two world events plainly indicated that the overly specialized ATF deserved reconsideration. First, demonstrations from the Baltic States to the Caucasus in the late 1980s began to reveal cracks in the Soviet Union's foundation. In October 1989, Mikhail Gorbachev formally announced a policy of nonintervention in the Warsaw Pact nations, effectively freeing them from Soviet influence. By the time Secretary Rice announced that the YF-22 had won the demonstration/evaluation competition in April 1991, the former Soviet Socialist Republics of Lithuania, Latvia, and Georgia had already declared independence. Although the Soviet Union formally existed until December 1991, it had already become evident that the presumed source of future air superiority threats was imploding. Based on these events, Secretary of Defense Dick Cheney ordered a review in January 1990 to reassess acquisition requirements and presented the Air Force with an opportunity to adapt the ATF program to the emerging post-Cold War reality. However, the service defended the program as planned.⁷³

The second event, the Gulf War of 1991, represented the first mass-on-mass US conventional military conflict in 40 years. F-15Cs achieved an extraordinary 31-to-0 exchange ratio in air-to-air combat.⁷⁴ Furthermore, this victory involved only 28 percent of the entire air superiority fleet of the US Air Force. Attack, multirole, and SEAD assets were more heavily stressed during this operation.⁷⁵ Although overall losses

proved lower than anticipated, older-generation Iraqi air defense systems managed to down 13 of the US Air Force's aircraft. The service lost no aircraft to airborne threats.⁷⁶ These facts should have made evident two very important realities: (1) fielded Air Force air-to-air fighters were quite capable of meeting near-term air superiority needs, and (2) surface-based weapons rather than airborne fighters were emerging as the primary threat to the United States' future offensive air operations. The Air Force did not draw these conclusions, subsequently issuing the EMD contract in August 1991 without any modification to requirements.⁷⁷

If the service's leaders had realized that surface-to-air-missile systems were eclipsing air-to-air threats as the primary danger to future air operations, they could have better leveraged the investment in ATF demonstration/evaluation to counter weapons like the S-300. The ATF's stealth made the aircraft inherently more survivable against these threats, but it lacked a robust air-to-ground attack capability to target them. Furthermore, niche air-to-air capabilities such as thrust vectoring and some specialized avionics could have been eliminated to reduce cost and weight. Range should have received more emphasis, possibly even at the expense of supercruise. In addition to JDAMs, the Air Force should have added air-to-ground radar, Link-16 data-link transmit capability, and an infrared targeting sensor. These modifications would have greatly enhanced the F-22's utility in threat environments dominated by surface threats without degrading air-to-air performance.

Any delay can seriously damage an acquisition program: costs increase, and the program might be killed outright. Undoubtedly, the Air Force knew this, and it may have used this fact in its decision to continue the program as originally planned. However, barring cancellation of the program, the Air Force could have better defended a less specialized F-22 and probably could have acquired more than 187. Although the JDAM was incorporated relatively easily, other upgrades took much longer; indeed, the Air Force began fielding air-to-ground

radar (enabling the F-22 to locate ground targets autonomously) and the small-diameter bomb in late 2011. Unfortunately, the Air Force has found it impossible to add an air-to-ground infrared sensor or rectify the F-22's limited range.

Continuing Fourth-Generation Procurement

Only a handful of fourth-generation F-15Es and F-16s were delivered after 1992, serving primarily to keep production lines open for future foreign sales. Although the GAO and members of Congress repeatedly urged the Air Force to consider acquiring additional fourth-generation fighter aircraft, the service has steadfastly concentrated on F-22s and F-35s for the last two decades.⁷⁸ By 2012 the results of this fifth-generation fighter acquisition policy had become clear: the Air Force has fielded 187 F-22s while the fighter fleet's average age has simultaneously grown to more than twice the historical average. Even if additional F-22 production proved feasible, it could not meet greater requirements for fighter recapitalization. First, the F-22's cost (APUC of \$191.6 million) virtually guarantees that the service cannot acquire it in sufficient numbers to address the increased need. More importantly, the F-22 is simply too specialized; it cannot execute interdiction, time-sensitive targeting, close air support, or SEAD missions as effectively as older fourth-generation aircraft. Today, the Air Force plans to recapitalize 1,770 aging F-15Es, F-16s, and A-10s entirely via the F-35 program.

Commenting on the F-35 in 2003, Air Force Chief of Staff John Jumper said, "I can guarantee you I'm going . . . to make damn sure that we don't fall into some of the early developmental traps that we fell in with the F/A-22."⁷⁹ Unfortunately, the F-35 has experienced many of the same problems. For example, Senator John McCain (R-AZ) identified concurrent development, which describes overlap between the development phase and mass production, as the leading cause of the F-35's developmental cost overruns.⁸⁰ However, concurrency issues were not new: a 1995 GAO report highlighted concurrency in the F-22 program as a major developmental risk.⁸¹ Massive cost overruns that

emerged in 2002 due to unanticipated avionics and structural problems validated those concerns. Today, concurrency issues are the primary reason that F-35 cost overruns have recently accelerated, with projected APUC increasing 17 percent from \$113.6 million to \$132.8 million in just one year. The total F-35 cost overruns experienced since EMD began in 2001 now exceed those that occurred in the F-22 program from the start of EMD through the end of production.⁸²

More importantly, the F-35 is years behind schedule, and Air Force IOC will not occur until at least 2018.⁸³ Consequently, the service recently announced that it must invest in a service-life extension program for the F-16. Finally, further delays and cost overruns are likely; the F-35 EMD is years from completion; and Secretary of Defense Leon Panetta recently announced another delay in the F-35's development and acquisition timelines.⁸⁴ The feasibility of an all-fifth-generation fighter fleet remains uncertain.

The Air Force should not have been surprised by these program cost overruns and schedule delays, given its F-22 experience and the program's similarity to the F-35. That is, both are fifth-generation fighters; both are made by Lockheed Martin; and both planned high levels of concurrent development. Responding to a question about purchasing updated fourth-generation fighters in 2009 after significant F-35 developmental problems had come to light, Gen Richard Hawley (retired commander of Air Combat Command) testified that "if we had addressed this question 10 or 15 years ago, the answer might be yes."⁸⁵ However, he had testified 18 years earlier that (even upgraded) fourth-generation aircraft could not meet future requirements.⁸⁶ This appears to confirm that Air Force senior leaders were surprised by the F-35's developmental problems, but they probably also viewed additional fourth-generation fighter acquisition as a direct threat to fifth-generation fighter programs.⁸⁷ Regardless, the Air Force failed to implement the only solution that could have eased today's recapitalization problems—acquiring additional fourth-generation fighters.

The Navy's F/A-18E/F Super Hornet program ran concurrently with the F-22. Unlike the F-22, the F/A-18E/F was not designed to counter any specific threat. Rather, it addressed shortcomings of the original F/A-18, namely limited range and limited ability to carry unexpended ordnance back to the ship.⁸⁸ This was a much less ambitious developmental program than the F-22, lacking stealth, supercruise, or thrust vectoring. Low developmental risk contributed to completion of the F/A-18E/F very nearly on time and on budget.⁸⁹ As of 2008, the Navy's total program cost amounted to \$46.3 billion for 493 F/A-18E/Fs (\$93.9 million per jet) while the Air Force's total program cost came to \$64.5 billion for 184 F-22s (\$350.5 million per jet).⁹⁰ In other words, the Navy is buying 3.73 Super Hornets for the cost of a single F-22.

Because the Navy did not develop the F/A-18E/F to counter any specific threat, it effectively defended procurement based solely on recapitalization needs. Simply put, old airplanes must be replaced. Although aircraft in the Navy's fighter fleet are an average of seven years younger than those in the Air Force, the Navy is recapitalizing its fleet much more rapidly.⁹¹ The Navy also uses F/A-18E/F acquisition to mitigate continuing F-35 developmental risk with 563 Super Hornets currently planned through FY 2014—and possibly more.⁹² The Russians and Chinese adopted a similar strategy with the Su-27 fighter. The Su-30MKK and F-11 combine the basic Su-27 airframe with updated avionics and weapons. These Chinese aircraft represent the most capable potential adversaries for the Air Force, and officials have frequently cited them as justification for additional F-22 production.

Conclusion

The ATF's overly specialized design constituted a fundamental flaw in the uncertain post-Cold War environment. The Air Force subsequently missed the best opportunity to adapt the F-22 when it issued the EMD contract without modification to ATF requirements. Throughout EMD, the service remained overly focused on the F-22 at the expense of A-10, F-15E, and F-16 recapitalization. When acquisition even-

tually shifted to the F-35, the Air Force largely ignored its F-22 experience and failed to plan for inevitable developmental problems with the F-35. Despite massive cost overruns and schedule delays, the Air Force continues to hope that the F-35 can solely recapitalize 1,770 aging F-15Es, F-16s, and A-10s. However, continuing developmental problems and the emerging national fiscal crisis threaten to undermine this strategy.

Although stealth is a powerful enabler for offensive systems, its greatest advantage lies in its ability to dramatically increase aircraft survivability against radar-dependent threats. Consequently, stealth's utility depends on the presence of those threats. By insisting on acquiring only stealth fighters (regardless of the cost), the Air Force assumes that future adversaries will not counter stealth technology and ignores the fact that many air combat operations continue to occur in low-threat environments. For example, allied fourth-generation fighters operated freely over large portions of Iraq (both in 1991 and 2003), Serbia, and Libya from the beginning of those conflicts. Future hostilities likely will continue this long-standing historical trend, and currently fielded stealth assets can mitigate risk to operations in high-threat environments where fourth-generation fighters are most vulnerable.

An all-stealth Air Force fighter fleet deserves reconsideration even today. Stealth technology demands significant trade-offs in range, security, weapons carriage, sortie generation, and adaptability. Stealth provides no advantage in conflicts such as those in Afghanistan or Iraq (since 2003), and (despite its obvious utility) it cannot guarantee success in future struggles with a near-peer adversary. Most importantly, the cost of F-22s and F-35s threatens to reduce the size of the Air Force's fielded fighter fleet to dangerously small numbers, particularly in the current fiscal environment. These facts suggest that the Air Force should reconsider its long-standing position that fifth-generation fighters are the only option for recapitalizing its fighter fleet. ★

Notes

1. Department of Defense, *Quadrennial Defense Review Report* (Washington, DC: Department of Defense, February 2010), 47, http://www.defense.gov/qdr/images/QDR_as_of_12Feb10_1000.pdf. A fighter wing equivalent is defined as 72 primary-mission aircraft designated for operational combat use, not including aircraft utilized for testing, training, and attrition reserve.
2. Senate, "Air Force Tactical Aircraft Programs," *Statement of Lt Gen Herbert J. Carlisle, USAF Deputy Chief of Staff, Operations, Plans, and Requirements, Department of the Air Force, to the Committee on Armed Services, Airland Subcommittee*, 112th Cong., 1st sess., 24 May 2011, 4, <http://armed-services.senate.gov/statemnt/2011/05%20May/Carlisle%2005-24-11.pdf>.
3. "Air Force Gen. T. Michael Moseley Transcript, Part One" [interview by Timothy Clark], *Government Executive*, 31 October 2007, <http://www.govexec.com/dailyfed/1007/103107gg1.htm>.
4. One hundred seventy-nine F-22s were built and funded through production monies, beginning with number 17. Earlier, 16 F-22s were built for dedicated test and evaluation purposes, but only eight of those were "production-representative." Throughout, the article refers to 187 total F-22s produced, including both "production" and "production-representative" aircraft.
5. General Accounting Office, *The Advanced Tactical Fighter's Costs, Schedule, and Performance Goals* (Washington, DC: General Accounting Office, January 1988), 15, <http://www.gao.gov/assets/150/146085.pdf>.
6. Bill Sweetman, *F-22 Raptor* (Osceola, WI: MBI Publishing Company, 1998), 10–11.
7. "Donald Rice Declares YF-22/YF119 a Winner in ATF Contest," *You Tube*, video file, 23 April 1991, <http://www.youtube.com/watch?v=9kR9aTZ9W3s>.
8. David F. Bond, "Risk, Cost Sway Airframe, Engine Choices for ATF," *Aviation Week and Space Technology* 134, no. 17 (29 April 1991). (All references to *Aviation Week and Space Technology* are derived from the LexisNexis Academic database.)
9. Sweetman, *F-22 Raptor*, 27.
10. Kevin N. Lewis, *Downsizing Future USAF Fighter Forces: Living within the Constraints of History* (Santa Monica, CA: RAND, 1995), 21–22, http://www.rand.org/pubs/monograph_reports/2006/MR480.pdf.
11. General Accounting Office, *F-15 Replacement Is Premature as Currently Planned* (Washington, DC: General Accounting Office, March 1994), 1, <http://www.gao.gov/assets/220/219340.pdf>. "Then-year" dollars represent the estimated cost as paid throughout program execution. All figures are then-year dollars unless otherwise noted and are rounded to one decimal place.
12. Senate, *Statement of Cindy Williams, Assistant Director, National Security Division, Congressional Budget Office, on Modernizing Tactical Aircraft, before the Subcommittee on Airland Forces, Committee on Armed Services*, 105th Cong., 1st sess., 16 April 1997, 12, <http://www.cbo.gov/ftpdocs/42xx/doc4295/1997doc20-Entire.pdf>.
13. General Accounting Office, *Changing Conditions Drive Need for New F/A-22 Business Case* (Washington, DC: General Accounting Office, March 2004), 6, <http://www.gao.gov/assets/250/241714.pdf>. APUC represents the total procurement cost divided by the number procured. It does not include research and development (including "preproduction" test aircraft) or facility construction. Procurement acquisition unit cost (PAUC) represents the en-

tire program's cost, including all research and development, program-specific support equipment, facility construction, and initial spare parts, divided by the number procured. Here APUC is calculated by dividing the production cost estimate by 648.

14. Eric V. Larson, David T. Orletsky, and Kristin Leuschner, *Defense Planning in a Decade of Change: Lessons from the Base Force, Bottom-Up Review and Quadrennial Defense Review* (Santa Monica, CA: RAND, 2001), 97, http://www.rand.org/content/dam/rand/pubs/monograph_reports/2007/MR1387.pdf; and House, *Statement of Lane Pierrot, Senior Analyst, National Security Division, Congressional Budget Office, on Aging Military Equipment, before the Subcommittee on Military Procurement, Committee on Armed Services, 106th Cong., 1st sess., 24 February 1999, 11*, <http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/10xx/doc1096/022499.pdf>.

15. John D. Morrocco, "U.S. Uses Gulf War to Frame New Strategy," *Aviation Week and Space Technology* 140, no. 3 (17 January 1994).

16. Air Force Personnel Center, accessed 12 September 2012, <http://www.afpc.af.mil/>.

17. Larson, Orletsky, and Leuschner, *Defense Planning*, 39.

18. General Accounting Office, *Status of the Air Force's Efforts to Replace the A-10 Aircraft* (Washington, DC: General Accounting Office, September 1988), 19, <http://www.gao.gov/assets/150/146941.pdf>.

19. Michael D. Williams, *Acquisition for the 21st Century: The F-22 Development Program* (Washington, DC: National Defense University Press, 1999), 111, <http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA421919>.

20. John D. Morrocco, "McPeak Sees Alternatives to Modernization Cuts," *Aviation Week and Space Technology* 141, no. 13 (26 September 1994).

21. Larson, Orletsky, and Leuschner, *Defense Planning*, 57. The A/F-X and Multirole Fighter technologies were rolled into the Joint Attack Strike Technology program, which in turn became the Joint Strike Fighter.

22. David A. Fulghum, "Pentagon to Kill A/F-X, Retain F-22," *Aviation Week and Space Technology* 138, no. 24 (14 June 1993). At Holloman AFB, New Mexico, F-22s replaced F-117s when the latter were retired in 2008.

23. John D. Morrocco, "F-22 to Have Limited Ground Attack Capability," *Aviation Week and Space Technology* 138, no. 22 (31 May 1993).

24. Department of Defense, *Report on the Bottom-Up Review* (Washington, DC: Department of Defense, October 1993), 28.

25. Fulghum, "Pentagon to Kill A/F-X."

26. Larson, Orletsky, and Leuschner, *Defense Planning*, 46.

27. David A. Fulghum, "Cost, Mission Disputes Jeopardize F-22," *Aviation Week and Space Technology* 140, no. 14 (4 April 1994); and David A. Fulghum, "Big F-22 Budget Drives Search for Flaws," *Aviation Week and Space Technology* 142, no. 15 (10 April 1995).

28. Merrill A. McPeak, *Selected Works, 1990-1994* (Maxwell AFB, AL: Air University Press, 1995), 224, http://ebooks.gutenberg.us/AU_Press_Collection/Books/McPeak/McPeak.pdf.

29. *Ibid.*, 142.

30. Morrocco, "U.S. Uses Gulf War." According to General McPeak, "So for me the F-22 makes sense whether we have to fight the Russians or police Bosnian airspace or whatever" (*ibid.*).

31. General Accounting Office, *F-15 Replacement Is Premature*, 5.

32. Obaid Younossi et al., *Lessons Learned from the F/A-22 and F/A-18E/F Development Programs* (Santa Monica, CA: RAND, 2005), 4, http://www.rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG276.pdf. Presently the F-22 can employ only older AIM-9M missiles rather than the newer AIM-9Xs (already fielded on F-15s and F-16s).
33. Fulghum, "Cost, Mission Disputes."
34. John D. Morrocco, "Lockheed Says Delay Would Hike F-22 Cost," *Aviation Week and Space Technology* 141, no. 9 (29 August 1994): 24.
35. David A. Fulghum and John D. Morrocco, "Deutch Demands Cuts, Services Scramble Anew," *Aviation Week and Space Technology* 141, no. 9 (29 August 1994).
36. Morrocco, "Lockheed Says," 24.
37. David A. Fulghum, "Expanding Roles May Shield F-22," *Aviation Week and Space Technology* 146, no. 1 (6 January 1997).
38. Ibid.
39. Ibid.
40. Assessments of actual capabilities are based on the author's experience as an F-22 pilot since 2002.
41. Fulghum, "Expanding Roles."
42. The author is referring to 18 F-15Cs fielded in 2000 with upgraded APG-63V2 radars, having very similar capability to the F-22's APG-77. Additional F-15Cs are being upgraded with the newer APG-63V3.
43. Fulghum, "Big F-22 Budget Drives."
44. William S. Cohen, *Report of the Quadrennial Defense Review* (Washington, DC: Department of Defense, May 1997), [79], http://hawk.ethz.ch/serviceengine/Files/ISN/32542/ipublicationdocument_singledocument/904a2c94-8ef7-4098-8b03-2edfc4b992aa/en/qdr97.pdf.
45. David A. Fulghum, "Critics Vow to Fight over Joint-STARS Cut," *Aviation Week and Space Technology* 146, no. 25 (16 June 1997).
46. Ronald O'Rourke, *Air Force F-22 Fighter Program: Background and Issues for Congress*, CRS Report for Congress (Washington, DC: Congressional Research Service, 16 July 2009), 9, http://www.policyarchive.org/handle/10207/bitstreams/1574_Previous_Version_2009-07-16.pdf.
47. Christopher Bolkom, *F-22A Raptor*, CRS Report for Congress (Washington, DC: Congressional Research Service, 5 March 2009), 6, <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA496273>.
48. Robert Wall, "USAF Readies Strategy for Increased F-22 Buy," *Aviation Week and Space Technology* 153, no. 21 (20 November 2000).
49. David A. Fulghum, "Roche on Warpath," *Aviation Week and Space Technology* 158, no. 9 (3 March 2003).
50. Secretary of Defense Donald H. Rumsfeld, "Testimony Prepared for Delivery on the 2002 Defense Department Amended Budget to the House Appropriations Committee," 16 July 2001, <http://www.defense.gov/speeches/speech.aspx?speechid=405>.
51. Leslie Wayne, "Air Force Campaigns to Save Jet Fighter," *New York Times*, 13 January 2005, <http://www.nytimes.com/2005/01/13/business/13fighter.html>.
52. Amy Butler and David A. Fulghum, "SIT DOWN: Is Silence Golden? Not for the Pentagon, Say Critics, Who Accuse Civilian Leaders of Quashing Dissent," *Aviation Week and Space Technology* 162, no. 1 (2 January 2005).

53. Government Accountability Office, *Air Force Still Needs Business Case to Support F/A-22 Quantities and Increased Capabilities* (Washington, DC: Government Accountability Office, March 2005), 3, <http://www.gao.gov/assets/250/245641.pdf>.

54. David A. Fulghum, "Raptor's Edge," *Aviation Week and Space Technology* 170, no. 6 (9 February 2009). Exchange ratio refers to the number of enemy aircraft shot down for each loss of a friendly fighter.

55. S-300/Favorit (SA-10 "Grumble" / SA-20 "Gargoyle"), Jane's Defense and Equipment Technology, 23 December 2011, <http://jdet.janes.com>.

56. The F-15E, a multirole version of the air-to-air F-15C, retains most of the F-15C's air-to-air capabilities although it is heavier and less maneuverable. The Air Force uses the F-15E primarily for air-to-ground missions.

57. Fulghum, "Raptor's Edge."

58. Younossi et al., *Lessons Learned*, 4. This is an assessment of each aircraft's maximum range during subsonic cruise. Although the F-22 is more efficient than the F-15 or F-16 at supersonic speeds, supersonic flight significantly reduces the range of all three aircraft.

59. "Response to F-22 Washington Post Article by Jeff Smith," 10 July 2009, [1], http://hatch.senate.gov/public/_files/USAFResponse.pdf.

60. Michael Bruno and Warwick Graham, "Mulled to Death," *Aviation Week and Space Technology* 171, no. 4 (27 July 2009).

61. Younossi et al., *Lessons Learned*, 60.

62. Larson, Orletsky, and Leuschner, *Defense Planning*, 34–35.

63. Robert Wall, "F-22 Software, Cost Scrutinized," *Aviation Week and Space Technology* 152, no. 3 (17 January 2000).

64. Senate, *Statement of Cindy Williams*, 12. The JET EMD estimate (\$18.7 billion) added to developmental/evaluation costs (\$3.7 billion) equals \$22.4 billion. The CBO and OSD CAIG estimated it slightly higher at \$22.5 billion.

65. Gertler, *F-22 Fighter Program*, 9.

66. Senate, *Statement of Cindy Williams*, 12. Their respective estimates for production of 339 aircraft were as follows: Air Force (\$48.3 billion), CBO (\$65.7 billion), OSD CAIG (\$64.4 billion), and JET (\$61.2 billion). Interestingly, the CBO, OSD CAIG, and JET estimates from 1997 were within 10 percent of the actual APUC.

67. Gertler, *F-22 Fighter Program*, 10.

68. *Ibid.*, 9.

69. Younossi et al., *Lessons Learned*, 10.

70. Department of Defense Selected Acquisition Report, *F-35 as of December 31, 2010*, 4, 15, <http://www.fas.org/man/eprint/F-35-SAR.pdf>. Figure 3 depicts 78 percent growth in the projected F-35 PAUC as reported in this selected acquisition report. For additional F-35 reports from 1996 through 2007, see http://www.dod.mil/pubs/foi/logistics_material_readiness/acq_bud_fin/09-F-1079_JSF_SARS_1996_Present.pdf.

71. Amy Butler, "Empty Nest," *Aviation Week and Space Technology* 173, no. 45 (19 December 2011): 61.

72. The Air Force maintains three operational active duty squadrons of F-15Cs although the Air National Guard now operates most of them.

73. David C. Aronstein, Michael J. Hirschberg, and Albert C. Piccirillo, *Advanced Tactical Fighter to F-22 Raptor: Origins of the 21st Century Air Dominance Fighter* (Reston, VA: American Institute of Aeronautics and Astronautics, 1998), 157.

74. General Accounting Office, *F-15 Replacement Is Premature*, 2. F-15s shot down 31 of the 33 Iraqi fighters downed during the Gulf War, and the worldwide F-15 fleet has a 104-to-0 record in air-to-air combat.

75. Lewis, *Downsizing Future USAF Fighter Forces*, 88. Twenty-eight percent of the US Air Force's air superiority fighter fleet deployed to Operation Desert Storm versus 63 percent of long-range attack, 41 percent of attack, 35 percent of multirole, and 57 percent of SEAD fleets.

76. Dr. Daniel L. Haulman, *USAF Manned Aircraft Combat Losses, 1990–2002* (Maxwell AFB, AL: Air Force Historical Research Agency, 9 December 2002), <http://www.afhra.af.mil/shared/media/document/AFD-070912-043.pdf>. Some evidence indicates that a US Navy F/A-18 was shot down by an Iraqi MiG-25 during the first Gulf War, but no official determination has been made, and evidence remains inconclusive. This is the only possible US loss in air-to-air combat since the Vietnam War.

77. Aronstein, Hirschberg, and Piccirillo, *Advanced Tactical Fighter*, 157–58.

78. Government Accountability Office, *DOD's Ability to Meet Future Requirements Is Uncertain, with Key Analyses Needed to Inform Upcoming Investment Decisions* (Washington, DC: Government Accountability Office, July 2010), 27, <http://www.gao.gov/assets/310/308236.pdf>.

79. David Bond, "Health of Stealth," *Aviation Week and Space Technology* 158, no. 9 (3 March 2003): 21.

80. "Floor Statement by Senator John McCain on the F-35 Joint Strike Fighter Program," website of Senator John McCain, Arizona, 5 December 2011, http://mccain.senate.gov/public/index.cfm?FuseAction=PressOffice.FloorStatements&ContentRecord_id=0FDCC4CC-EA5C-882C-25A3-DE5218AACB05. Senator McCain described excessive concurrency as "the grand, enormously expensive lesson of the Joint Strike Fighter program" (ibid.).

81. General Accounting Office, *Concurrency in Development and Production of F-22 Aircraft Should Be Reduced* (Washington, DC: General Accounting Office, April 1995), 2, <http://www.gao.gov/assets/230/221075.pdf>.

82. For the F-35 costs identified in this paragraph, see Department of Defense Selected Acquisition Report, *F-35 as of December 31, 2010*, 4, 15, 38. F-22 developmental cost and APUC both increased 56 percent from 1991 through 2007. The F-35 has already experienced 58 percent developmental and 81 percent APUC cost increases (compared to the 2001 baseline). However, at \$125.2 million (APUC), the Air Force variant will be slightly less expensive than the other F-35 variants, compared to the overall program average of \$132.8 million (APUC).

83. Senate, "Air Force Tactical Aircraft Programs," 9.

84. Christopher Drew, "Military Contractors Brace for Cutbacks," *New York Times*, 26 January 2012, <http://www.nytimes.com/2012/01/27/business/military-contractors-brace-for-cutbacks.html>.

85. Senate, *Hearing to Receive Testimony on the Current and Future Roles, Missions, and Capabilities of U.S. Military Air Power, Subcommittee on Airland, Committee on Armed Services*, 111th Cong., 1st sess., 30 April 2009, 27, <http://armed-services.senate.gov/Transcripts/2009/04%20April/Airland/09-24%20-%204-30-09.pdf>.

86. Bond, "Risk, Cost Sway Airframe."

87. Robert Wall and David A. Fulghum, "USAF Reviews Plans for JSF, F-22, and U-2," *Aviation Week and Space Technology* 156, no. 19 (13 May 2002).

88. Younossi et al., *Lessons Learned*, 2. By the 1980s, the Navy had concluded that it did not need to counter the enemy aircraft threat with a dedicated air-to-air fighter; thus, the Navy replaced the F-14 with the multirole F/A-18E/F.

89. *Ibid.*, 5. The F/A-18E/F program actually cost 2 percent less than forecast at the beginning of EMD.

90. "DOD Selected Acquisition Reports (SAR) Program Acquisition Cost Summary as of June 30, 2008," *Aerospace Daily and Defense Report*, 20 August 2008.

91. Congressional Budget Office, *Alternatives for Modernizing U.S. Fighter Forces* (Washington, DC: Congressional Budget Office, May 2009), 12, <http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/101xx/doc10113/05-13-fighterforces.pdf>.

92. US Navy designations: F/A-18E, F/A-18F, and EA-18G Growler. Jane's Defense and Equipment Technology, 13 June 2011, <http://jdet.janes.com>. The F/A-18E/F number does not include the "Growler" electronic combat variant.



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Lieutenant Colonel Niemi (BSME, MSME, Georgia Institute of Technology) served as an F-15E mission commander during Operations Allied Force and Northern Watch. In 2002 he transitioned to the F-22 and has since served in test, training, and operational units, most recently as squadron commander of the 525th Fighter Squadron in Alaska. Lieutenant Colonel Niemi is a graduate of the US Air Force Weapons School, the Army Command and General Staff College, and the George C. Marshall European Center for Security Studies, where he was a Marshall Center Fellow.

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