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Sustaining America's Strategic Advantage in Long-Range Strike

MARK A. GUNZINGER

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About the Author

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A retired Air Force Colonel and Command Pilot with over three thousand flight hours, he joined the Office of the Secretary of Defense in 2004, serving OSD/Policy as Director of Resources. He was appointed to the Senior Executive Service and served as Principal Director of the Department's central staff for the 2005–2006 QDR.

Following the 2006 QDR, he was appointed Director for Defense Transformation, Force Planning and Resources on the National Security Council staff where he championed defense priorities at the national level and played a major role in shaping the 2007 "surge" of US forces in Iraq.

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EXECUTIVE SUMMARY

The ability to conduct long-range strike operations has long provided the United States with a decisive military advantage over its enemies. Today, that advantage is dissipating. Despite the crucial role long-range strike capabilities have played in our nation's wars over the last seventy years, it is unclear whether the United States will make the investments needed to sustain this advantage in the future. Chronic underinvestment in the US military's long-range strike "family of systems"—land-based bombers, carrier-based strike aircraft, cruise missiles and supporting airborne electronic attack platforms—combined with the creeping obsolescence of current systems could lead to a future force that is relegated to fighting on the periphery and cannot effectively penetrate anti-access/area-denial (A2/AD) battle networks. Considering the time that is required to develop and field new weapon systems, if the next defense budget continues to defer needed long-range strike investments, a gap is likely to emerge in which the nation could lose its conventional long-range strike advantage for a decade or more. Consequently, the United States has a critical choice to make: either accept this loss on the assumption that long-range strike is less relevant in the future, or implement a plan and provide sufficient resources to maintain its long-range strike advantage. This paper suggests options for the latter choice as a point of departure for developing and sequencing new capabilities that will sustain America's long-range strike strategic advantage for the next thirty years.

A FRAMEWORK FOR THINKING ABOUT LONG-RANGE STRIKE

Defining a framework of assumptions for thinking rigorously about the opportunities and risks of various capability options is a first critical step toward assessing the US military's long-range strike requirements. Using the wrong assumptions about the character of plausible conflicts, airbase availability, emerging threats and potential target sets could lead to flawed analysis and, ultimately, plans and investments that would leave the United States ill-prepared for the future.

The planning framework developed by the Defense Department in the immediate aftermath of the Cold War was based on assumptions that its power-projection capabilities would be able to deploy and operate from forward bases relatively unhindered by enemy threats. This "sanctuary" status extended to in-theater operations of tactical fighter aircraft, aircraft carriers, aerial refueling tankers, C4ISR networks and supporting logistics systems. The First Gulf War reinforced these assumptions and contributed to the Defense Department's development of a new force-planning construct based on sizing and structuring US military forces primarily for conducting two nearly simultaneous "rapid halt" regional conflicts, putatively in Iraq/Iran and Korea. Pentagon planners viewed long-range strike as a "first day" capability that would be needed to help rapidly halt invading enemy forces, after which short-range tactical aircraft flying from nearby bases in relatively permissive operating environments could carry out the majority of strike missions. Collectively, these assumptions led to twenty years of defense budgets that have favored investments in both land- and carrier-based short-range fighters at the expense of major new long-range strike programs.

On reevaluation, the Defense Department's 1990s planning assumptions provide an unsuitable framework for assessing strike capabilities that may be needed for future contingency operations. Today, a number of foreign militaries—including, but not limited to, those of China and Iran—are investing in A2/AD battle networks that can pose a direct and formidable challenge to the traditional forms of US conventional power-projection in all operating domains. Conflicts involving such A2/AD networks would likely require US short-range land- and sea-based strike aircraft to operate from much longer ranges, nullifying their ability to attack land targets at depth and greatly reducing sortie generation rates. Moreover, enemy integrated air defense systems may render areas under their coverage all but impassable to non-stealthy aircraft and cruise missiles. Potential adversaries are also adopting defensive measures to defeat attacks from US precision-guided munitions, such as concealing, camouflaging and mobilizing military systems, and hardening or deeply burying key facilities.

This monograph offers an alternative framework for evaluating options for the next long-range strike family of systems. It is based on the fundamental premise that future operating environments will be increasingly non-permissive in nature, regardless of the level of conflict. This new framework should assume US land- and sea-based forces will have to operate from longer ranges, will need to penetrate and persist in high-threat environments, may not be supported by on-call C4ISR, and will need the capacity to strike thousands of targets that are increasingly mobile, relocatable, hardened, deeply buried, and located deep in an enemy's territory.

ASSESSING ATTRIBUTES FOR A FUTURE LONG-RANGE STRIKE FAMILY OF SYSTEMS

The new framework of assumptions proposed by this paper suggests the Defense Department's next long-range strike family of systems will require certain attributes. The vast distances involved in operating in some potential theaters of operation, the growing missile threat to US forward bases, and an increasingly challenging target set will require land-based strike platforms with the capability of flying 4,000–5,000 nautical miles (nm) between aerial refuelings and persisting over target areas located in contested environments characterized by dense, modern air defense networks. Anti-access/area-denial networks like the one being developed by the PRC and other states with the resources to buy advanced military systems will likely pose unacceptably high risks to US Navy surface forces and compel them to operate initially as far as 1,000 nm or more from an adversary's coastline. This suggests the need for a carrier-based aircraft with a range that is at least two to three times that of the F/A-18E/F or F-35C if carriers are to contribute meaningful strike capacity at the outset of future operations. Moreover, land- and sea-based aircraft penetrating dense, sophisticated integrated air defenses will require all-aspect, broadband low-observable characteristics. Finally, hedging against the loss of vulnerable C4ISR battle networks will require strike platforms to be capable of operating effectively independent of these networks. Simply put, the combination of range, persistence, stealth and independence of action will likely be the sine qua non for effective strike operations over the coming decades.

THE NEXT LONG-RANGE STRIKE FAMILY OF SYSTEMS

Using this new framework to assess the Defense Department's current long-range strike family of systems reveals the following capability shortfalls:

> Land-based bombers, with the exception of the small B-2 force, lack the ability to penetrate and persist in high-threat air defense environments;

> US carrier air wings lack the range, persistence and survivability to support long-range strike operations in A2/AD environments, especially if enemy threats force carriers to operate beyond effective ranges for strike operations;

> Current and planned land- and sea-based strike systems, including both manned and unmanned, lack the capability and capacity to strike large target sets that are increasingly mobile, relocatable, hardened, deeply buried, and located deep in contested areas;

> Standoff weapons lack the ability to strike targets which are increasingly mobile, relocatable, time-critical, hardened or deeply buried; and

> Airborne electronic attack platforms lack the range and survivability needed to support long-range strike operations in contested airspace.

The Air Force's current bomber force lacks the capabilities and capacity needed to penetrate contested airspace to strike thousands of targets in future air campaigns. While a new penetrating bomber will require all-aspect, broadband stealth and other self-protection features, its weight and payload capacity cannot result in an average unit cost that is so great that it would effectively limit the Air Force to procuring a small "silver bullet" force on the order of today's twenty-aircraft B-2 fleet. Options that could reduce a new bomber program's impact on the defense budget include avoiding requirements creep; fully resourcing program development and competitive prototyping; taking advantage of technologies and systems developed for other programs; and delivering capabilities in incremental block upgrades. Developing a new bomber that could be optionally manned depending on mission requirements would increase combatant commanders' options in future air campaigns, especially in degraded satellite communications environments. An optionally manned bomber, if appropriately designed, could also preserve the option to carry nuclear weapons with relatively minimal modifications, thereby preserving future flexibility.

Reversing the erosion of the Navy's strike advantage will require investments in a new generation of capabilities to increase the range, persistence and survivability of carrier aircraft. The Navy's Unmanned Combat Air System Demonstration program represents a first possible step toward fielding an unmanned platform with all-aspect, broadband low observability, a combat radius of 1,500 nautical miles, and mission durations of up to fifty hours with aerial refueling. Without such investments, US aircraft carriers will be locked into a concept of operations that is dependent on relatively benign, permissive operating conditions. With new investments, the Navy could make a bold shift toward enabling effective strike operations against enemies with robust A2/AD battle networks, thereby ensuring that its future forward presence and immediately employable strike forces will remain effective.

Given the expected service life of the Air Force's current bombers and their continued ability to perform standoff attack missions, it may be possible to defer development of a new standoff platform until production of a penetrating bomber is nearly completed. In lieu of this option, investing in a joint Air Force-Navy cruise missile that could be air- and sea-launched from a wide variety of platforms would increase the US military's standoff weapons magazine while taking advantage of economies of scale via a larger procurement and steady sustained production over time to reduce total cost per missile. The Defense Department should also consider buying a small magazine — one hundred or fewer — of conventional prompt global strike munitions for defeating a small number of critical targets that might have to be engaged within an hour or less.

To support penetrating strike systems, including standoff attack missiles, the Defense Department should develop a long-range penetrating airborne electronic attack aircraft. As DoD assesses alternatives for this new aircraft, it must ensure they have the same attributes that are needed by other long-range strike systems, e.g., all-aspect, broad-band low observability and sufficient range and persistence to support operations deep into an enemy's landmass. Leveraging other development programs and off-the-shelf technologies to develop this platform may help reduce its cost and avoid the long lead times typically associated with developing new aircraft designs.

INITIATIVES AND IMPLEMENTATION

This report presents four options to illustrate how the Defense Department might prioritize investments over time to meet DoD's known and emerging long-range strike capability shortfalls. All options recommend developing an unmanned multi-mission aircraft to extend the range of the Navy's carrier air wings. They also recommend procuring a small magazine of conventional prompt global strike weapons. Option 1 defers a new bomber decision until the mid-2020s to allow the maturation or invention of new technologies for an even more capable penetrating aircraft. Option 2 calls for developing a new standoff-only bomber without the stealth and supporting systems needed for it to survive in contested airspace. Option 3 accords priority to developing a new penetrating bomber first, while taking advantage of the lengthy remaining service lives of existing bombers for standoff attack operations. Option 4 suggests procuring one penetrating aircraft to replace the Air Force's entire bomber force.

This report argues that Option 3 appears to offer the most balanced approach for sustaining the nation's long-range strike strategic advantage over the next thirty years. Accordingly, it recommends that the Department of Defense:

> Initiate a new Air Force program to procure up to one hundred new optionally-manned penetrating bombers with all-aspect, broadband stealth, a payload capacity of approximately 20,000 pounds and a range of 4,000 to 5,000 nautical miles. The bomber should have on-board surveillance and self-defense capabilities to permit independent operations against fixed and mobile targets in degraded C4ISR environments;

> Defer procuring a new standoff strike platform until production of a penetrating bomber is nearly completed;

> Develop an air-refuelable naval UCAS with at least a 1,500 nautical mile combat radius and the all-aspect, broadband low-observable characteristics required to survive in the face of advanced air defense networks;

> Invest in a joint cruise missile that could be launched from long-range and short-range strike platforms and be capable of carrying either conventional or nuclear warheads;

> Develop a small inventory (a hundred or fewer) of conventional prompt global strike weapons to support limited strikes against very-high-value targets requiring a total response time measured in hours;

> Field an AEA platform to support long-range strike operations, leveraging other DoD programs and off-the-shelf technologies to reduce program development time and cost; and

> Design the new penetrating bomber to have the potential to carry nuclear weapons to sustain the air leg of the nuclear triad and hedge against uncertainty.

Of course, developing the next long-range strike family of systems is more than a question of incorporating new technologies and procuring new platforms. It will also require the Defense Department to deliberately and effectively manage its program investments to ensure its industry partners sustain a highly skilled workforce upon which, ultimately, the US military's future capabilities depend. Accordingly, the Defense Department and Congress should work together to determine resources required to do so, and to support programs that will enable the US military to sustain its long-range strike advantage over the nation's future adversaries.

INTRODUCTION

> In the case of China, Beijing's investments in cyberwarfare, antisatellite warfare, antiaircraft and antiship weaponry, submarines, and ballistic missiles could threaten the United States' primary means to project its power and help its allies in the Pacific: bases, air and sea assets, and the networks that support them. This will put a premium on the United States' ability to strike from over the horizon and employ missile defenses and will require shifts from short-range to longer-range systems, such as the next-generation bomber.
>
> —Secretary of Defense Robert M. Gates[1]

For well over seventy years, the ability to conduct long-range strike operations has distinguished the United States as a global military power. During World War II, US Army Air Force bombers opened a new front for the Allied Powers in the skies over Europe and became the principal means for striking at the heart of Japan's military-industrial complex in the Pacific. Over the forty-plus years of the Cold War, fielding new long-range strike capabilities to deter the nuclear forces of the Soviet Union remained among the US military's highest priorities. Over the last twenty years, Air Force bombers and Navy cruise missiles have been used to conduct precision conventional strikes in support of operations in Kosovo, the Persian Gulf and Afghanistan.[2]

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1 Robert M. Gates, "A Balanced Strategy: Reprogramming the Pentagon for a New Age," *Foreign Affairs*, January/February 2009, accessible online at http://www.foreignaffairs.com/articles/63717/robert-m-gates/a-balanced-strategy.

2 Recent CSBA reports that trace recent long-range strike operations include Barry D. Watts, *The Case for Long-Range Strike: 21st Century Scenarios* (Washington: CSBA, 2008), and Thomas P. Ehrhard and Robert O. Work, *Range, Persistence, Stealth, and Networking: The Case for a Carrier-Based Unmanned Combat Air System* (Washington: CSBA, 2008), available at www.csbaonline.org. Consistent with other CSBA reports, for the purposes of this paper the term "long range" pertains to operations occurring in excess of 3,000 nautical miles (nm).

Despite their crucial role in every major conventional conflict over the past seventy years, the Defense Department (DoD) and the Air Force came to see long-range bombers as lower-priority capabilities after the fall of the Soviet Union. During the Cold War, DoD developed long-range bombers as part of the US nuclear triad. The B-2 was focused on attacking Soviet relocatable targets such as intercontinental ballistic missiles (ICBMs) with nuclear weapons during an all-out nuclear exchange. The collapse of the United States' primary adversary undermined the rationale for a large fleet of long-range bombers in two ways. First, it greatly reduced the requirement for nuclear-weapon delivery vehicles. Second, the end of the Cold War changed US budget priorities, with the administrations of George H.W. Bush and Bill Clinton cutting DoD's budget in order to provide a "peace dividend."

The First Gulf War coincidentally helped give DoD a new force-planning construct privileging short-range strike capabilities just as the end of the Cold War undercut the rationale for sizing and shaping the bomber force. DoD based its new post-Cold War framework around the assumption that its forces should be sized and structured primarily for conducting two nearly simultaneous regional contingency operations similar to Operation Desert Storm, presumably in Southwest Asia (Iraq and/or Iran) and Northeast Asia (Korea). This assumption drove other assumptions. For example, the relatively small size of these potential theaters of operation, relatively large number of potential air bases, and lack of serious threats to base operations — including carrier operations at sea — facilitated an emphasis on employing large numbers of short-range aircraft. Pentagon planners viewed long-range strike as a "first day" capability for rapidly halting invading enemy forces, after which short-range tactical aircraft flying from close-in bases in relatively permissive operating environments could carry out the majority of strike missions.

In the early 1990s, these assumptions, combined with declining defense budgets and the Air Force leadership's changing priorities, led to a twenty-year long-range strike procurement holiday in favor of investments in two short-range fighters, the F-22 and the F-35. During this time the Air Force and DoD undertook a series of studies assessing long-range strike requirements which continues to this day. These studies have yet to stimulate action. In 2001, DoD decided to begin funding long-lead technology development that would support a future long-range strike acquisition program "beginning in the FY 2012–2015 timeframe."[3] Eight years later, however, Secretary of Defense Robert Gates cancelled the Next-Generation Bomber (NGB) program in favor of yet another study. Current DoD plans find it spending $78 billion on new fighter programs in FY

[3] From a memo to the Air Force signed by Under Secretary of Defense for Acquisition, Technology, and Logistics E.C. Aldridge Jr., November 2, 2001.

2011–2015 compared to the $9.2 billion over the same period for new long-range strike capabilities.[4]

The nation's contemporary conventional air power projection force, then, is the product of a force-planning framework based on assumptions DoD developed in the early 1990s emphasizing short-range strike capabilities far more than those associated with long-range strike. Today, the emergence of serious threats to US forward-based aircraft suggests DoD must adopt a planning framework that assumes that such "non-permissive" operating environments will increasingly be the norm. A number of foreign militaries — including, but not limited to, those of China and Iran — have observed American military operations over the last twenty years and are investing in networks of "anti-access/area-denial" (A2/AD) systems designed to challenge traditional forms of US conventional power-projection in all operating domains.[5] Except for the B-2 force, of which at most sixteen are capable of responding to short-notice contingency operations at any given time, Air Force bombers cannot penetrate the integrated air defense systems (IADS) that are being fielded by China, Iran and other states with the resources to buy advanced military systems.[6] Furthermore, foreign militaries are taking steps to complicate US targeting by hardening, mobilizing, and relocating their most valued military systems deeper inland. Air Force fighters required to operate from available theater bases, especially bases located in the Pacific, lack the range or persistence to attack many of these targets. The operational challenge for short-range aircraft is further complicated by adversary ballistic and cruise missiles that can strike the airfields at which these aircraft are based. Similarly, Navy fighter wings that are "best suited for striking targets at ranges between 200 and 450 nautical miles (nm) from their carriers" will not have

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4 The $78 billion for fighter programs includes funding for F-22 modernization, F/A-18E/Fs, EA-18G "Growlers," and all three variants of the F-35 "Joint Strike Fighter." The $9.2 billion for long-range strike includes modernization programs for the B-52, B-1 and B-2, the Navy's Unmanned Combat Air System demonstration program, Air Launched Cruise Missile sustainment, and technology investment for a potential new bomber. This translates to the Air Force dedicating over 15 percent of its overall FY2011 modernization budget to the F-35. By FY2015, Air Force F-35 expenditures "will be over three times the size of the next largest program — for a total of more than $32 billion across the FYDP." General Norton A. Schwartz, Chief of Staff of the United States Air Force, "Win Today and Prepare for Tomorrow," keynote address to the Combat Air Forces Airpower Symposium, May 19, 2010, accessible online at http://www.af.mil/shared/media/document/AFD-100521-072.pdf.

5 For the purposes of this paper, "anti-access" (A2) threats are defined as those associated with preventing US forces from deploying to forward bases in a theater of operations, while "area-denial" (AD) threats aim to prevent the US military's freedom of action in an area of operations. See Andrew F. Krepinevich, *Why AirSea Battle?* (Washington, DC: CSBA, 2010), pp. 8–11.

6 There are eighteen "Primary Mission Aircraft Inventory" (PMAI) B-2As. PMAI aircraft are "assigned to a unit for performance of its wartime mission." See "Standardized Terminology For Aircraft Inventory Management," Chairman of the Joint Chiefs of Staff Instruction 4410.01B, October 31, 2001, p. A-1, accessible online at http://www.dtic.mil/doctrine/jel/cjcsd/cjcsi/4410_01b.pdf. Realistically, up to 16 B-2s may be available for combat operations at any given time.

the requisite range and persistence for air campaigns in non-permissive environments, especially if long-range ballistic and cruise missile threats force US carriers to standoff 1,000 nm or more from an enemy's coastline.[7]

As DoD applies a new framework to identify its long-range strike priorities, it must take a holistic approach, examining the entire "family of systems" that is needed to sustain the nation's long-range strike advantage. A long-range strike family of systems consists of standoff and penetrating platforms and munitions for precision strike, plus supporting capabilities for airborne electronic attack (AEA) and intelligence, surveillance and reconnaissance (ISR). This family of systems is not theoretical; it is how our nation's military organizes itself to conduct combat air operations.[8] Today's long-range strike family of systems includes manned and unmanned ISR platforms; B-2, B-1 and B-52 bombers; air-launched and sea-based standoff attack cruise missiles; and EF-18G, EA-6B and EC-130H airborne electronic attack aircraft. Future family-of-systems capabilities could include new penetrating aircraft for AEA, ISR and strike, a new conventional cruise missile and conventionally-armed ballistic missiles.[9]

Defense Department planners will need to enhance the synergistic potential of this family of systems to overcome the challenges of future non-permissive operating environments. For example, future long-range penetrating AEA platforms could strike enemy air defenses and prevent them from engaging penetrating US aircraft and weapons effectively. New Air Force and Navy strike aircraft capable of penetrating advanced integrated air defenses and persisting in such an environment could find and strike mobile targets such as air defense systems and long-range missiles, thus enhancing the survivability of other US power-projection forces and the bases from which they operate. Similarly, air and sea-based standoff attacks against enemy IADS such as surface-to-air missile (SAM) emplacements and long-range surveillance radars, especially those on the enemy's perimeter, would help enable other long-range family-of-systems capabilities to penetrate and persist in enemy airspace.

The Defense Department will also need to develop a coherent plan to field the next long-range strike family of systems. This plan must prioritize DoD's

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7 *Range, Persistence, Stealth, and Networking*, 2008, p. 3.

8 For example, in 1980 the Air Force's Strategic Air Command created a "Strategic Projection Force" consisting of a package of B-52s combined with intelligence, reconnaissance, command, control, and communications capabilities to support DoD's new concept for a "Rapid Deployment Force" for conventional operations.

9 The conventionally armed ballistic missiles are intended to be part of DoD's "prompt global strike" capability. DoD describes "Conventional Prompt Global Strike" ballistic missiles, which can be land-based or sea-based, as being capable of conducting global strikes with a total response time measured in hours and with less than one hour between a final strike order and target destruction. From an unclassified briefing "Requirements for a Conventional Prompt Global Strike Capability," Matt Bille, ANSER and Major Rusty Lorenz, Air Force Space Command, May 2001, accessible online at http://www.dtic.mil/ndia/2001missiles/bille.pdf.

long-range strike capability needs and sequence new programs over time according to these priorities. The plan must also incorporate measures that reduce upfront program costs, such as deferring the incorporation of capabilities that are not immediately needed for follow-on block upgrades. Prioritizing, sequencing, and reducing total program costs will be especially important in light of Secretary Gates' recent observation on the defense budget:

> Given America's difficult economic circumstances and parlous fiscal condition, military spending on things large and small can and should expect closer, harsher scrutiny. The gusher has been turned off, and will stay off for a good period of time.[10]

Declining resources combined with growing threats add even greater urgency to the issue, given the aging of the US military's long-range strike capabilities. To put it in perspective, the average age of the nation's fleet of 76 B-52s, 66 B-1s and 20 B-2s is over thirty-three years. The Air Force accepted delivery of its newest B-52 when President Kennedy was in office, and the last B-2 joined the active inventory in 1997. Based on current projections, pilots not yet born may be flying B-52s until the year 2048, at which time the aircraft will be a remarkable eighty-two years old.[11] But age is less a problem in and of itself than an indicator of the bomber fleet's waning survivability in the face of growing high-threat air defenses. The large radar signatures of the B-52s and B-1s have long since relegated them to standoff missions when operating in contested environments characterized by dense, modern air defense networks. While the B-2 is capable of penetrating existing IADS under certain conditions, the history of the competition between penetrating platforms and defenders suggests this ability is by no means permanent.

Given the extremely long timeframe involved in developing and fielding a sufficiently capable and survivable family of systems, the US military could—for the first time in nearly three-quarters of a century—lose its ability to conduct effective long-range strike campaigns in the near future against enemies equipped with high-end IADS and be unable to reconstitute it for a decade or more. Thus the United States has a critical choice to make: either proceed with investments in the next defense budget that will sustain the nation's long-range strike strategic advantage, or lose a major and longstanding source of advantage in the military competition.

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10 "Remarks as Delivered by Secretary of Defense Robert M. Gates," Abilene, KS, Saturday, May 8, 2010, accessible online at http://www.defense.gov/speeches/speech.aspx?speechid=1467.

11 Air Force B-52, B-1, and B-2 service lives may extend to the years 2044, 2047, and 2058 respectively. From an unclassified Air Force briefing, "Air Force Long Range Strike Strategy," February 27, 2009.

ROADMAP

This monograph uses the following approach to assess sea- and land-based capabilities that are needed to sustain the US military's long-range strike capabilities over the next thirty years.

> Chapter 1, "A Framework for Thinking About Long-Range Strike," explains how the planning framework developed by DoD in the immediate aftermath of the Cold War influenced the size and capabilities mix of today's long-range strike portfolio of capabilities. It then offers an alternative framework based on the fundamental premise that future operating environments will be increasingly non-permissive in nature.

> Chapter 2, "Assessing Attributes for a Future Long-Range Strike Family of Systems," uses Chapter 1's alternative framework to evaluate the capability shortfalls of DoD's current mix of standoff and penetrating long-range strike capabilities.

> Chapter 3, "The Next Long-Range Strike Family of Systems," builds on previous chapters to explore options to fill DoD's long-range strike capability gaps. These options include a new penetrating bomber for the Air Force, an unmanned aircraft for the Navy's carrier air wing strike aircraft, standoff strike weapons, and a supporting airborne electronic attack platform.

> Chapter 4, "Initiatives and Implementation," outlines an approach for prioritizing and sequencing investments that may reduce the cost barrier for fielding DoD's next generation of long-range strike capabilities while sustaining the aircraft development industrial base.

CHAPTER 1 > **A FRAMEWORK FOR THINKING ABOUT LONG-RANGE STRIKE**

> Every military force in history that has successfully adapted to the changing character of war and the evolving threats it faced did so by sharply defining the operational problems it had to solve.
>
> —General James N. Mattis, Commander, US Joint Forces Command[12]

A critical first step toward informing the development of DoD's next long-range strike family of systems involves establishing the right framework for thinking rigorously about the opportunities and risks of the various capability options. Using the wrong framework could lead to flawed analysis and, ultimately, plans and investments that would leave the United States ill-prepared for the future.

This chapter begins by reviewing how the framework developed by DoD in the immediate aftermath of the Cold War was based on assumptions that US military power-projection capabilities would be able to deploy to forward theaters and operate relatively unhindered by enemy threats. This assumption regarding "sanctuary" status extended to in-theater operations of tactical fighter aircraft, aircraft carriers, aerial refueling tankers, C4ISR networks and supporting logistics systems. Based on this post-Cold War framework, over the last twenty years DoD has invested in capabilities that are best suited for operating in permissive theater environments at the expense of new systems with increased survivability, range and persistence.

The chapter makes the case that a more relevant framework of assumptions for evaluating options for the next long-range strike family of systems is needed, one that is based on the fundamental premise that future operating environments

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[12] The *2010 Joint Operating Environment* (Suffolk, VA: United States Joint Forces Command, February 18, 2010), Foreword, accessible online at http://www.jfcom.mil/newslink/storyarchive/2010/JOE_2010_o.pdf.

will be increasingly non-permissive, regardless of the level of conflict. Given the continuing global proliferation of advanced military technologies, prudent planning dictates that the US military should expect future adversaries to be equipped increasingly with precision-guided munitions (PGMs) and advanced IADS designed to challenge US power-projection operations regardless of the level of conflict, whether nominally "high-end" or "low-end." Such adversaries may be powerful states—or they may be weaker states or non-state actors that nonetheless have acquired some sophisticated military systems capable of inflicting disproportionate damage or losses to US military systems.[13] Succeeding chapters will employ this alternative framework of assumptions to assess the need for future long-range strike systems that are capable of operating in a range of non-permissive environments.

Future operating environments will be increasingly non-permissive, regardless of the level of conflict.

DOD'S POST-COLD WAR PLANNING FRAMEWORK

During the Cold War, Air Force long-range strike capabilities such as the B-47 and B-52 were designed primarily to conduct nuclear strike missions deep inside the Soviet Union. Over the last twenty years of the Cold War, the Air Force procured the B-1, B-2 and nuclear-tipped Air Launched Cruise Missile (ALCM) to ensure the nuclear triad would include an airborne leg capable of penetrating Soviet airspace as the B-52 lost its ability to survive Soviet bloc air defenses. In the 1980s the Defense Department procured one hundred B-1s, whose ability to fly at low altitudes and sprint at high subsonic and low supersonic speeds would help them to elude Soviet air defense threats. Prior to the Soviet Union's collapse, the Air Force had planned to procure 132 stealthy B-2s capable of evading Soviet air defenses and attacking relocatable targets such as rail- or road-mobile ICBM launchers. The ALCM followed a path similar to the B-1 and B-2. Originally designed to give the B-52 a standoff nuclear strike capability when the bomber lost its ability to penetrate, a limited number of ALCMs were later converted to carry conventional warheads to give the USAF a global non-nuclear precision strike capability.[14]

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13 The *2010 QDR Report* touches on this by explaining future "hybrid" conflicts may involve "state adversaries that employ protracted forms of warfare, possibly using proxy forces to coerce and intimidate, or non-state actors using operational concepts and high-end capabilities traditionally associated with states." See *Quadrennial Defense Review Report* (Washington, DC: Office of the Secretary of Defense, February 2010), p. 8. The entire report, which will be referred to hereafter as the *2010 QDR Report*, is accessible online at http://www.defense.gov/qdr/images/QDR_as_of_12Feb10_1000.pdf.

14 The renamed Conventional Air Launched Cruise Missile was first used in combat during Operation Desert Storm.

With the dissolution of the Soviet Union and Warsaw Pact, the Air Force lost its primary rationale for sizing and shaping its long-range strike force. In January 1992, President Bush asked Congress to terminate the B-2 program at twenty aircraft and cancel further production of the Advanced Cruise Missile based on the perceived diminished need for strategic nuclear forces.[15] On June 1 of that year, the Air Force deactivated its Strategic Air Command and transferred all bomber forces to a newly-established Air Combat Command (formerly Tactical Air Command) which did not have operational control over nuclear forces. In effect, this placed the bomber force in the hands of Air Force fighter generals, a fact that has been reflected in budgets that have remained heavily skewed toward short-range strike capabilities to the present day.

As luck would have it, in the same year as the Soviet Union's collapse the US military engaged in a theater conflict that would suggest a new rationale for sizing and shaping the Air Force's bomber arm. During the First Gulf War (Operation Desert Storm), B-52s flew up to fifty sorties per day and dropped close to half of all bombs used by the Air Force.[16] Building on lessons learned from Desert Storm, in June 1992 the Air Force published *The Bomber Roadmap* which proposed that bombers armed with a new generation of PGMs could play a major role in future regional conflicts.[17] At the start of a conventional conflict, the roadmap envisioned bombers flying sorties from the continental United States and theater bases to strike high-value targets, "especially those time critical targets which, if not destroyed in the first hours or days of a conflict, would allow unacceptable damage to be inflicted on the friendly side."[18] Accordingly, the roadmap

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15 The FY1993 President's Budget Submission formally asked Congress to terminate B-2 procurement at 20 aircraft. Secretary of Defense Cheney had previously reduced the planned B-2 buy to 75 aircraft as result of a major aircraft review completed in 1990. The first B-2 was delivered to the Air Force in December 1993. Also see the transcript of President Bush's 1992 State of the Union Address: "These are actions we are taking on our own because they are the right thing to do. After completing 20 planes for which we have begun procurement, we will shut down further production of the B–2 bombers. We will cancel the small ICBM program. We will cease production of new warheads for our sea-based ballistic missiles. We will stop all new production of the Peacekeeper missile. And we will not purchase any more advanced cruise missiles." See "Public Papers of the Presidents, George Bush — 1992, Volume 1," accessible online at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1992_public_papers_vol1_text&docid=pap_text-79.

16 Lt Col V. Frank Vollmar, "The Conventional Bomber Force War Horses For Global Conflicts," Air University Press, October 1992, p. ix.

17 *The Bomber Roadmap: Enhancing the Nation's Conventional Bomber Force* (Washington, DC: Department of the Air Force, June 1992).

18 Ibid., p. 3.

advocated investing in conventional weapons upgrades for the fleet of ninety-five B-52Hs, ninety-six B-1s and, when delivered, twenty B-2s.[19]

The Air Force's bomber assessment was subsequently validated by DoD's first post-Cold War strategic assessment, the 1993 Bottom-Up Review (BUR). The BUR envisioned using bombers during the opening stages of two nearly-simultaneous Major Regional Contingencies (MRCs) — for example, conventional conflicts with Iraq and North Korea — to "delay, disrupt, and destroy enemy ground forces and damage roads along which they are moving in order to halt the attack."[20] The BUR assumed threat environments for these "rapid halt" scenarios would not pose a serious challenge to US carriers or theater airbases. Such permissive operating environments, combined with the relatively small sizes of the theaters, would also allow deployed short-range Air Force, Marine Corps and Navy fighters — with aerial refueling — to reach the majority of enemy targets. Consequently, the BUR's "building block" of major forces needed for one MRC included four to five Navy carrier battle groups, ten Air Force fighter wings, and one hundred bombers. Two MRCs required double these forces with the exception of bombers. This was based on the assumption that bombers would make their most significant contribution during the early days of the first MRC before US fighters could arrive in theater. With the fighter forces in place, the bombers could "swing" to help effect a rapid halt of advancing enemy forces in a second theater conflict. Armed with these insights, the BUR concluded that a total force of 184 B-52s, B-1s, and B-2s with improved capabilities to deliver PGMs was sufficient for future contingency operations.[21]

Two other major 1990s studies helped mature DoD's new planning framework for its long-range strike capabilities. The 1995 Heavy Bomber Force Study, led by Dr. Paul Kaminski, the Under Secretary of Defense for Acquisition and Technology, supported the BUR by concluding that 181 bombers, including 20 B-2s, would be sufficient to support air operations in two nearly simultaneous

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[19] While the Air Force's 1992 *Bomber Roadmap* officially supported ending B-2 production at 20 aircraft, this decision was not embraced by all senior Air Force leaders. Two years after he retired from the Air Force, General Charles "Chuck" Horner, who commanded all US and allied air forces during Operations Desert Shield and Desert Storm, observed: "In 1991, I returned from the Gulf convinced that tomorrow's air commanders required — and would indeed have — a fleet of sixty or more long-range stealthy bombers. Inexplicably, the B-2 fleet was slashed from seventy-five to twenty, undermining our ability to employ a newly relevant strategy." General Charles A. Horner, USAF (Ret.), "What We Should Have Learned in Desert Storm, But Didn't," *Air Force Magazine*, Vol. 79, No. 12, December 1996, accessible online at http://www.airforce-magazine.com/MagazineArchive/Pages/1996/ December%201996/1296horner.aspx.

[20] See *Report on the Bottom-Up Review* (Washington, DC: Office of the Secretary of Defense, October 1993), p. 16. The entire report, which will be referred to hereafter as the *1993 Bottom-Up Review Report*, is accessible online at http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA359953&Location=U2&doc=GetTRDoc.pdf.

[21] This author was the Air Force's lead for developing the Bottom-Up Review's bomber force sizing rationale.

MRCs. As Dr. Kaminski testified to the Senate Armed Services Committee, these recommendations were based on the study's conclusion that:

> ...tactical air forces have a big impact on the campaign outcomes. If one examines these results in detail, bombers are far more important during the early halt phase as tactical air forces are arriving. Once all the tactical air forces are in place and fully employed—the bomber contribution shrinks to a small portion of the overall aggregate force.[22]

The 1997 Deep Attack Weapons Mix Study (DAWMS) echoed Dr. Kaminski's insights. Completed in conjunction with DoD's first QDR, DAWMS analysts, using regional conflict scenarios for Northeast Asia and Southwest Asia similar to the BUR's scenarios, reaffirmed that while Air Force bombers, including twenty stealthy B-2s, would be useful during the early days of a major conventional theater conflict, there would be less need for bombers once US land- and carrier-based fighters arrived in theater.[23]

Real-world lessons learned from post-Desert Storm air campaigns reinforced DoD's planning assumptions. During conflicts in the Balkans, Iraq and Afghanistan, US land- and carrier-based fighters quickly achieved air superiority or even wide-area air supremacy needed to support non-stealth bomber operations.[24] The B-1 made its combat debut in 1998 during Operation Desert Fox by striking Iraqi targets using conventional Mark 82 500-pound-class unguided bombs, while the Navy launched Tomahawk missiles and attacked multiple targets ashore without the loss of a single carrier aircraft.[25] In 1999's Operation Allied Force, B-2s armed with GPS-guided Joint Direct-Attack Munitions (JDAMs) highlighted the revolutionary combination offered by stealth, range, payload and precision. During Operation Enduring Freedom (OEF), one Navy admiral reported carrier-based fighters "provided 75 percent of OEF strike sorties" through

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22 See "Hearings Before The Committee On Armed Services United States Senate One Hundred Fourth Congress First Session On S.1026," May 18, 1995, p. 373.

23 "Report of the Defense Science Board on Deep Attack Weapons Mix Study," Office of the Under Secretary of Defense for Acquisition and Technology, January 1997, p. 8. In addition to assessing the mix and quantities of precision conventional munitions needed for winning two conventional MRCs, then called "Major Theater Wars" or MTWs, DAWMS attempted to define an optimum mix of deep strike platforms, including legacy bombers, B-2s, fighters, long-range missiles, and helicopters. Thus DAWMS was one of the first in-depth analyses of DoD's joint long range strike family of systems.

24 With exceptions. On March 27 1999, Serbian forces downed an Air Force F-117A stealthy fighter-bomber with an SA-3. Some argue this shoot-down presaged the advent of a new generation of IADS that threaten US current generation combat aircraft.

25 Air Force Association, *Return of the Bomber,* February 2007, p. 13, accessible online at http://www.afa.org/mitchell/reports/0207bombers.pdf. The B-2 made its first combat strike in 1999 during Operation Allied Force, flying 51 strike sorties to deliver more than 650 Global Positioning System-guided Joint Direct Attack Missions.

December 2001.[26] The Air Force continued to rely on B-1 sorties during Operation Enduring Freedom (OEF). The B-1s dropped nearly 67 percent of all precision-guided JDAMs used during the conflict, and followed this in the Second Gulf War (Operation Iraqi Freedom (OIF)) in delivering 42 percent of all JDAMs employed in that conflict.[27] Air Force B-52s flew combat operations in OIF and OEF, exploiting their ability to loiter over the battlefield in a highly permissive threat environment to provide on-call strike support to US ground forces.

In summary, DoD's post-Cold War planning framework for its power-projection forces has been based on the following key assumptions:

> A NARROW RANGE OF SCENARIOS: US power-projection forces should be primarily sized and shaped for conducting two simultaneous conventional theater conflicts, one in Northeast Asia and one in Southwest Asia. These scenarios would be limited geographically and in scope. Given their limited role after US fighter forces arrived in theater, bombers could swing from the first theater conflict to the second, thereby reducing the required size of the bomber force, including stealth bombers.

> PERMISSIVE OPERATING ENVIRONMENTS: Regional adversaries equipped with unsophisticated IADS and limited air, naval, space and cyberspace power-projection capabilities would not pose a serious anti-access/area-denial challenge to US military forces and could not seriously contest the continuity of US C4ISR or logistics. Furthermore, US land- and sea-based short-range and long-range strikes could quickly roll back enemy air defenses, permitting non-stealthy aircraft wide freedom of action.

> UNCONSTRAINED AND UNCONTESTED THEATER BASING: The US military's air forces, and short-range aircraft in particular, would enjoy the use of land and sea bases in close proximity to the enemy's territory. Land bases would face no serious threat from air, missile or WMD attacks, while Carrier Strike Groups would be able to close within range of their strike systems without concerted challenges by air, surface or undersea threats. Political or diplomatic base access restrictions would, at most, prove a minor annoyance. Once deployed into theater, US fighters could reach the vast majority of enemy targets with direct-attack or standoff munitions, reducing the need for long-range strike systems.

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26 Rear Admiral Terry B. Kraft, "It Takes A Carrier: Naval Aviation and the Hybrid Fight," *Proceedings*, September 2009, accessible online at http://www.usni.org/magazines/proceedings/story.asp? STORY_ID=2023.

27 United States Air Force Fact Sheet on the B-1B Lancer, December 23, 2009, accessible online at http://www.af.mil/information/factsheets/factsheet.asp?id=81.

Since the end of the Cold War, DoD has employed this planning framework with these embedded assumptions to prioritize developing and procuring short-range fighters at the expense of bombers. Retired Air Force Lieutenant General Brent Scowcroft observed as early as 1997 that "a corresponding indicator of fighter dominance is the steadily growing ratio of fighters to bombers in the USAF operational inventory. This ratio increases from about 4-1 in the 1950's, to 6-1 in the 1970's, to 10-1 in the 1990's, and trending toward about 14-1 in the near future."[28] In 2008, the Congressional Research Service reported that the Air Force's fighter-bomber ratio did, indeed, exceed Scowcroft's 14:1 assessment.[29] In programmatic terms, Scowcroft predicted that Air Force fighter procurement would exceed bomber procurement by 20:1 between the years 2000 and 2020. In this he was slightly off target; the Air Force's latest budget proposes spending $26.15 billion for the F-22 and F-35 programs compared to approximately $1.65 billion for technology related to future development of a new bomber — a ratio of 16:1.[30]

TOWARD A NEW PLANNING FRAMEWORK

DoD's post-Cold War planning framework and its assumptions did not meet with universal acceptance. Looking ahead rather than backward, two retired Air Force generals suggested a different set of assumptions that they believed would provide a more appropriate baseline for assessing bomber requirements. In 1996, General Charles "Chuck" Horner, who commanded all US and allied air forces during Operations Desert Shield and Desert Storm, observed:

> Current US warfighting strategy hinges on the deployment of short-range fighters and ground forces to foreign bases in the theater of conflict. Desert Storm and the postwar inspections of Iraq's WMD programs underscored the grave risks entailed with such a strategy. The 1996 Iraqi crisis demonstrated that foreign base access cannot be taken for granted. Once Jordan, Saudi Arabia, and Turkey opted out, the entire landbased fighter force was effectively neutralized, leaving US military capabilities seriously circumscribed. Carrier airpower could not compensate. We need the power to fight effectively from beyond the theater, and that means shifting much of the burden to long-range air....The Gulf War gave me a glimpse into the future of

[28] *Congressional Record—House*, Vol. 143, June 23, 1997, p. H4176, accessible online at http://www.gpo.gov/fdsys/pkg/CREC-1997-06-23/pdf/CREC-1997-06-23-house.pdf.

[29] Anthony Murch, "The Next Generation Bomber: Background, Oversight Issues, and Options for Congress," Congressional Research Service, March 7, 2008, p. 12, accessible online at http://www.policyarchive.org/handle/10207/bitstreams/19415.pdf.

[30] Ratios are based on the FY2011–2015 President's Budget Submission. To be fair to General Scowcroft, the ratio exceeds 20 to 1 in favor of investment in the F-22 and F-35 if spending for FY2010 is included in the total, or if planned spending for FY2011 only is used.

> warfare. I saw adversaries who attacked without warning. I saw adversaries armed with WMD and ballistic missiles.[31]

In 1997, former National Security Advisor and retired Lieutenant General Brent Scowcroft led a congressionally-directed Independent Bomber Force Review that also challenged DoD's post-Cold War planning assumptions: "Pentagon preferences for short-range instead of long-range air power raise a puzzling contradiction. The long-range bomber fleet is an element of the force structure that appears ideally suited to the demands of the new security environment."[32]

The outlines of the new security environment that were accurately envisaged by Generals Horner and Scowcroft were in many ways almost a negative image of the assumptions behind DoD's official planning framework.

The outlines of the new security environment that were accurately envisaged by Generals Horner and Scowcroft were in many ways almost a negative image of the assumptions behind DoD's official planning framework. The reason for this was quite simple: while the lessons from post-Cold War campaigns were interpreted by many, especially in the Navy and Air Force, as reinforcing planning assumptions developed in the immediate aftermath of the Cold War, potential adversaries drew their own conclusions, using these lessons as a guide for thwarting US power-projection capabilities. Over the last twenty years, as DoD has developed strike forces and concepts of operations reliant on access to secure bases, unfettered C4ISR and logistics and the ability to operate in relatively uncontested environments, potential adversaries have been developing and investing in capabilities to exploit each of these dependencies systematically in what has broadly become known as A2/AD battle networks. What follows is a brief summary of the constituent components of such a strategy, insofar as they are relevant to informing assumptions behind the development of a new planning framework for long-range strike.[33]

INCREASING OPERATIONAL RANGE

One of the key assumptions underlying DoD's post-Cold War planning framework, and thus the ratio of investment between short- and long-range strike capabilities, was the belief that long-range strike made its most important contribution during the early days of a conflict. In this construct, after long-range

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[31] General Charles A. Horner, USAF (Ret.), "What We Should Have Learned in Desert Storm, But Didn't," *Air Force Magazine*, Vol. 79, No. 12, December 1996, accessible at http://www.airforce-magazine.com/MagazineArchive/Pages/1996/December%201996/1296horner.aspx.

[32] Lieutenant General Scowcroft's memo to the House National Security Committee summarizing findings of his review is accessible at http://www.fas.org/nuke/guide/usa/bomber/970000-ibr.htm.

[33] For more thorough discussions of A2/AD battle networks and their implications, see Ehrhard and Work, *Range Persistence and Stealth* and Andrew F. Krepinevich, *Why Airsea Battle?* (Washington DC: CSBA, 2010), accessible online at csbaonline.org. Also see Roger Cliff, Mark Burles, Michael S. Chase, Derek Eaton and Kevin L. Pollpeter, *Entering the Dragon's Lair*, RAND, 2007, accessible at www.rand.org/pubs/monographs/2007/RAND_MG524.pdf.

forces helped achieve a rapid halt of an advancing enemy and US forces arrived at their forward bases, air- and sea-based fighters would conduct the majority of strike missions. This approach assumed there would be adequate access to forward basing, and made the additional assumption that an adversary could not or would not attempt to attack these bases. US planners, however, should not assume that either condition will apply in the future.

Although useful for giving DoD a post-Cold War organizing principle, the Iraq and North Korea scenarios distorted the relative importance of short- versus long-range striking capability. Neither state is particularly large geographically, thereby allowing short-range aircraft to cover a large percentage of their territory. Putative Iran or China scenarios, on the other hand, involve operating areas

FIGURE 1. ILLUSTRATIVE RANGES

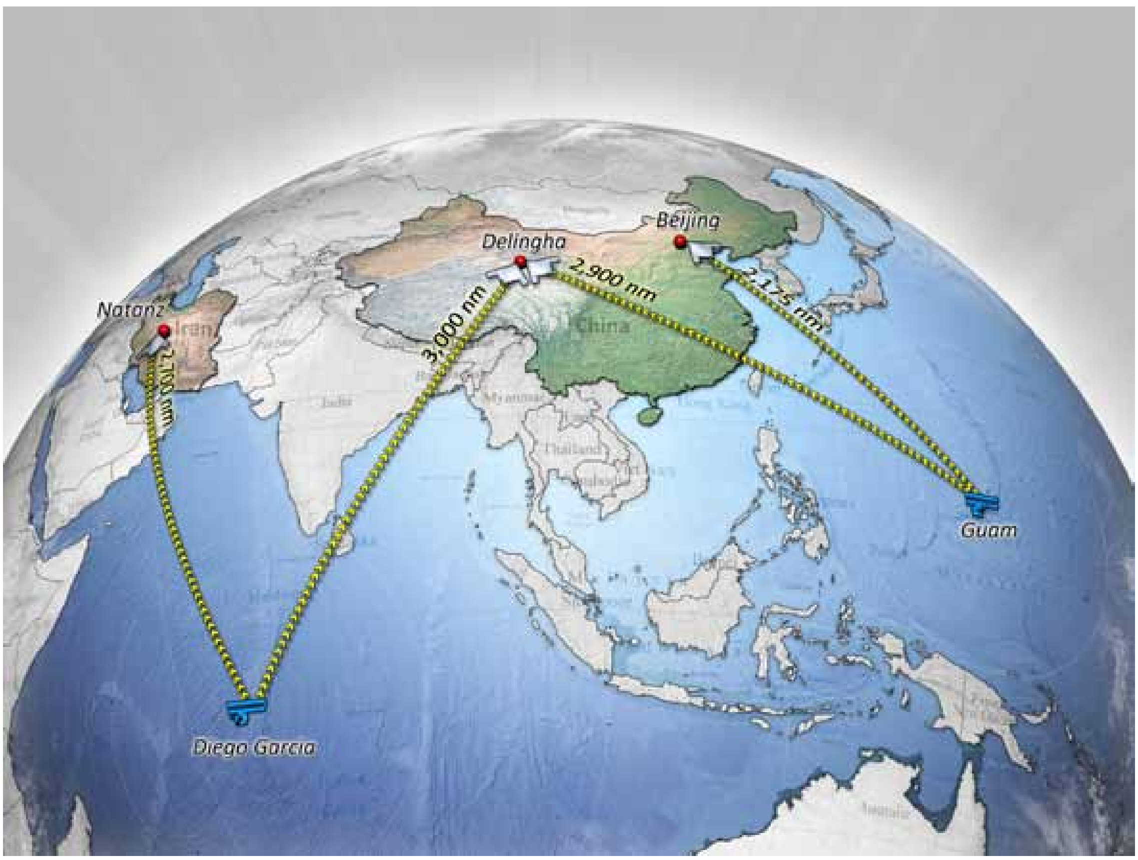

Image: CSBA

with much greater depth, requiring longer-range capabilities to strike targets. The need for persistence over geographically distant target areas only increases this requirement.

Possible future operations might see US strike aircraft operating across much greater distances than has been the case in recent conflicts. As a purely theoretical example, the distance from Guam's Andersen Air Force Base (AFB) to Beijing is approximately 2,200 nm, and the Delingha ballistic missile fields in central China are 700 nm further. In the Persian Gulf, to reach Iran's nuclear enrichment facilities at Natanz, US long-range aircraft staging out of Diego Garcia would have to travel 2,700 nm directly, and potentially much greater distances to allow for threat avoidance maneuvers and flight routes needed to approach potential targets from various axes of attack.

Planners should not assume regional bases will be available for short-range fighters.

THREATS TO FORWARD BASES

Compounding the impact of the distances involved in potential future scenarios is a lack of adequate basing. During the First Gulf War, and for any potential conflict with North Korea, DoD planners assumed nearly unlimited access to numerous bases in theater. As General Horner observed in 1996, planners should not simply assume bases will be available for short-range fighters, even in regions with existing bases. Domestic politics, diplomatic concerns, or the threat of military or economic reprisal can all influence allies and partners to restrict US operations from their territory. During an Iran scenario, for example, the threat of terrorist and missile attacks, disruption of maritime commerce in the Persian Gulf, or the possibility of domestic backlash from restive Shiite populations could persuade US regional partners to deny base access.

Should US forces gain access to theater bases, a panoply of threats could endanger their operations. Regional powers such as Iran and China observed the First Gulf War and determined that Saddam Hussein's decision to allow the United States to mass combat power unmolested on Iraq's borders in late 1990 through early 1991 was an egregious blunder. Accordingly, these nations have invested heavily in capabilities to hold forward bases at risk:

> BALLISTIC MISSILES: Both the PRC and Iran have built substantial ballistic missile inventories, though the PRC far outstrips Iran in terms of both quantity and quality of missiles. The People's Liberation Army 2nd Artillery Corps has over a thousand short-range ballistic missiles (SRBMs) within range of Taiwan. Some, such as the CSS-6/DF-15, are capable of reaching US bases on Okinawa and, depending on the method of employment, Misawa Air Base on the Japanese island of Honshu. The PLA 2nd Artillery also possesses more than fifty CSS-5/DF-21 medium-range ballistic missiles (MRBMs), and

is developing variants capable of reaching distant US installations such as Andersen AFB on Guam.[34]

Iranian ballistic missiles, such as the Scud-based, liquid-fueled Shahab-1 and Shahab-3, have much smaller ranges and are less precise than their Chinese counterparts. At present, such missiles would likely be of little use against US bases or forces in the field given their lack of precision guidance, but they could be effective as terror weapons against population centers, which would allow Iran to coerce its neighbors into denying access to US forces. According to several sources, Iran is also developing more advanced missiles, such as the solid-fueled Fateh-110, and upgrading variants of the Shahab-3. Over time, Iran's missile forces could evolve from a terror coercion weapon into a central element of an integrated A2/AD battle network.[35]

> LAND-ATTACK CRUISE MISSILES: To augment their ballistic missile strike capabilities, potential US adversaries such as the PRC are developing and fielding ground-, sea-, undersea- and air-launched land-attack cruise missiles (LACMs) that could be used to threaten US forward bases. While limited in range and speed compared to ballistic missiles, the multitude of possible launch platforms, and therefore potential attack axes, give cruise missiles some crucial advantages. In addition, their lower cost in contrast to ballistic missiles allows militaries to acquire them in greater numbers.[36]

> AIRCRAFT: Strike aircraft such as the H-6K (a Chinese-built variant of the Soviet Tu-16) and the many variants of the Sukhoi Su-27/30 airframe provide adversaries with yet another means of striking US forward bases. While the missile inventories of adversaries are likely to be cost-constrained and difficult to replenish in the midst of a conflict, these aircraft could carry out repeated strikes on forward bases after initial missile barrages destroy or substantially degrade US air defenses.[37]

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34 Office of the Secretary of Defense, *Annual Report to Congress on the Military Power of the People's Republic of China*, 2009, p. VIII, accessible online at http://www. defenselink.mil/pubs/pdfs/China_Military_Power_Report_2009.pdf) on November 22, 2009.

35 For more information on the proliferation of ballistic missile technology, see "Ballistic and Cruise Missile Threat 2009," *National Air and Space Intelligence Center (NASIC)*, April 2009, pp. 8–17, accessible online at http://www.fas.org/programs/ssp/nukes/NASIC2009.pdf. Also see Stephen A. Hildreth, "Iran's Ballistic Missile Programs: An Overview," *Congressional Research Service*, Feb. 4, 2009, pp. 3–5, accessible online at: http://www.fas.org/sgp/crs/nuke/RS22758.pdf.

36 For more on cruise missile capabilities and proliferation, see National Space and Intelligence Center, "Ballistic and Cruise Missile Threat 2009," NASIC-1031-0985-09, pp. 26-29, and Andrew Feickert, "Cruise Missile Proliferation," *Congressional Research Service*, July 28, 2005, pp. 2–5. Accessible online at: http://www.fas.org/sgp/crs/nuke/RS21252.pdf.

37 Cliff, et al., "Entering the Dragon's Lair," pp. 76, 83.

> GUIDED ROCKETS, ARTILLERY, MORTARS, MISSILES (G-RAMM) AND OTHER ASYMMETRIC THREATS: Nation-state adversaries are not alone in seeking to prevent US forces from gaining access to a theater of operations or maneuvering freely once there. Various non-state and irregular adversaries are seeking similar capabilities. At present, these actors are mostly limited to harassing attacks with unguided munitions. As precision-guided weapons become more affordable and more widely available, what have previously been random harassing attacks could emerge as serious threats. Given the importance of airbases to US operations and the strategic significance of destroying or even damaging a handful of aircraft, if future opponents acquire a G-RAMM capability, large, fixed and oft-poorly defended facilities such as airbases would likely become priority targets.[38]

An adversary capable of denying surface vessels the freedom to maneuver in the littorals could severely limit US strike capacity in the event theater air bases are unprepared, unavailable or incapacitated.

The proliferation of A2/AD capabilities such as those listed above will force US aircraft to operate from distant bases and will greatly reduce their sortie generation rates. Operations in the Western Pacific region would be particularly problematic in this regard. While the United States has a number of air bases in the region, these are either so close to China (e.g., Kadena, Kunsan, Osan) that they are under threat of devastating air or missile strikes, or so distant (e.g., Andersen AFB, Diego Garcia, and RAAF Base Darwin) that they are of limited utility to a force primarily comprised of short-range aircraft.

THREATS TO SURFACE VESSELS

Incidents such as the use of Navy carrier battle groups in the 1996 Taiwan Strait Crisis have taught potential adversaries that denying the US military the ability to project power will require capabilities that force US carrier air wings to operate at longer ranges. An adversary capable of denying surface vessels the freedom to maneuver in the littorals (i.e., several hundred nautical miles from shore) could severely limit US strike capacity in the event theater air bases are unprepared, unavailable or incapacitated. Accordingly, Iran and the PRC are making major investments in capabilities to counter the Navy's surface strike forces and aircraft carriers in particular.

Following in the footsteps of the Soviet Union, the PRC is developing a complex of maritime reconnaissance and strike capabilities on their eastern coast that reaches well into the Western Pacific. If, as Lord Nelson once said, "a ship's a fool that fights a fort," then the PRC may hope to turn its eastern shore into a

[38] For further explanation of the G-RAMM threat, see Thomas Ehrhard, Andrew Krepinevich and Barry Watts, *Near-Term Prospects for Battlefield Directed-Energy Weapons* (Washington, DC: CSBA, January 2009), p. 2, accessible online at: http://www.csbaonline.org/4Publications/PubLibrary/B.20090205.Near-Term_Prospect/ B.20090205.Near-Term_Prospect.pdf.

massive twenty-first century "fort" from which it can threaten surface vessels out to what PRC military publications refer to as the "Second Island Chain" (from Japan southward through the Marianas to New Guinea). The PRC is building this fort, not with stone and cannons, but with a layered system of long-range C4ISR and anti-surface warfare capabilities.[39]

To project power from the Asian landmass into a maritime theater as vast as the Western Pacific first requires the ability to maintain situational awareness over a broad area, followed by the ability to provide timely ISR for targeting long-range weapons. The PRC has developed a layered ISR infrastructure with several key components. At extremely long ranges, the PRC depends on space-based ISR assets such as the Yaogan, Haiyang, CBERS and Huanjing families of satellites.[40]

To provide coverage out to the Second Island Chain and beyond, the PRC has built a system of over-the-horizon radars (OTHRs) which bounce high-frequency signals off the ionosphere to achieve long-range coverage. While adequate for situational awareness, OTHRs are poorly suited for providing targeting-quality data. To fill this gap, the PRC has developed long-range maritime patrol aircraft and weapons with terminal seekers.[41] In addition to these capabilities, the PRC exploits a wide array of unconventional ISR sources such as vessels that appear to be fishing junks or cargo ships.

The first defensive layer of this complex in the littorals consists of mines, land-based anti-ship cruise missiles (ASCMs) and small fast-attack craft carrying ASCMs, such as the PLAN's *Houbei*-class.[42] The next layer would likely comprise PLAN surface vessels such as the *Sovremenny*-class guided-missile destroyer (DDG).[43] Further out, air-independent propulsion diesel attack submarines (SSKs) like the Russian-built *Kilo*-class and the Chinese *Song*-class would form a defensive picket line. Using advanced wake-homing torpedoes and ASCMs such as the supersonic Klub/SS-N-27B Sizzler, these boats could hold US surface vessels at risk while their extremely quiet operation thwarts US anti-submarine

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39 For more on the PRC's maritime reconnaissance-strike network, see Ehrhard and Work, *Range Persistence and Stealth: The Case for a Carrier-Based Unmanned Combat Air System*, pp. 161–195.

40 "2009 Military Power of the People's Republic of China," p. 26. For use of space-based ISR in support of ASBM operations, see Andrew Erickson, "Chinese ASBM Development: Knowns and Unknowns," Jamestown Foundation, June 24, 2009. Accessible online at http://www.jamestown.org/single/?no_cache=1&tx_ttnews[tt_news]=35171&tx_ttnews[backPid]=7&cHash=3ac55b5a15. In particular, "information regarding carrier battle groups...should be gathered on a real-time basis." Potential sources of "real-time intelligence" include "military reconnaissance satellites, domestic and foreign remote sensing satellites, and established satellite reconnaissance target image information processing systems."

41 Andrew Erickson, "Eyes in the Sky," *Proceedings*, Vol. 136, No. 4 (April 2010), pp. 36–41.

42 Ronald O'Rourke, "China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress," *Congressional Research Service*, April 9, 2010, pp. 15–16, accessible online at www.fas.org/sgp/crs/row/RL33153.pdf.

43 Ibid., p. 6.

warfare efforts.[44] Exploiting their extremely long unrefueled range, PLANAF strike aircraft such as the H-6K and Su-30MKK could use advanced air-launched ASCMs to provide yet another anti-surface warfare (ASuW) defensive ring.[45] Even further out in the Pacific, PLAN nuclear attack submarines (SSNs) could hunt carriers as they steamed westward from CONUS or Pearl Harbor.

The latest element of the PRC's emerging A2/AD battle network is perhaps the most threatening to carrier operations: the anti-ship ballistic missile (ASBM). Built on a variant of the aforementioned DF-21/CSS-5 MRBM, the ASBM would use initial targeting data from an OTHR, then refine this data in flight using its terminal seeker before striking the carrier, most likely with submunition warheads. With a nominal range exceeding 1,100 nautical miles, ASBMs could hold carriers at risk well outside the range of F/A-18E/F Super Hornets and F-35Cs, the Carrier Air Wing's (CVW) primary strike aircraft for the foreseeable future.[46]

Assisted by the constrained geography of the Straits of Hormuz and the Persian Gulf, Iran can concentrate its smaller arsenal of generally less sophisticated and shorter-range weapons in attempting to deny US surface vessels freedom of maneuver over a limited area. Like the PRC, Iran deploys mines, swarming fast-attack craft and even mini-submarines in its constricted littoral waters. To strike targets further from shore, Iran could use a variety of air-, sea- and ground-launched ASCMs, including the supersonic SS-N-22 Sunburn, with an approximate range of 150 km. Again following the PRC's lead, Iran has invested in *Kilo*-class SSKs which could hold US surface vessels at risk well outside Iran's littoral regions.[47]

The ability to use land- and littoral-based assets to hold naval surface vessels at risk is not limited solely to state actors such as Iran and the PRC. In the 2006 Lebanon War, Hezbollah struck the INS *Hanit* with what most analysts agree was an Iranian-supplied C-802 ASCM. Although the *Hanit* survived the attack, it was severely damaged and forced to return to port.[48] The impact of such an attack on a US Navy vessel supporting operations ashore would likely be significant, and would probably require moving surface vessels to areas located outside the effective range of ASCM threats.

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44 Ibid., pp. 7–10.

45 Cliff et al., "Entering the Dragon's Lair," p. 92.

46 Andrew S. Erickson and David D. Yang, "Using the Land to Control the Sea," *Naval War College Review*, Autumn 2009, Vol. 62, No. 4, accessible online at www.cffc.navy.mil/Using-the-Land-to-Control-the-Sea-Chinese-Analyst.pdf.

47 See Caitlan Talmadge, "Closing Time: Assessing the Iranian Threat to the Strait of Hormuz," *International Security*, Vol. 33, Issue 1, Summer 2008, accessible online at http://belfercenter.ksg.harvard.edu/publication/18409/closing_time.html.

48 Mark Mazzetti and Thom Shanker, "Arming of Hezbollah Reveals U.S. and Israeli Blind Spots," *New York Times*, July 19, 2006, accessible online at http://www.nytimes.com/2006/07/19/world/middleeast/19missile.html.

The development and widespread fielding of advanced ASuW capabilities will likely force costly and scarce Navy strike platforms to operate from much longer ranges. Deployed effectively, these capabilities could effectively nullify the surface Navy's current ability to strike land targets at depth, thereby placing a much heavier burden on limited undersea and USAF long-range strike capacity.

COMPLICATING LONG-RANGE OPERATIONS

Striking from long range is a complex exercise even in benign threat environments, requiring the precise coordination of numerous disparate elements to place ordnance on target. US power-projection operations depend upon a number of critical support systems without which long-range strike would be nearly impossible. In concert with their efforts to deny US forces access to forward bases and freedom of maneuver at sea, potential adversaries are developing sophisticated capabilities aimed at disrupting or destroying these support systems in the event of a conflict.

On January 11, 2007, the PLA successfully tested a kinetic anti-satellite (ASAT) weapon, destroying an aging Chinese weather satellite.[49] The significance of this development and what it represents are difficult to overstate. US long-range operations depend heavily on space-based capabilities for everything from ISR to precision navigation and timing (PNT), satellite communications (SATCOM), and command and control for unmanned aviation systems. Making matters worse, these systems are not only crucial but also inherently fragile and hugely expensive to develop and deploy. Along with their demonstrated kinetic ASAT capability, the PRC also possesses laser dazzler-blinders and radio-frequency jammers potentially capable of disrupting US space-based capabilities essential for supporting long-range strike operations.

In addition to the ability to attack US C4ISR assets with ASAT weapons, the PLA has also developed robust cyber warfare and electronic warfare resources.[50] Combined, these three capabilities could severely degrade the battle networks on which US power projection relies.

US power projection depends on inherently vulnerable information-centric capabilities such as space-based C4ISR and logistics networks. These systems may become an Achilles' heel for long-range operations, allowing weaker opponents to hobble far more potent US weapons systems.[51] The proliferation of

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49 See Phillip C. Saunders and Charles D. Lutes, "China's ASAT Test: Motivations and Implications," *Joint Forces Quarterly*, Issue 46, 3rd Quarter 2007, pp. 39–45, accessible online at http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA517485&Location=U2&doc=GetTRDoc.pdf.

50 Cliff et al., "*Entering the Dragon's Lair*," pp. 52–59.

51 Problematically from the US perspective, potential adversaries do not face the same obstacles. The PRC, for example, has built a closed, hardened and buried fiber-optic C2 network and can rely on simple overland logistics to sustain its forces.

capabilities that could threaten these weak links would seemingly privilege platforms with the ability to operate autonomously or with minimal support over long ranges.

DENYING AIRSPACE WITH DENSE, ADVANCED IADS

Integrated air defense systems represent yet another layer in an A2/AD battle network. These systems consist of search-and-track radars, SAMs, interceptor aircraft and potentially, over time, directed-energy weapons, all connected with advanced C4 networks for coordination. Employed effectively, IADS can render the areas under their coverage all but impassable to non-stealthy aircraft and standoff weapons. Given the effectiveness of modern air defense capabilities, potential US adversaries have made significant investments in developing dense, advanced IADS.

The PRC has deployed what is likely the world's most formidable IADS.

Capitalizing again on Russian research, development and engineering efforts, the PRC has deployed what is likely the world's most formidable IADS. Combining dense, overlapping radar and SAM coverage with hundreds of advanced interceptor aircraft such as the SU-30MKK, and connected with a closed, hardened and buried fiber-optic C2 network, the PRC's IADS represents an all-but-impenetrable barrier to non-stealthy US aircraft and standoff munitions.[52]

The acquisition of advanced SAMs, such as the Russian-built S-300 PMU-2 Favorit (NATO Codename SA-20) and the development of maritime SAM systems like the HHQ-9 and HHQ-16 are quickly increasing the range and sophistication of the PRC's IADS.[53] The SA-20 can engage aircraft targets out to 200 km, and the S-400 Triumf (NATO Codename SA-21 Growler) increases this range to 400 km, while the developmental S-500 could increase this range yet again to 600 km.[54] Additionally, Russian sources claim that the S-400 may be capable of

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52 For more on the PRC's IADS, see Cliff, et al., *Entering the Dragon's Lair: Chinese Anti-access Strategies and Their Implications for the United States*, p. 85, and for more on the PRC's fiber optic networks see James C. Mulvenon and Thomas J. Bickford, "The PLA and the Telecommunications Industry in China," *The People's Liberation Army in the Information Age*, James C. Mulvenon and Richard H. Yang, editors, pp. 246–255, accessible online at www.rand.org/pubs/conf_proceedings/ CF145/CF145.chap12.pdf.

53 *Report to Congress on the Military Power of the People's Republic of China*, p. 4, and Dmitry Solovyov, "China buys air defense systems from Russia," Reuters, April 2 2010, accessible online at http://www.reuters.com/article/ idUSTRE6310WG20100402. Each S-300 battery has 4 transporter erector launchers and 16 missiles.

54 "Russia set to finish development of new air defense system," Russian News & Information Service Novosti, September 16, 2009, accessible online at http://en.rian.ru/mlitary_news/20090916/156150066.html.

engaging stealthy aircraft.[55] These systems are quite survivable due to their mobility; an S-300 battery requires just five minutes to fire after coming to a halt.[56]

Because of the capabilities of these SAMs against aircraft that lack advanced stealth, their proliferation, or even potential proliferation, is cause for alarm. In 2007, Russia agreed to sell Iran five batteries of S-300s. After three years of intense US and Israeli diplomatic pressure and Russian vacillation, Russia apparently has canceled the deal in order to comply with recent UN sanctions on Iran.[57] This cancellation will not likely curb Iran's appetite for procuring advanced air defense systems. Despite their setback with Iran, given the demand for these systems and Russia's stated goal of increasing its weapons exports, further proliferation is a near-certainty.

A CHANGING TARGET SET

While potential adversaries are making large investments in an attempt to negate US power-projection capabilities, they are also modifying key military systems to ensure their survivability. These investments are proceeding along several paths, including concealment, camouflage, positioning targets in dense urban terrain, increasing targets' mobility and hardening or deeply burying key facilities. Although each of these methods can increase the survivability of potential targets, the latter two (mobility and hardening/burying) present particular problems for US strike operations.

Potential adversaries are modifying key military systems to ensure their survivability.

The move toward increasing the mobility of vulnerable systems is widespread, both in terms of the militaries pursuing this capability and the systems being modified. For the purposes of this analysis, however, two groups of systems illustrate the problem quite starkly: ballistic missile TELs and mobile SAMs. The reliance of nations such as the PRC and Iran on ballistic missiles to provide them with A2/AD striking power ensures that these weapons and their support vehicles and infrastructure will be priority targets for US strike campaigns. To increase the survivability of such key systems, advanced ballistic missiles such as the ASBM are almost exclusively equipped with solid-fuel propulsion systems (to shorten launch preparation times) and are road-mobile.[58] Just as ballistic missiles are crucial to the offensive power of an A2/AD network, so are SAMs to its defensive power.

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55 "Russia deploys S-400 air defense systems in Far East," Russian News & Information Service Novosti, Aug. 26, 2009. Accessible online at http://en.rian.ru/mlitary_news/20090826/155930246.html.

56 Sino Defence "S-300PMU (SA-10) Air Defence Missile System," accessible online at http://www.sinodefence.com/army/surfacetoairmissile/s300.asp, last updated May 8, 2008.

57 "Russian officials confirm Iran sanctions block S-300 missile sale," Russian News & Information Service Novosti, June 11, 2010, accessible online at http://en.rian.ru/russia/20100611/159390025.html.

58 NASIC, "Ballistic and Cruise Missile Threat 2009," and Erickson and Yang, "Using the Land to Control the Sea," p. 74.

Accordingly, these systems are quite mobile; as mentioned earlier, the SA-10/S-300 system requires only five minutes to be operational after coming to a halt.[59]

During the last nine years of operations in Afghanistan and Iraq, US air forces have refined their ability to strike moving targets with precision to a remarkable degree. By combining advanced targeting pods such as the Litening III (and now Generation IV) and the Sniper XR with guided munitions, US aircraft can now engage moving targets accurately and autonomously.[60] This capability, however, requires two things that will likely be difficult to sustain in future operating environments against a high-end foe. First, aircraft striking targets in this manner must loiter in the target area, both to acquire the target and then to designate it with a laser. Second, targeting pods such as the Litening and Sniper are inherently unstealthy, being externally-mounted. As discussed in the previous section on IADS, non-stealthy aircraft will have difficulty entering the target area, to say nothing of loitering there long enough to acquire and destroy moving targets. Standoff munitions, such as the Tomahawk Land-Attack Missile (TLAM), are capable of hitting relocatable targets, provided the targets do not move during the missile's fairly long flight time. Serbian forces took advantage of this weakness during Operation Allied Force in 1999 by relocating their SAMs every several hours.[61]

Standoff conventional munitions do not have the requisite destructive power to penetrate very hard and very deeply buried targets.

Some targets, such as munitions depots or nuclear sites, will by necessity remain fixed. Increasingly, countries are burying these fixed facilities deep underground, covering them with tons of reinforced concrete, or both.[62] Such investments sharply limit the number of US weapons that can be used to destroy these targets. Standoff conventional munitions like the TLAM simply do not have the requisite destructive power to penetrate very hard and very deeply buried targets, and tactical aircraft — with the exception of the F-15E Strike Eagle — cannot carry the heavier munitions, such as the penetrating GBU-28, required to destroy them.[63] At longer ranges in denied environments, this leaves only the small number of B-2 bombers to destroy such targets.

The inability of most US aircraft to participate in a notional strike campaign against an adversary with the depth and capabilities described above is

59 Sino Defence "S-300PMU (SA-10) Air Defence Missile System," accessible online at http://www.sinodefence.com/army/surfacetoairmissile/s300.asp.

60 For more on targeting pods and the Litening in particular, see "$27M for LITENING Targeting and Recon Pods," *Defense Industry Daily*, July 28, 2005, accessible online at: http://www.defenseindustrydaily.com/27m-for-litening-targeting-recon-pods-0929/.

61 Ibid., p. 3.

62 See "Report to Congress on the Defeat of Hard and Deeply Buried Targets," Department of Defense in conjunction with the Department of Energy, July 2001, pp. 8, 9, accessible online at: http://www.nukewatch.org/facts/nwd/HiRes_Report_to_Congress_on_the_Defeat.pdf.

63 Robert Haffa and Michael Isherwood, "The 2018 Bomber: the Case for Accelerating the Next-Generation Long Strike System," Northrop Grumman Analysis Center, August 2008, p. 11, accessible online at: http://www.northropgrumman.com/analysis-center/paper/assets/The_2018_Bomber_the_case_for_a.pdf.

particularly jarring when considering the sheer potential size of such a campaign. Past campaigns may shed some light on the total strike capacity needed in terms of desired mean points of impact (DMPI or "targets" in layman's terms). In the forty-three days of the Operation Desert Storm air campaign, for example, allied air forces averaged 961 DMPIs per day. During the opening thirty days of Operation Iraqi Freedom, USCENTAF attacked approximately 20,000 DMPIs over a thirty-day period for an average of 663 DMPIs per day.[64] While using these numbers to extrapolate the number of DMPIs for a putative campaign against a much larger country such as the PRC would be inexact, it should go without saying that any such campaign would be far larger in scale — perhaps by as much as an order of magnitude or greater, considering the differences between the size of Iraq and the PRC. Clearly, sixteen penetrating B-2 bombers and a handful of standoff weapons launched from Navy surface and sub-surface platforms would be insufficient in the event of a conflict with the PRC.

ASSUMPTIONS FOR A NEW FRAMEWORK

The aforementioned threats to US power projection operations are not theoretical. In its annual assessment released earlier this year, the Office of the Director of National Intelligence (DNI) reported that China's military modernization programs for all of the capabilities listed above are beginning to mature and will "improve China's ability to execute an anti-access and area-denial strategy in the Western Pacific."[65] Although the PRC may represent the most capable challenger to the US military's ability to project power, countries around the globe are investing in similar capabilities. The combination of demand for these systems with the Russian defense industry's willingness to supply them augurs for even greater proliferation. Moreover, these capabilities will not remain the sole province of national militaries. Non-state actors such as Hezbollah have demonstrated their desire to acquire and use guided munitions, and non-kinetic capabilities such as

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64 Operation Desert Storm DMPI information is from an unclassified Air Force briefing "Long Range Strike Overview", January 12, 2010. For Operation Iraqi Freedom data, see Lt. Gen. T. Michael Moseley, "Operation IRAQI FREEDOM–By the Numbers," USCENTAF Assessment and Analysis Division, April 30, 2003, p. 5, accessible online at http://www.globalsecurity.org/military/library/report/2003/uscentaf_oif_report_30apr2003.pdf .

65 The report states: "Important PLA modernization programs include: ballistic and cruise missile forces capable of hitting foreign military bases and warships in the Western Pacific; anti-satellite (ASAT) and electronic warfare weapons to defeat sensors and information systems; development of terrestrial and space-based, long-range intelligence, surveillance, and reconnaissance systems to detect, track, and target naval, air, and fixed installations; and continuing improvements to its increasingly capable submarines to place naval surface forces at risk." Director of National Intelligence, "Annual Threat Assessment of the US Intelligence Community for the Senate Select Committee on Intelligence," February 2, 2010, pp. 28–29.

US power-projection forces should be prepared for a wider range of scenarios against regional state and non-state aggressors, including enemies equipped with weapons of mass destruction and A2/AD systems.

cyber warfare weapons are available to any adversary with enough money and the right contacts.

Based on this assessment, remaining chapters will use the following framework for assessing capabilities and options for the next long-range strike family of systems.

> A WIDER RANGE OF SCENARIOS: US power-projection forces should be prepared for a wider range of scenarios against regional state and non-state aggressors, including enemies equipped with weapons of mass destruction and A2/AD systems such as precision-guided munitions, advanced air defenses, and long-range ballistic and cruise missiles.[66]

> LONGER OPERATIONAL RANGES: Potential theaters of operation such as the Western Pacific will require the ability to operate at much longer ranges.

> THREATS TO FORWARD BASES: Diplomatic and political pressure may constrain or deny use of existing forward bases, while missile, air and G-RAMM threats could render available bases unusable.

> THREATS TO SURFACE VESSELS: The PRC's emerging maritime reconnaissance-strike complex will allow it to project power from land against surface targets at very long ranges. This layered, multi-dimensional complex and its synergy with other A2/AD capabilities will allow it to remain effective even if US forces can defeat or disrupt certain key components, such as ASBMs. Aside from the PRC, the rapid and widespread proliferation of ASCMs, smart mines, advanced strike aircraft and quiet diesel attack submarines will push US surface vessels further out to sea in a wide range of theaters. This ability to deny surface vessels freedom of maneuver will greatly reduce the US military's ability to mass striking power quickly in a distant forward theater, placing greater reliance on long-range systems.

> DISRUPTIONS TO LONG-RANGE C4ISR AND LOGISTICS: The C4ISR and logistics capabilities crucial to supporting long-range power projection will be under constant attack from both kinetic and non-kinetic weapons. Platforms and weapons with the ability to operate independently of such systems to the greatest degree possible will be far more effective.

> ADVANCED STEALTH WILL BE REQUIRED TO PENETRATE AND PERSIST IN DENIED ENVIRONMENTS: The development and proliferation of advanced air defense systems such as the SA-10/20/21 and the Su-30 will increase the need for strike aircraft and penetrating weapons with advanced stealth technologies.

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66 The 2010 QDR acknowledged the need to use a broad range of planning scenarios to assess the Defense Department's capability needs. See *2010 QDR Report*, pp. 41–44.

> TARGETS WILL INCREASINGLY BE MOBILE OR HARDENED AND BURIED: To increase the survivability of their assets in the event that US forces can gain access and execute strike missions, potential adversaries are making their targets mobile where possible and hardening and/or burying stationary targets.

CHAPTER 2 > ASSESSING ATTRIBUTES OF A FUTURE LONG-RANGE STRIKE FAMILY OF SYSTEMS

> Many questions remain to be explored—manned or unmanned, nuclear or conventional only, or standoff versus penetration, for example.
>
> —General Norton "Norty" Schwartz, Chief of Staff, United States Air Force[67]

In the immediate aftermath of the Cold War, the Department of Defense adopted a framework of planning assumptions which emphasized investments in precision strike capabilities in relatively permissive environments where US forces would enjoy a great deal of freedom of action. Chapter 1 briefly described how many of these assumptions fail to address the challenge to US power-projection capabilities today, let alone the far greater challenges that will emerge from the trends described above. In place of these outdated assumptions, Chapter 1 described a future operating environment wherein:

> Potential adversaries will have much greater geographical strategic depth than the putative adversaries that drove post-Cold War defense planning;

> US forward bases will be limited in number and under attack from multiple systems, to include land-based ballistic missiles; air-, sea-, and submarine-launched cruise missiles; strike aircraft; and G-RAMM;

> US Navy surface vessel operations will be pushed outside the range of enemy land-based ASBMs, air-, sea- and submarine-launched ASCMs, and attack submarines carrying wake-homing torpedoes;

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67 From General Schwartz's address to the 2010 UK Royal Air Force Airpower Conference, June 18, 2010, p. 6, accessible online at http://www.af.mil/shared/media/document/AFD-100621-070.pdf.

> Key support infrastructure that enables US long-range power projection, such as space-based C4ISR systems and logistics networks will be under kinetic and non-kinetic attack;

> Adversaries will possess dense advanced IADS comprising "double-digit" SAMs and interceptors that, in the absence of a long and potentially costly suppression of enemy air defenses (SEAD) campaign, will deny access by any aircraft lacking advanced stealth; and[68]

> Key enemy targets will, if possible, be mobile and where this is not possible, they will be hardened or deeply buried to increase survivability.

This new framework of assumptions about the future operating environment suggests certain requirements for DoD's next long-range strike family of systems. The vast distances involved in some potential theaters of operation, the growing missile threat to US forward bases and the increasing number of mobile, relocatable, hardened, and concealed targets will require land-based platforms with greater range along with the ability to persist over a target area. Maritime anti-access/area-denial networks like the one being developed by the PRC will likely pose unacceptably high risks to US naval surface forces and compel them to operate initially as far as 1,000 nm or more from shore. This suggests the need for carrier-based strike aircraft with much greater range than the F/A-18E/F or F-35C if carriers are to contribute meaningful strike capacity at the outset of a future AirSea Battle operation.[69] Penetrating dense, sophisticated IADS will require aircraft with all-aspect, broad-band low-observable characteristics.[70] The most survivable aircraft are those that have both "all-aspect" and "broad-band" low-observable (LO) characteristics. As opposed to "single-aspect" stealth aircraft that are low-observable from only one direction (e.g., the front), "all-aspect" stealth aircraft have a "360-degree" low RCS which allows them greater freedom of maneuver in an enemy's airspace. Additionally, aircraft that have stealth characteristics across the entire radio frequency band employed by various types of radar will have a better chance of survival against advanced air defenses than aircraft that are designed to be low-observable in only a few radio frequency

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68 Advanced surface-to-air missile systems such as SA-10s and SA-20s are commonly known as "double-digit" SAMs.

69 An "AirSea Battle" concept of operations is one which is designed to preserve the US military's ability to project power in the face of growing anti-access/area-denial challenges, to include the formidable challenge posed by the Chinese military. See Andrew F. Krepinevich, *Why AirSea Battle?* (Washington, DC: CSBA, 2010), p. viii.

70 See Michael G. Vickers and Robert C. Martinage, *The Revolution In War* (Washington, DC: CSBA, December 2004), p. 41, Thomas P. Ehrhard and, Robert O. Work, *Range, Persistence, Stealth, and Networking: The Case for a Carrier-Based Unmanned Combat Air System* (Washington: CSBA, 2008), p. 126, and Rebecca Grant, *The Radar Game* (Arlington VA: IRIS Independent Research, 1981), p. 30.

bands. Known as "broad-band" stealth, aircraft with this characteristic increase their survivability by simultaneously avoiding detection from search radars that use lower frequency bands as well as target-tracking radars and anti-aircraft missile guidance radars that use higher frequency bands. Hedging against the loss of vulnerable C4ISR battle networks will require that long-range strike platforms be capable of operating effectively independent of these networks. Simply put, range, persistence, stealth, and independence of action will likely be the sine qua non for effective strike operations over the coming decades. Systems lacking these attributes will probably be relegated to supporting or standoff missions, lest they risk unacceptably high rates of attrition. Accordingly, Chapter 2 will discuss specific desired capabilities for:

Range, persistence, stealth, and independence of action will likely be the sine qua non for effective strike operations over the coming decades.

- Land-based long-range strike aircraft range and persistence;
- Sea-based strike aircraft range and persistence;
- Survivability, to include all-aspect, broad-band stealth;
- Independence of action, looking at the relative merits of manned, unmanned and optionally manned platforms; and
- The balance between penetrating and standoff strike capacity.

LAND-BASED LRS AIRCRAFT RANGE AND PERSISTENCE

As Chapter 1 outlined, A2/AD threats, combined with the shift in the locus of the principal challenges to US security from Europe to the vast distances of the Pacific and Asian landmass will "place a premium on forces capable of sustained operations at great distances into denied areas."[71] Of all the possible requirements for future long-range strike capabilities, range and persistence emerge as the most critical. Given the inherent size limitations of carrier-based fighter-bombers (discussed in further detail in Chapter 3), larger land-based aircraft that can carry large fuel loads have inherent advantages for striking targets at extremely long ranges, especially in defended airspace. A US long-range strike family of systems lacking a land-based platform with sufficient range or persistence will grant potential adversaries blessed with strategic depth sanctuaries in which they can husband key assets from harm. No amount of speed, stealth or precision will enable a future strike system to destroy a target it cannot reach (or cannot find). This section will address how much reach future strike operations might require.

No amount of speed, stealth or precision will enable a future strike system to destroy a target it cannot reach (or cannot find).

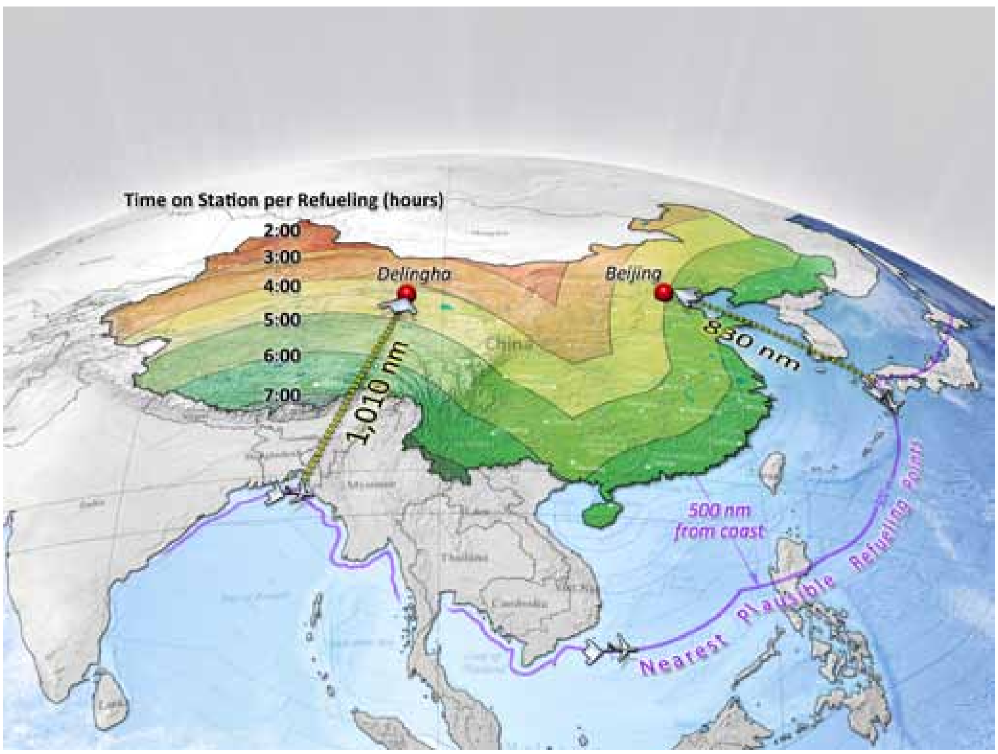
[71] See *2006 Quadrennial Defense Review Report* (Washington, DC: Office of the Secretary of Defense, February 6, 2006), p. 30, accessible online at http://www.defense.gov/qdr/report/Report20060203.pdf.

An aircraft's true operational "reach" is defined by several different factors other than its combat radius. Combining aerial refueling with standoff weapons can extend an aircraft's effective strike radius significantly. For example, an aircraft with a 2,500 nm combat radius (or a total of 5,000 nm between aerial refuelings) could reach any target in the PRC. Extending this example, the Congressional Budget Office concluded that a future bomber with a 2,000–2,500 nm combat radius, refueled prior to penetration, "would fully cover all countries" in the world.[72]

As illustrated in Figure 2, the combat radius potential of an aircraft that is not "spent" travelling to and from a target area translates into persistence which

[72] See "Alternatives for Long-Range Ground Attack Systems," Congressional Budget Office, March, 2006, pp. 16–17, accessible online at http://www.cbo.gov/ftpdocs/71xx/doc7112/03-31-StrikeForce.pdf. CBO's estimate of the worst-base penetration distances for countries of the world assumed long-range strike aircraft would refuel 100 nm outside an adversary's borders before penetrating, and subtracted a 30% range penalty to account for avoiding air defenses.

FIGURE 2. ILLUSTRATIVE RANGE AND PERSISTENCE FOR AIRCRAFT WITH A 2,500 NM COMBAT RADIUS*



* The approximate loiter times are based on an aircraft with a typical weapons load, 450 knots true air speed, a combat radius of 2,500 nm and a 20 percent fuel reserve to allow for maneuvering around threats inflight.

Image: CSBA

can then be used to search for mobile targets, take advantage of fleeting target opportunities, or support other long-range strike platforms by providing ISR or suppressing threats through airborne electronic attack. While there are no unclassified assessments available on how much persistence is necessary in future air campaigns, the need to find and target the growing arsenal of mobile military systems described in Chapter 1 will require strike platforms with hours, not minutes, of endurance over the projected target area.[73] Moreover, as demonstrated in Iraq and Afghanistan, strike aircraft with long loiter times can provide air campaign commanders the means to provide immediate support to troops in contact with the enemy or exploit pop-up opportunities to attack time-critical targets.

The need to find and target the growing arsenal of mobile military systems will require strike platforms with hours, not minutes, of endurance.

[73] As noted by CSBA's *AirSea Battle* Report, the persistent presence of US strike platforms can help suppress an enemy's offensive cruise and ballistic missile operations. The Gulf War Air Power Survey Volume II, Part 2, reached this conclusion and has a chart showing the suppression of Scud launches.

FIGURE 3. ILLUSTRATIVE RANGE AND PERSISTENCE FOR AIRCRAFT WITH A 1,500 NM COMBAT RADIUS

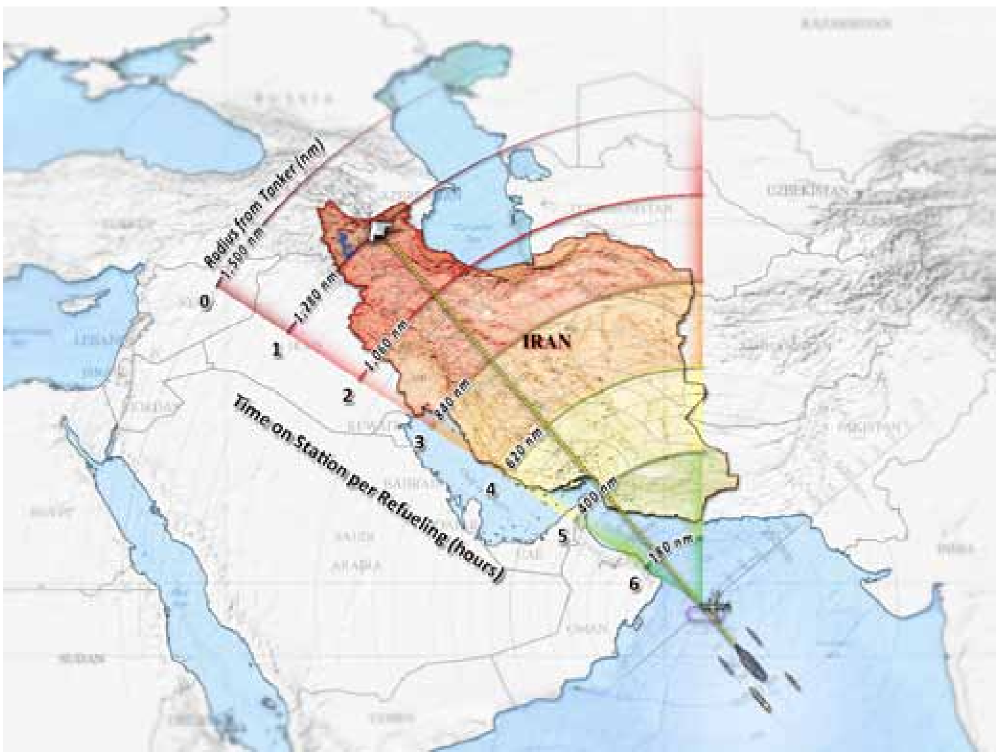


Image: CSBA

SEA-BASED AIRCRAFT RANGE AND PERSISTENCE

While future land-based aircraft will have their range requirement defined by the need to strike targets at extremely long distances, the range needed by future sea-based strike aircraft will be defined more by threats to a carrier's freedom of maneuver and the physical constraints of operating from a carrier deck. As an illustrative example, the myriad of threats to surface vessels outlined in Chapter 1 (e.g., strike aircraft, quiet diesel-electric submarines, advanced wake-homing torpedoes, supersonic anti-ship cruise missiles and the carrier-killer anti-ship ballistic missile) are being developed and fielded by the PRC with the aim of excluding carrier operations within a zone stretching out anywhere from 1,000 to 1,500 nm from the coast of mainland China.[74] A carrier-based aircraft with a combat radius of approximately 1,500 nm capable of aerial refueling would allow US aircraft carriers to contribute long-range strike capacity to an AirSea Battle campaign from the outset of a conflict while remaining outside the range of the PRC's A2/AD threats. Conveniently, a combat radius of 1,500 nm from a point of last refueling 250 nm offshore would allow such an aircraft to cover any target in Iran, or persist over target areas to search for mobile threats such as TELs and SAMs at ranges less than 1,500 nm (see Figure 3).

Platforms that cannot penetrate and survive dense, sophisticated IADS will be of little to no utility in future operating environments.

SURVIVABILITY OF PENETRATING AIRCRAFT

Although range is arguably the most important requirement for the future family of systems, platforms that cannot penetrate and survive in the teeth of dense, sophisticated IADS described in Chapter 1 will be of little to no utility in future operating environments. Decisions regarding the future long-range strike platform mix must therefore be informed by the long-term viability of the US military's stealth advantage and the need for airborne electronic attack platforms to support aircraft designed to penetrate advanced air defenses.

Stealth aircraft, in the most basic sense, are not "invisible" to the enemy nor do they need to completely avoid detection to survive in hostile airspace. Instead, "stealth" is used to describe a combination of planform shaping, radar absorbent materials, and tactics to avoid detection by air defense radars. Planform shaping is considered to provide the majority of an aircraft's passive signature reduction, which is then enhanced by adding radar-absorbent materials. Stealth aircraft also include design techniques such as "hiding" engine inlets and exhaust in the upper surfaces of its planform, and cooling/dispersing hot engine exhaust to reduce the probability of detection by enemy infrared sensors. Rather than rendering an aircraft invisible, these low-observable technologies, combined with smart

[74] Ehrhard and Work, "Range Persistence, Stealth and Networking: The Case for a Carrier-Based Unmanned Combat Air System," pp. 170–173.

mission planning and tactics designed to avoid lethal air defense areas, reduce information available to an enemy and prevent him from achieving a successful firing solution.[75]

As in any military competition, the advantages of technological innovations such as low observability in the aircraft versus air defense, or "hiders versus finders" competition have tended to instigate the development of offsetting technologies and tactics.[76] With the delivery of the first stealth F-117 fighter-bomber in 1982, the US military gained a new, revolutionary capability for attacking targets in defended airspace. DoD's current generation of stealth aircraft, such as the B-2 and F-22, provide US airmen with the low observability needed to reduce the effectiveness of modern acquisition and targeting radar systems. Despite the continuing evolution of US low-observable capabilities, some stealth skeptics contend that inventions such as active electronically scanned array (AESA) radars and "Moore's Law" advances in processing power now advantage counter-stealth systems and will outstrip the capacity of US aerospace engineers to design future penetrating aircraft and weapons.[77]

The first argument in favor of counterstealth technology focuses on the potential of new air defense systems that use very-high-frequency (VHF) and ultra-high-frequency (UHF) radar wavelengths of 30 to 600 centimeters to detect stealth aircraft believed to be designed primarily to defeat "X band" radar wavelengths of 7 to 25 millimeters.[78] Early VHF and UHF long-wavelength radars, which have been operational for decades, could not provide information on approaching aircraft accurate enough for targeting and fire control. Today, some claim new systems that combine VHF radars with advanced targeting and fire control systems, aided by improved information processors, may provide an enhanced counterstealth capability.[79]

A second line of thought suggests that new "passive coherent location" systems will be capable of detecting stealth aircraft. Passive location systems take advantage of emitters of convenience, such as television, mobile phone and radio

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[75] For an extensive discussion on stealth and counter-stealth, see Rebecca Grant, *The Radar Game* (Arlington VA: IRIS Independent Research, 1981). In essence, stealth has the effect of reducing information gathered by surveillance systems and, as a consequence, their ability to provide useful cues to targeting systems in terms of aircraft range, angle, and altitude.

[76] For an explanation of this "hiders versus finders" competition, see Michael G. Vickers and Robert C. Martinage, *The Revolution In War* (Washington, DC: CSBA, December 2004), pp. 109–114.

[77] See Lieutenant Colonel Arend G. Westra, "Radar versus Stealth: Passive Radar and the Future of U.S. Military Power," *Joint Force Quarterly,* 4th Quarter 2009, pp.136–143. Also see Gordon E. Moore, "Cramming More Components onto Integrated Circuits," *Electronics,* April 19, 1965, accessed at ftp://download.intel.com/research/silicon/moorespaper.pdf. Dr. Moore projected that the number of transistors and resistors that can be placed on a single integrated circuit doubles every two years. In 2005, he declared that "Moore's law" based on silicon chip technology would not continue indefinitely.

[78] Westra, "Radar versus Stealth," p. 139.

[79] Westra, "Radar versus Stealth," p. 139.

Moore's law and new technologies will benefit both sides of the stealth-counterstealth competition, not just the defense.

transmitters to detect reflections from aircraft without generating a revealing radar beam. Although the first known experiment with passive location radars took place in 1935, insufficient signal-processing power to "integrate data from multiple receivers, cancel signal interference, differentiate real targets from ghost signals and clutter, and establish a target track" have prevented them from becoming operationally useful.[80] New passive location systems equipped with advanced processors, such as the Czech-made VERA-E that China would like to procure, are thought by some to have overcome these limitations and offer a means of detecting stealth aircraft.[81]

There are reasons to doubt that either of these approaches has given a decisive advantage to the defense. First and foremost, Moore's law and new technologies such as AESA radars will benefit both sides of the stealth-counterstealth competition, not just the defense. Incorporating advanced sensors and processors similar to the F-35's avionics architecture into future long-range low-observable aircraft would allow them to rapidly compute flight path changes to avoid previously unknown "pop-up" air defense threats, something that the F-117 was incapable of doing. Furthermore, equipping new long-range strike aircraft with AESA radar could enable them to actively jam enemy radars and use countermeasures such as digital radio frequency memory (DRFM) to provide false information back to enemy radars on the aircraft's RCS, range, angle, and velocity.[82] Modern combat aircraft can also be designed to have broad-band low-observable characteristics that counter not only high-frequency SAM engagement radars, but also low-frequency VHF radars.[83] Emerging tailless aircraft design concepts, such as the Navy's Unmanned Combat Air System (UCAS), by virtue of their

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80 Westra, "Radar versus Stealth," p. 140.

81 Jiri Kominek, "China seeks Czech military technology through Europe's backdoor," The Jamestown Foundation, accessible online at http://www.asianresearch.org/articles/2761.html.

82 DRFM is a well known technology for copying an incoming radar signal and digitally modifying it before transmitting it back to the enemy radar. DRFM can increase aircraft survivability by "delaying, denying, and defeating threat air-to-air and surface-to-air missile systems operating in the radio frequency spectrum." see William Balderson, Deputy Assistant Secretary of the Navy (Air Programs), statement before the Airland Subcommittee, Senate Armed Services Committee, April 26, 2007, p. 4, accessible online at http://www.globalsecurity.org/military/library/congress/2007_hr/070426-balderson.pdf, and David A. Fulghum, "Airborne Electronic Attack to Become Joint and Centralized," Aviation Week, May 9, 2010, accessible at http://www.aviationweek.com/aw/blogs/defense/index.jsp?plckController=Blog&plckScript=blogScript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog%3A27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post%3Ab402bc31-4ef6-4a93-ab8e-42b784dd5c1c. Also see Richard J. Wiegand, "Electronic Counter Measure System Utilizing a Digital RF Memory," Patent 4,743,905, May 10, 1988, pp. 1–2, accessible online at http://www.patentstorm.us/patents/4743905/fulltext.html.

83 See Bill Sweetman, "Ultra Stealth," *Aviation Week*, accessible online at http://www.aviationweek.com/aw/jsp_includes/articlePrint.jsp?storyID=news/DTI-Bomber.xml&headLine=Ultra%20Stealth.

absence of vertical planform elements — which are generally incompatible with low-frequency RCS reduction — may be capable of such low-observability.[84]

As for passive location radar systems, there is significant doubt that they will be capable of overcoming the false information they tend to generate or the effects of potential US countermeasures.[85] Penetrating aircraft using passive deception methods, such as dispensable or towed decoys that generate multiple false targets, could create a "cloud" of false information to confuse enemy air defenses. Fusing information from many different tracks, including false data generated by deception methods, and separating truth from fiction would be very difficult for a defender using passive location radar systems, especially in the midst of the fog and friction that characterize a combat environment. Additionally, radar-based passive location air defenses dependent on a centralized network would be vulnerable to physical and (possibly) cyber attacks. When asked about the potential of passive location radar systems, Dr. Kaminksi, former Under Secretary of Defense for Acquisition and Technology, observed that while it is easy to make sweeping claims that they will work, "actually using them to detect targets in a many-against-many with counters environment" would be extremely difficult, at best.[86]

The US military has been able to operationalize advances in processing power and other critical technologies more quickly than our nation's potential adversaries.

Over the history of the stealth-counterstealth competition, the US military, backed by a strong aerospace industry, has been able to operationalize advances in processing power and other critical technologies more quickly than our nation's potential adversaries. With appropriate funding, the aerospace industry should be capable of developing the next generation of low-observable capabilities needed to preserve the US military's survivability advantage. Perhaps the strongest indication that DoD remains confident in the long-term viability of stealth is evidenced by its commitment to field a low-observable fighter force. Three Services

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84 See "U.S. Navy's Unmanned Combat Air System Demonstration (UCAS-D) Program," accessible online at http://www.northropgrumman.com/review/005-us-navy-ucas-d-program.html#requirements. Also see David A. Fulghum, "Northrop Crafts Multimission N-UCAS," Aerospace Daily and Defense Report, March 21, 2008, accessible online at http://www.aviationweek.com/aw/generic/story_generic.jsp?channel=defense&id=news/NUCAS032108.xml&headline=Northrop%20Crafts%20Multimission%20N-UCAS.

85 Office of the Secretary of the Air Force, "USAF Analysis of Passive Coherent Location Systems," Secretary of the Air Force Public Affairs, Washington, D.C., June 15, 2001.

86 From the author's interview with Dr. Kaminski, October 22, 2009.

are investing the majority of their combat aircraft budgets to procure F-35s.[87] With this degree of confidence, it would seem that DoD would want to provide its long-range strike family of systems with the same survivability advantage.

OTHER KEYS TO SURVIVABILITY

The survivability of long-range strike aircraft and standoff weapons, both of which penetrate air defenses, is more than a matter of attaining the lowest possible RCS to avoid enemy detection. Against modern air defenses, strike packages achieve survivability through the coordinated use of passive and active electronic warfare measures, including stealth, expendable decoys that confuse and saturate an air defense network, described in Chapter 1, and self-protection capabilities such as electronic attack systems, air-to-surface anti-radiation missiles to destroy enemy radars and air-to-air missiles to kill air interceptors.[88]

As the previous section notes, AESA radars would give future long-range strike aircraft the potential to do more than deliver air-to-surface munitions with precision. For example, the F-35's AN/APG-81 AESA radar has a multi-mode capability to support electronic attack missions, cue strikes against multiple moving ground targets, and support air-to-air strikes against enemy aircraft. The advantage of large payloads inherent to long-range strike systems such as bombers would enable them to carry a mixed load of air-to-ground and air-to-air weapons, including the AIM-120 Advanced Medium-Range Air to Air Missile (AMRAAM). Providing future long-range penetrating aircraft with AESA radars and air-to-air weapons would increase their overall survivability against pop-up air threats, especially for independent operations deep into hostile airspace when unaccompanied by a supporting strike package.

Electronic attack has long been a key component of US strike operations. During World War II, the proliferation of Germany's Freya early warning radar and Wurzburg ground control intercept radars threatened the success of Allied

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[87] Today, stealth fighters constitute a little more than 7 percent of DoD's total inventory of fixed-wing combat air forces. By 2020, DoD's inventory of 5th generation stealth aircraft will grow by 350 percent. For the Air Force, over 75 percent of its fighters will be 5th generation when its last F-35A is delivered in FY2034. For a description of the F-35 program see Jeremiah Gertler, "F-35 Joint Strike Fighter (JSF) Program: Background and Issues for Congress," Congressional Research Service, December 22, 2009, accessible online at http://www.fas.org/sgp/crs/weapons/RL30563.pdf. See also See "Aircraft Investment Plan Fiscal Years (FY) 2011–2020," Department of Defense, February 2010, p. 12, accessible online at http://www.militarytimes.com/static/projects/pages/30yearaviation.pdf.

[88] DoD defines electronic warfare as operations to secure and maintain freedom of action in the electromagnetic spectrum. Electronic warfare is subdivided into electronic attack, electronic protection and electronic warfare support. Electronic attack includes the use of electromagnetic energy, directed energy, or anti-radiation weapons to degrade, neutralize, or destroy enemy combat capabilities. See Joint Publication 3-13.1, "Electronic Warfare," January 27, 2007, pp. v–vi and I-2–I-4, accessible online at http://ftp.fas.org/irp/doddir/ dod/jp3-13-1.pdf.

bombing missions in Europe. The use of jamming and tactics, such as dispensing chaff to clutter German radars, saved thousands of US airmen and hundreds of aircraft.[89] Operations in Vietnam during the 1960s prompted the development of the Navy Department's EA-6B and the Air Force's EF-111 tactical jamming support aircraft. During Operation Allied Force, US "Compass Call" EC-130H communication jamming aircraft, "Prowler" EA-6Bs and F-16CJ fighters flew thousands of missions to suppress Serbian air defense threats that challenged the ability of non-stealthy aircraft to penetrate and survive. Moreover, a DoD post-Operation Allied Force analysis concluded that AEA will remain a critical means for enabling future air operations in contested environments: "(a) complete and comprehensive AEA capability will continue to be needed as part of a dominating United States air superiority capability. AEA and other survivability approaches, such as air vehicle electronic self-protection, physical threat destruction, low-observable technology, and information operations are individually and collectively most effective when employed in a balanced manner."[90]

As DoD assesses alternatives for new AEA capabilities that will "buy back airspace" in these future air operations, it should ensure they have the same attributes that are needed by other long-range strike systems for the new planning framework described in Chapter 1, e.g., all-aspect, broad-band low-observable characteristics and sufficient range and persistence to support operations deep into an enemy's landmass.

New AEA capabilities should have the same attributes that are needed by other long-range strike systems.

ATTRIBUTES OF UNMANNED AND MANNED AIRCRAFT

> Unmanned systems provide additional advantages and contributions beyond replacing humans in dull, dirty, and dangerous roles. For example, higher survivability, increased endurance, and the achievement of higher G-forces, as well as smaller sizes and thus signatures, in UASs are all made possible by removing the human from the aircraft.
>
> — Department of Defense Unmanned Systems Roadmap 2007–2032 [91]

Using the new planning framework from Chapter 1 as a baseline, this section assesses the advantages and disadvantages of unmanned long-range strike aircraft

[89] See Alfred Price, *The History of US Electronic Warfare, Volume I* (Association of Old Crows), p. 197.

[90] See "Airborne Electronic Attack Analysis of Alternatives (AEA AoA)," 2002, p. 1, accessible online at http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA399083&Location=U2&doc=GetTRDoc.pdf. For additional details on OAF lessons-learned, see "Kosovo/Operation Allied Force After-Action Report," Department of Defense, January 31, 2000, p. xxiv.

[91] See "Unmanned Systems Roadmap 2007–2032," Department of Defense, December 10, 2007, p. 19.

as compared to manned and optionally manned variants.[92] Chapter 3 will assess the potential for future unmanned designs to increase the survivability, range and persistence of carrier air wings, since carrier aircraft are constrained by different physical and operational factors than land-based platforms.

There is little difference between the survivability characteristics of unmanned and manned aircraft that are based on the same planform.

The US military has recognized that unmanned aircraft systems (UAS) have certain advantages over traditional manned aircraft. Unmanned systems are unconstrained by the physiological needs of a human aircrew, can endure up to the limits of the aircraft's systems (which exceed human limitations and often by a significant margin), and can be used on missions without risking the loss of a pilot. Accordingly, over the last ten years DoD has fielded thousands of UASs ranging in size from tiny hand-launched, man-portable models to the RQ-4 Global Hawk with a wingspan of 116 feet. Their freedom from the limitations of a human pilot makes UASs the platform of choice for very-long-duration missions. DoD's 2007 "Unmanned Systems Roadmap" provides an excellent summary of why UAS are particularly suited to performing "dull, dirty, and dangerous" missions such as extremely-long-duration flights (the dull), operating in contaminated environments (the dirty), or on missions that would pose an unacceptably high risk to a human crew (the dangerous).[93]

Beyond the absence of a crew, however, there is little difference between the survivability characteristics of unmanned and manned aircraft that are based on

92 "Optionally manned" refers to platforms that are equipped to be flown with or without an aircrew.

93 "Unmanned systems are highly desired by combatant commanders (COCOMs) for the many roles these systems can fulfill. Tasks such as mine detection; signals intelligence; precision target designation; chemical, biological, radiological, nuclear, explosive (CBRNE) reconnaissance; and communications and data relay rank high among the COCOMs' interests." See "Unmanned Systems Roadmap 2007–2032," p. 19.

FIGURE 4. ILLUSTRATIVE STEALTH BOMBER DESIGN CENTER-LINE PROFILE

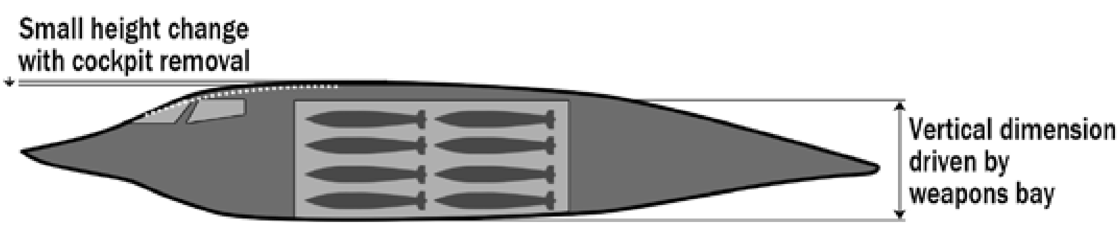

Image: CSBA

the same planform.[94] The passive signatures of large low-observable military aircraft such as the B-2 are overwhelmingly driven by the shape of their outer mold lines rather than the presence of a cockpit. For a large strike aircraft required to carry sizable internal weapons payloads, the dimensions of its planform are driven by the dimensions of its weapons bay, as shown in Figure 4. Removing the cockpit would not significantly change the aircraft's planform. Moreover, the upper surfaces of a future large stealthy aircraft can be designed to minimize the potential that the interior of its cockpit will reflect revealing radar energy.

The mission effectiveness of unmanned aircraft is more than a matter of platform survivability. Today, all four US military Services are investing in unmanned platforms that are partially autonomous and partially controlled remotely by pilots and mission commanders.[95] Maintaining a "man-in-the-loop" for hundreds of unmanned aircraft operating simultaneously in future air campaigns would require a complex infrastructure of secure C2 links and huge bandwidth capacity. Given that current-generation unmanned aircraft are heavily dependent on off-board inputs for mission changes, threat avoidance, target cueing, aircraft systems contingency management and, above all else, decisions about weapons release, UAS operations in degraded communications environments will likely be very difficult. The investments (described in Chapter 1) being made by potential adversaries to attack these crucial, but inherently vulnerable connections, should give DoD pause before building all of its future long-range strike capabilities as unmanned systems. As Lieutenant General Breedlove, USAF Deputy Chief of Staff for Operations, Plans and Requirements, has noted:

UAS operations in degraded communications environments will likely be very difficult.

> We are in a situation now where we are a little bit bold by the success of our unmanned capability. We need to be very, very careful to remember that our unmanned capability is flourishing in an absolutely, completely, uncontested environment. There are game-changers out there right now that could change that [permissive environment] in a minute.[96]

To be fair, future technologies promise to reduce the dependence of unmanned aircraft on remote C2 architectures. A number of current generation UASs are capable of limited autonomous operation, including internal aircraft management functions, takeoffs and landings and performing other pre-planned tasks. Developmental UASs, such as the Navy's X-47B, are testing the feasibility of

94 The passive signature of unmanned aircraft could be affected if they require additional apertures for data links that reflect radar energy.

95 Admiral Roughead recently remarked "there is no such thing as an unmanned system," reflecting the need for current generation UAS to have continuous links to mission commanders and pilots. See "The Future of Unmanned Naval Technologies," The Brookings Institution, November 2, 2009, p.15, accessible online at http://www.brookings.edu/events/2009/1102_naval_technologies.aspx.

96 See "Air Force General Cautions Against Using Unmanned Aircraft For Nuclear Attacks," *Defense News*, April 22, 2010.

autonomous air refueling operations and landing on moving aircraft carrier decks. Unfortunately, providing true autonomy for complex unmanned systems that must operate in dynamic high-threat combat environments is beyond today's state-of-the-art technologies.[97]

Absent full autonomy or off-board C2, unmanned long-range strike aircraft would be limited to flying pre-programmed routes to strike known fixed targets. In effect, they would become re-usable cruise missiles that carry a larger payload. Without a man in the loop, unmanned aircraft are incapable of changing targets in-flight, locating and characterizing targets that have moved, or determining the difference between an actual target and a convincing decoy. In the words of a former commander of the USAF Air Combat Command, manned aircraft "also have much greater flexibility to change missions and to adapt to different scenarios than do cruise missiles and unmanned aircraft."[98] Even if equipped with current automatic target recognition systems, the sheer computational power needed by

[97] According to General Schwartz: "while unmanned platforms likely better serve this required persistence from a physiological perspective, current technology does not allow for the type of fully autonomous and dynamic systems that are required in an opposed and networked environment. See General Norty Schwartz, "Keynote Address at the Air, Space, and Cyberspace Power in the 21st Century Conference," January 20, 2010, accessible online at http://www.af.mil/shared/media/document/AFD-100121-002.pdf.

[98] General (retired) John Michael Loh, "Simulation-Reality Mismatch," *AIR FORCE Magazine*, March 2010, p. 34.

FIGURE 5. X-47B UCAS

Source: US Navy

a UAS to autonomously determine if a weapons release would result in unacceptable collateral damage goes well beyond the state of the art in artificial intelligence.

One additional operational issue for a potential future unmanned long-range strike aircraft is worth consideration: based on nuclear safety and surety requirements, it may not be capable of supporting nuclear strike missions.

Turning from operational concerns to resource issues, DoD is presently considering developing a future bomber that could be unmanned based in large part on the persistent belief that removing a cockpit from an aircraft has the potential to significantly reduce its cost while simultaneously increasing its performance.[99] This is not always the case. Removing a cockpit from aircraft that are fighter-sized

[99] For example, see Bill Sweetman, "NGB Questions," *Aviation Week,* May 29, 2008, accessible online atahttp://www.aviationweek.com/aw/blogs/defense/index.jsp?plckController=Blog&plckScript=blogscript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog%3A27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post%3A8bf1ca39-1e33-4d93-a76a-a01def0cb680RES.

FIGURE 6. EXAMPLE MANNED/UNMANNED AIRCRAFT WEIGHT COMPARISON

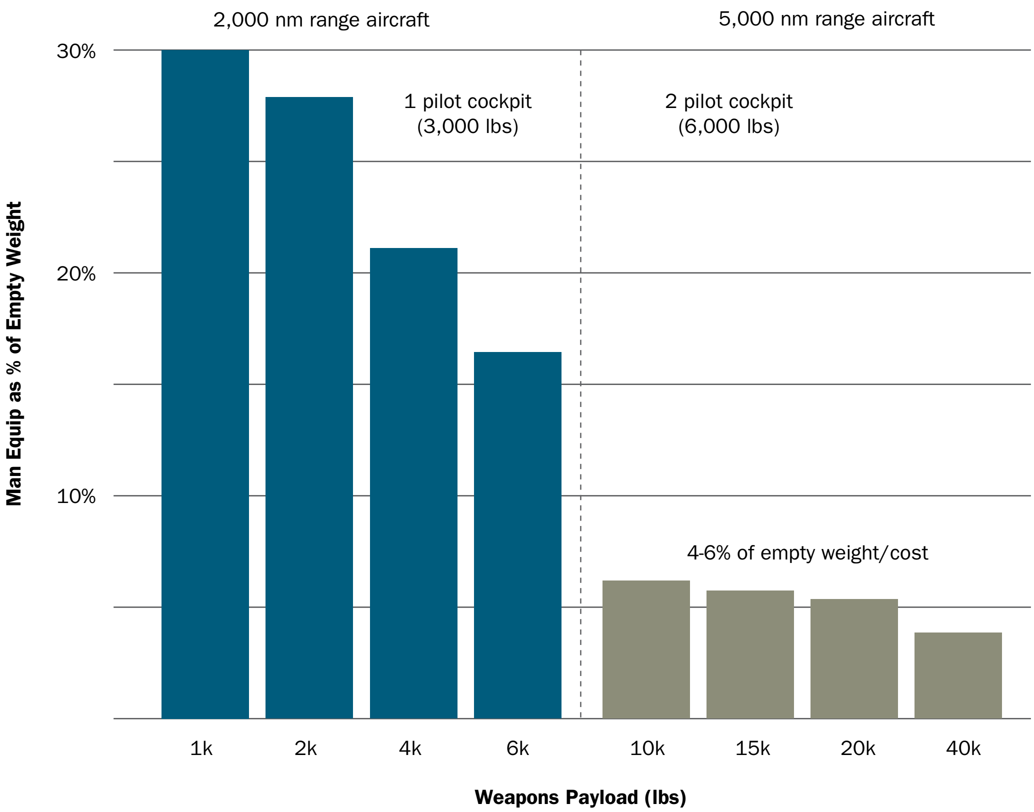

Image: CSBA

or smaller can indeed generate significant reductions in weight and cost as a percentage of the total airframe. For a large aircraft such as a bomber, however, the requirements to support two crewmembers do not increase its empty weight significantly on a percentage basis. For example, the accommodations for two pilots in a combat aircraft approximately the size of a B-2 with a 40,000-pound payload might weigh around 6,000 pounds, just 4 percent of its empty weight.[100]

This 4 percent weight "penalty" for a manned aircraft would not make a significant difference in its useful fuel payload, which translates directly to mission range and persistence, compared to the same aircraft design sans cockpit.

Continuing with this example, it is a well-accepted fact that the cost of large modern aircraft is a linear function of their weight. In other words, DoD buys aircraft by the pound. Based on the previous comparison, if weight was the only consideration there would be little difference—approximately 4 percent—between the cost of procuring unmanned, manned, and optionally manned aircraft that are based on the same aircraft planform.

If weight was the only consideration there would be little difference between the cost of unmanned, manned, and optionally manned aircraft

Compared to equivalent-sized manned aircraft designs, testing and mission reliability requirements for a large UAS strike platform may increase its developmental cost. Persistence is one of the most compelling attributes of unmanned aircraft systems. Unfortunately, unmanned aircraft that are designed to fly very-long-duration sorties require more redundancy in their critical subsystems to reduce the probability that an in-flight system failure would jeopardize mission success. As an example, a UAS designed for fifty-hour sorties would require a 250 percent increase in mean time between critical failures for its flight controls, communications, fire and leak detection, guidance and electrical systems to achieve the same 80 percent probability of mission success as a UAS designed for eighteen-hour missions. The need for additional backup systems increases the UAS's weight and cost. Compared to a manned aircraft of equivalent size, moreover, a large UAS could require a year or more of additional testing time during its Engineering and Manufacturing Development (EMD) phase, further increasing its cost.

In summary, a set of beliefs concerning the advantages of unmanned aircraft have evolved from years of real-world experience with small UASs designed to operate in permissive environments. In many cases these beliefs, such as the notion that a large UAS may be inherently more stealthy and would cost less than a manned long-range strike aircraft, do not hold up to close scrutiny. Indeed, there are significant disadvantages to operating unmanned aircraft in non-permissive environments with dynamic targeting requirements that are both likely characteristics of future long-range strike missions.

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[100] The 6,000 pounds for a two-person cockpit includes the weight of ejection seats, life support/oxygen generating equipment, avionics, aircraft controls, and other incidental equipment.

There is another option for a future long-range strike platform. Designing an *optionally* manned aircraft that is equipped to fly with or without pilots depending on mission requirements may have greater mission flexibility than either manned or unmanned platforms.[101] Optionally manned aircraft could fly without a crew for extremely long-duration missions into very high threat areas, or with a crew when a human presence is required to react quickly to pop-up threats, take advantage of fleeting target opportunities, or for nuclear strike missions. The ability to fly with an aircrew would be especially important for deep attack operations into environments postulated by Chapter 1 where sustained command and control may not be sufficiently reliable. Assuming they are based on the same planform, moreover, there would not be much of a difference between the cost of unmanned and optionally manned variants of a large land-based strike aircraft.

[101] Optionally manned aircraft are a reality. Boeing has flown an optionally manned A/MH-6X demonstration variant of the "Little Bird" helicopter used by the US Army Special Operations Command. Sikorsky and the US Army have announced their intentions to develop an optionally piloted variant of the "Black Hawk" UH-60 utility helicopter. See "U.S. Army, Sikorsky Team on Optionally Piloted Black Hawk Demos," Defense News, April 15, 2010, accessible online at http://www.defensenews.com/story.php?i=4584545.

TABLE 1. MANNED/UNMANNED/OPTIONALLY MANNED AIRCRAFT COMPARISON

	Manned	Unmanned	Optionally Manned
Aircrew at Risk	Yes	No	Mission dependent
Stealth Characteristics	Negligible difference	Negligible difference	Negligible difference
Mission Persistence	Limited by human factors	Limited by machine factors	Mission dependent
Need for Secure C2, Adequate Bandwidth	Desired	Required for current UAS	Mission dependent
Inflight Retasking & Situational Awareness	Immediate and onboard	Remote or by rule set	Mission dependent
Weapons Release Consent	Immediate and onboard	Remote or by rule set	Mission dependent
Empty Weight	4-6% increase compared to unmanned		4-6% increase compared to unmanned
Cost	Negligible difference	Negligible difference	Negligible difference
Probability for Loss of Control		Very long sorties increase need for on-board systems redundancy	Very long unmanned sorties increase need for on-board systems redundancy
Nuclear Mission C2	No issues	Not capable of meeting nuclear C2 requirements	No issues when manned

PENETRATING AND STANDOFF STRIKE ATTRIBUTES

> Never provide your adversary with only a few problems to solve because if you do, he'll solve them.
>
> —Robert D. Kaplan[102]

Unsurprisingly, range is a crucial parameter for evaluating a long-range strike family of systems and, as the first section of this chapter pointed out, a "reach" of around 2,500 nm would appear to be adequate to cover potential future target sets. Earlier sections noted that targets at extremely long ranges would remain the responsibility of larger, land-based aircraft, while sea-based aircraft with a combat radius of 1,500 nm could permit aircraft carriers to launch strike sorties against targets from outside the range of current-generation ASCM and ASBM threats. While aircraft with these ranges, supported by aerial refueling, provide a global strike capability, standoff weapons extend the reach of strike platforms and permit them to launch attacks against targets in highly defended areas while remaining outside the detection range of enemy air defenses. This section assesses the advantages of a future force mix that can conduct both penetrating (direct) and standoff long-range strikes against the target sets and operating environments characterized in Chapter 1, as opposed to a force that is capable of only one kind of attack or the other.

A long-range strike family of systems capable of attacking targets only from standoff distances creates a one-dimensional problem for defenders.

A long-range strike family of systems capable of attacking targets only from standoff distances creates a one-dimensional problem for defenders. If DoD chooses to field a purely standoff long-range strike force, it will permit potential adversaries to optimize their air defenses to defeat US cruise and ballistic missiles. These opponents might also choose to further focus their military investments on the kinds of capabilities mentioned in Chapter 1 that are intended to attack US C4ISR networks that are essential to providing standoff platforms and cruise missiles with targeting information. Similarly, a standoff-only US long-range strike portfolio would further incentivize potential defenders to increase their use of passive measures that are particularly effective for countering the current generation of US standoff munitions that have limited ranges and small payloads, such as hardening, deeply burying, mobilizing and moving military systems even further inland.

A mix of standoff and penetrating strike systems, by contrast, presents adversaries with a multi-dimensional air defense problem. Penetrating aircraft with sufficient range to reach beyond coastal areas to threaten targets across the width and depth of an enemy's landmass would greatly complicate the enemy's strategic and operational planning. To counter this threat, defenders would be

[102] Robert Kaplan, "How We Would Fight China," *Atlantic Monthly*, June 2005, accessible online at http://www.theatlantic.com/magazine/archive/2005/06/how-we-would-fight-china/3959/1/.

forced to choose between dispersing their air defenses over a greater geographic area or investing in additional SAMs, fighters and air defense battle networks, potentially at the expense of buying new offensive capabilities. DoD's leadership has acknowledged the "cost-imposing" impact of penetrating strike aircraft during the Cold War. Senior US policy makers should consider factors such as these in developing the next long-range strike family of systems.[103]

From the perspective of US commanders, standoff weapons are essential for striking fixed targets in very heavily defended areas or when use of a penetrating aircraft is not feasible. Long-range standoff weapons such as cruise missiles are essentially small expendable unmanned aircraft equipped with guidance and propulsion systems that allow them to attain ranges of 500 nm or more depending on their weapons payload and configuration. Today's conventional cruise missile inventory consists of the Air Force's Conventional Air-Launched Cruise Missile (CALCM), the Navy's TLAM and the shorter-range Joint-Air-to-Surface Standoff Missile (JASSM).[104] Together they form a class of weapons useful for striking fixed targets from beyond the range of enemy air defenses. CALCMs were first used operationally when B-52s flying from Louisiana fired the opening shots of the First Gulf War by launching thirty-five missiles. The Navy's newest TLAM, called the Block IV Tactical Tomahawk "TACTOM," can carry a 1,000-pound unitary conventional warhead, has a two-way UHF satellite link for communicating target changes while in flight, and is equipped with a camera to pass information as it loiters over a target area.[105] TLAMs are carried by a variety of Navy surface and undersea vessels, including guided-missile cruisers and destroyers (CGs and DDGs), attack submarines (SSNs) and *Ohio*-class guided-missile submarines (SSGNs). Navy warships first used TLAMs during the First Gulf War to launch 288 independently-targeted strikes against high-value targets in Iraq. The low-

Long-range standoff weapons such as cruise missiles are essentially small expendable unmanned aircraft equipped with guidance and propulsion systems.

[103] Former Secretary of Defense William Perry testified to the Senate Armed Services Committee that during the Cold War: "the Russians spent an excessive amount in our judgment on air defense and they would not have been spending that on air defense did we not have the bomber force and if they had not been spending it on air defense, they would have been spending it on offensive forces that might have been a greater worry to us." Senate Armed Services Committee, May 7, 2009, webcast accessible online at http://armed-services.senate.gov/Webcasts/2009/May/05-07-09Webcast.htm.

[104] CALCMs, converted from excess nuclear-tipped Air Launched Cruise Missiles, can deliver unitary conventional warheads up to 3,000 pounds in weight. The latest "CALCM-D" variant is equipped with a 1,200 pound enhanced penetrating warhead. See US Air Force Fact Sheet "AGM-86B/C/D Missiles," accessible online at http://www.af.mil/information/factsheets/factsheet_print.asp?fsID=74&page=1.

[105] Block IV TACTOMs have a range of approximately 870 nm and can be retargeted inflight to strike up to 15 preplanned targets. See Col Steven J. Walker brief "Managing the Net-Enabled Weapons Kill Chain Testing in a Live-Virtual-Constructive Environment," Joint Command and Control for Net-Enabled Weapons Joint Test, accessible online at http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA513903&Location=U2&doc=GetTRDoc.pdf. Also see "Tomahawk Cruise Missile," accessible online at http://www.raytheon.com/capabilities/products/stellent/groups/public/documents/content/cms01_055764.pdf.

observable, subsonic JASSM has a range of over 200 nm and an infrared terminal seeker to give it some capability against relocatable targets.[106]

Although standoff weapons will likely remain a central element of the US military's long-range strike capability, a future force that is limited solely to long-range standoff strikes is unlikely to cover many key enemy mobile or relocatable targets as defined in future air campaign target sets described in Chapter 1. Standoff missiles with long flight times or lacking a self-contained capability to locate and attack targets in denied communications environments will be limited to conducting strikes against known fixed targets, leaving mobile and relocatable targets untouched. As an illustrative example, a CALCM would require almost two hours to reach a target located 1,000 nm from the missile's launch point, well in excess of the time needed for a road-mobile missile launcher to move, erect,

[106] The Air Force is considering developing future JASSM variants with data links for inflight updates and capability to attack moving maritime targets. A future "JASSM-Extended Range" (JASSM-ER) may have a range in excess of 500 nm. See "JASSM — The Air Force's Next Generation Cruise Missile," Air Armament Center Public Affairs, Air Force Materiel Command, March 8, 2006, accessible online at http://www.afmc.af.mil/news/story.asp?storyID=123017010.

FIGURE 7. MASSIVE ORDNANCE PENETRATOR

Source: US Air Force

shoot, move again and hide. To strike targets that are able to relocate in minutes, long-range standoff weapons must receive aimpoint updates while in flight, making them dependent on off-board C4ISR architectures that are vulnerable to enemy disruption.[107] In the context of air campaigns where many hundreds of mobile and relocatable aimpoints might be attacked on a daily basis, this would place a very heavy strain on a commander's C4ISR assets. The only way to free cruise missiles from this dependency on off-board systems would require inventing and developing autonomous on-board systems that can find, characterize and strike mobile and relocatable targets.

In addition to their limited capabilities against mobile/relocatable targets, standoff weapons cannot carry conventional warheads large enough to be effective against very hard and very deeply buried targets. Similar to an aircraft, the lethal payload of a cruise missile, typically 1,000 to 2,000 pounds, is constrained by the size of the missile body and the need to account for fuel, a propulsion unit and guidance systems. Thus to defeat the relatively small warheads found on conventional cruise missiles, adversaries could simply harden their high-value assets. By contrast, a single B-2 can deliver eight 5,000-pound GBU-28 direct-attack laser-guided penetrating weapons made famous for their "bunker busting" during the First Gulf War. When the Air Force accepts delivery of its 30,000-pound Massive Ordnance Penetrator, B-2s will be the only US military platform capable of using it to defeat very hard and deeply buried targets such as WMD production and storage facilities in contested environments.[108] New warhead technologies yet to be developed could theoretically increase the penetrating potential of 1,000–2,000-pound class of stand-off weapons, but this is not assured.

The effectiveness of long-range standoff weapons also depends on their ability to *reach* their intended targets. While CALCMs, TLAMs and JASSMs are considered long-range weapons, if they are launched by *non-penetrating* aircraft and sea-based platforms that are required to standoff outside the effective ranges of an enemy's perimeter air and missile threats such as those described in Chapter 1, they will be unable to reach targets located deep within the interiors of large countries. Increasing the reach of standoff cruise missiles will require the development of larger — and hence more expensive — missile bodies.[109]

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107 Standoff weapons could receive inflight updates from overhead satellites and penetrating ISR platforms if data links are available. Of course, if a penetrating ISR platform is needed to provide standoff weapons with targeting information, it would make sense to equip it to carry PGMs in the first place.

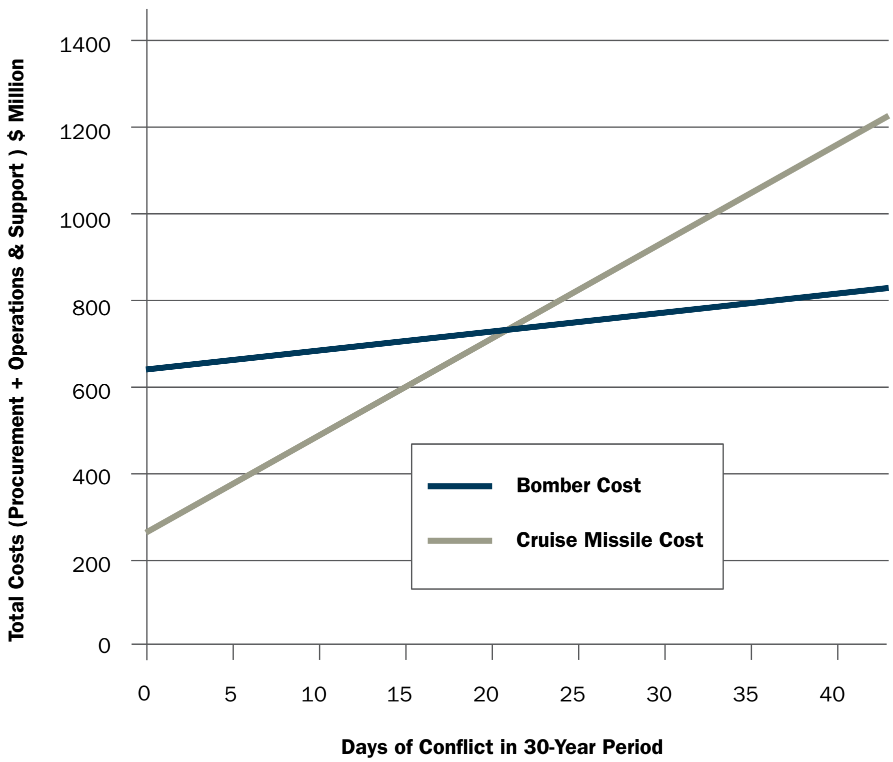
108 Massive Ordnance Penetrators (MOP) are designed to penetrate up to 200 feet underground before exploding. See "B-2, MOP a devastating combo," 509th Bomb Wing Public Affairs, December 27, 2007, accessible online at http://www.whiteman.af.mil/news/story.asp?id=123080436.

109 The US military could also increase the reach of its standoff weapons by developing conventional ballistic missiles. This option is addressed in Chapter 3.

Cruise missiles are vulnerable to the same air defenses that threaten larger penetrating strike aircraft.

Since they are essentially small aircraft, cruise missiles are vulnerable to the same air defenses described in Chapter 1 that threaten larger penetrating strike aircraft. Cruise missiles do have relatively small radar cross sections and can employ tactics such as flying at low altitudes to reduce their potential of detection by enemy air defenses, and the JASSM adds low observability to the weapons mix. However, modern SAM systems such as the SA-20 are advertised as having an ability to engage cruise missiles. To successfully reach targets located deep inside enemy territory, cruise missiles must fly pre-planned routes that avoid known air defense sites. Although these flight plans will be based on the best intelligence available prior to launch, strike planners cannot predict the locations of all air defense systems, especially those that move frequently. To survive in such dynamic threat environments, DoD's next generation of cruise missiles will likely need to incorporate very low passive signatures and exploit other on-board and off-board threat suppression capabilities, similar to what will be required for future penetrating aircraft. All of this would add significantly to the missile's cost.

FIGURE 8. BOMBER/CRUISE MISSILE COST COMPARISON



Source: RAND Project Air Force Paper WR-778-AF

A mix of standoff and penetrating strike capabilities, by contrast, would increase a commander's options in future air campaigns. Penetrating strike aircraft equipped with on-board sensors would provide air campaign commanders with an autonomous capability to strike the full target set with persistence while reducing the need for off-board target cueing information. This independent strike capability would be especially important for operations in environments where communications and data links may be degraded or unavailable. Furthermore, a manned penetrating platform has the potential to assess the effectiveness of its own attacks to determine if an immediate re-strike is required. This can help reduce the strain on a commander's precision-guided weapons magazine, since standoff strikes into environments that prohibit bomb damage assessments may require the inefficient use of several weapons to ensure the desired effect is achieved for a single target. It would also reduce the need for bomb damage assessment assets.

Penetrating strike aircraft also have the advantage of being more versatile than standoff weapons carriers.

Penetrating strike aircraft also have the advantage of being more versatile than standoff weapons carriers. Appropriately equipped penetrating aircraft could exploit their large payloads to perform missions other than strike, such as acting as ISR collectors or conducting airborne electronic attack in support of other penetrating weapons and aircraft. Furthermore, if appropriately equipped, penetrating platforms could deliver direct-attack *and* standoff weapons. By contrast, a non-penetrating "missile truck" would be limited to standoff attack missions only.

The US military's ability to cover future air campaign targets with standoff capabilities is affected by another consideration: the high cost of standoff weapons relative to direct-attack munitions. To deliver its payload, a cruise missile essentially throws away every on-board system it uses to reach a target area. For example, CALCM-Ds cost nearly $2 million when procured, while the unit cost for a new Block IV TACTOM exceeds $1.5 million.[110] At these prices, expending standoff missiles to reach targets that are a few hundred miles inland can be an expensive operating concept compared to employing a $22,000 JDAM delivered by a penetrating aircraft to strike the same targets, especially if the target set consists of thousands of targets as described in Chapter 1.[111] Figure 8 compares the total life-cycle cost of one new penetrating bomber that is capable of flying one sortie per day with the cost of new cruise missiles that are used at a rate of twelve per day. In the context of future air campaigns, if the US military is required to fight

[110] See US Air Force Fact Sheet "AGM-86B/C/D Missiles," accessible online at http://www.af.mil/information/factsheets/factsheet_print.asp?fsID=74&page=1. Also see Also see DoD's Selected Acquisition report for the Tactical Tomahawk Cruise Missile, December 31, 2009, and "$202.7M to Raytheon for 196 Tomahawk Block IV Missiles," Defense Industry Daily, January 27, 2010, accessible online at http://www.defenseindustrydaily.com/2027M-to-Raytheon-for-196-Tomahawk-Block-IV-Missiles-06135/.

[111] See US Air Force Fact Sheet "Joint Direct Attack Munition GBU- 31/32/38," accessible online at http://www.af.mil/information/factsheets/factsheet_print.asp?fsID=108&page=1.

adversaries equipped with moderate-threat air defenses for more than twenty days cumulatively over a thirty-year period, the total cost of a new penetrating bomber could be less than the cost of expendable cruise missiles used at a rate of twelve per day to achieve the same results as the bomber.[112] Moreover, high costs can be a limiting factor on the total number of standoff weapons procured by DoD. If the US military makes a choice to invest in an all-standoff long-range strike force, it could encourage potential adversaries to modify their planning toward operational concepts that wait for the US military to expend its magazine of standoff munitions. The high cost of standoff weapons relative to direct-attack PGMs is not lost on US commanders, as reported by General Horner, who orchestrated the US air campaign during the First Gulf War:

A future long-range strike family of systems should consist of a mix of standoff and penetrating strike capabilities.

> Cruise missiles are too expensive for sustained operations; cost was the reason Washington ordered me to stop firing Tomahawks during the Gulf War. The forty-four cruise missiles fired at Iraq in September [1996] cost more than $100 million — 100 times more than an equivalent number of B-2-delivered precision guided munitions.[113]

Summarizing these insights, and considering the stakes involved, prudence dictates that a future long-range strike family of systems should consist of a mix of standoff and penetrating strike capabilities, rather than moving toward a standoff-only force. This mix will provide future commanders with the capabilities needed to strike future target sets described in Chapter 1 while hedging against the loss of off-board C4ISR networks that would become a vulnerable center of gravity for a standoff-only force.

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[112] See Thomas Hamilton, "Comparing the Cost of Penetrating Bombers to Expendable Missiles over Thirty Years," RAND Project Air Force paper WR-778-AF, August 2010. RAND's cruise missile cost estimate did not include the cost to procure standoff launch platforms.

[113] See USAF General (retired) Charles A. Horner, "What We Should Have Learned in Desert Storm, But Didn't," *Air Force Magazine* (December 1996), accessible online at http://www.airforce-magazine.com/MagazineArchive/Pages/1996/December%201996/1296horner.aspx. Horner went on to say: "More important, current-generation cruise missiles are not effective against mobile or heavily hardened targets. If the US finds it necessary to truly influence a future Saddam-initiated crisis, planners will have to target hardened and deeply buried facilities inside Baghdad and the highly mobile Republican Guard — and convince the national command authorities of a high probability that no one will get shot down. This demands stealth aircraft and direct-attack precision weapons. Period."

CHAPTER 3 > **THE NEXT LONG-RANGE STRIKE FAMILY OF SYSTEMS**

This chapter proposes options for a new long-range strike family of systems comprised of a land-based bomber, carrier-based strike aircraft, standoff strike weapons, and AEA capabilities needed to sustain the nation's long-range strike advantage. While these options may not provide the optimum mix of long-range strike capabilities, they represent a significant improvement over the Defense Department's current program of record. Because two of the Air Force's bombers, the B-52H and B-2A, are tasked to serve as part of the nation's nuclear deterrent, a final section will assess initiatives needed to sustain the air leg of the nuclear triad, assuming that remains a priority. Each section begins by evaluating systems in the current program of record that support long-range strike missions and concludes by proposing initiatives to fill anticipated capability gaps. Each recommendation is based on insights from previous chapters that conclude DoD's next long-range strike family of systems must have the following characteristics:

> RANGE: Sufficient reach, nominally 4,000–5,000 nm between aerial refuelings for a land-based strike platform and 3,000 nm for a carrier-based platform, to strike targets deep in the enemy's interior;

> PERSISTENCE: Adequate loiter time in target areas to locate and strike mobile and relocatable targets;

> SURVIVABILITY: Sufficient all-aspect, broad-band low-observable characteristics complemented by on-board self-defense systems and off-board supporting airborne electronic attack to operate effectively in contested environments;

> INDEPENDENT OPERATIONS: Sufficient ability to conduct independent operations is essential when operating in environments where C2, off-board ISR and GPS-provided position, navigation and timing information may not be available; and

> PENETRATING AND STANDOFF STRIKE: A mix of standoff and penetrating platforms and weapons with the capability and capacity to strike the full range of targets that can number in the thousands of DMPIs in future air campaigns, including mobile, relocatable, hardened, deeply buried, and geographically deep targets — thereby vastly complicating any enemy's planning challenge.

TOWARD A BALANCED LAND-BASED BOMBER FORCE

A new penetrating bomber must be designed with a payload capacity that results in an affordable average aircraft unit cost and permits procurement of a sizable force of new aircraft.

The Defense Department's challenge is to sustain the nation's long-range strike strategic advantage. Fielding a bomber fleet with the range, persistence, and onboard systems needed to defeat fixed and mobile targets located deep within denied areas is an essential element in meeting this challenge. To survive in such an environment, penetrating bombers will almost certainly require all-aspect, broad-band stealth and self-protection features such as electronic warfare systems and potentially air-to-air missiles. The bomber force should include penetrating and standoff platforms to support operations against targets that may number in the thousands. A new penetrating bomber must be designed with a payload capacity that results in an affordable average aircraft unit cost and permits procurement of a sizable force of new aircraft. Lastly, considering a new bomber may have a service life of over thirty years, it should be designed to accept block upgrades over time that will improve its mission versatility and refresh its systems by incorporating new technologies as they are developed.[114]

ARE TODAY'S BOMBERS UP TO THE CHALLENGE?

Today's bomber force consists of 122 primary-mission aircraft with an average age of thirty-four years. Despite their age and small numbers, it would be inaccurate to say that the bomber force consists of the same aircraft that were originally developed for Cold War-era nuclear strikes.

As the long-standing workhorse of the bomber fleet, B-52s have been upgraded periodically to deliver nearly every precision and non-precision weapon in the Air Force inventory at unrefueled ranges exceeding 8,800 nm.[115] Recent modifications

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[114] As an example, the B-52 was originally designed in the 1950s to be a high altitude penetrating nuclear strike platform. B-52s have remained viable over the last 50 years due to upgrades that increased their functionality — such as becoming precision conventional strike platforms, and their flexibility — such as performing penetrating or standoff strikes depending on the nature of the threat environment.

[115] References for unrefueled ranges are accessible online at http://www.af.mil/information/factsheets. These ranges will be reduced when aircraft are carrying full weapons loads, e.g., 3,600 nm for the B-1 and 4,000 nm for the B-2. See Anthony Murch, "The Next Generation Bomber: Background, Oversight Issues, and Options for Congress," Congressional Research Service, March 7, 2008, p. 3.

to carry LITENING Advanced Targeting pods and Sniper Advanced Targeting Pods (Sniper ATP) enable B-52s to strike moving targets independently with laser-guided precision. DoD's latest budget proposal would fund an internal weapons bay upgrade that would greatly increase the B-52's capacity to carry PGMs such as the JDAM. With such improvements, the Air Force expects the B-52's service life to extend until the year 2044.[116]

The Air Force has also funded major upgrades to enable B-1s to deliver PGMs such as JDAMs, advanced cluster munitions and laser-guided bombs independently and over intercontinental ranges. A small number of B-1s are modified to carry Sniper ATPs to provide a new, persistent "eye in the sky" for identifying and striking moving targets in support of operations in Afghanistan. With a capacity to carry up to 75,000 pounds of weapons per sortie coupled with onboard synthetic aperture radars for targeting moving vehicles, B-1s have matured as a platform for conventional long-range strike missions in permissive threat environments.[117] The B-1's service life may extend to the year 2047.

Following the pattern set by the B-52 and B-1, the Air Force has invested in a series of upgrades to provide the B-2 with new avionics, weapons management, and radar systems to conduct conventional precision strikes. Today, the B-2 is the only US combat aircraft capable of delivering as many as eighty independently-targeted 500-pound JDAMs in a single sortie at unrefueled ranges of up to 6,000 nm. While B-2s excel at striking fixed targets with precision, they will not be able to attack moving ground targets unless they receive appropriate upgrades such as

[116] From an unclassified Air Force briefing "Air Force Long Range Strike Strategy," February 27, 2009.

[117] Compared to 70,000 pounds of payload for the B-52 and 40,000 pounds for the B-2. Bomber payload information accessible online at http://www.af.mil/information/factsheets/.

TABLE 2. BOMBER INVENTORY AND AVERAGE AGE

	Total Active Inventory	Primary Mission Aircraft Inventory	Average Age in Years
B-2A	20	18	16
B-1B	66	50	23
B-52H	76	54	48

the ability to carry and cue the new Small Diameter Bomb II (SDB II).[118] The B-2s are expected to remain part of the bomber force until 2058.

Notwithstanding their upgrades and expected longevity, B-52s and B-1s are no longer penetrating strike aircraft. In the early 1990s, the Air Force prohibited B-52s from penetrating medium- and high-threat areas.[119] Even with its smaller radar cross-section (RCS) and higher sprint speeds relative to the B-52, B-1s have been limited by the Air Force to standoff attacks in high-threat environments.

Over time, the B-2 should be expected to follow the same path as the B-52 and B-1 and lose its ability to penetrate advanced multi-layered air defenses. Today, the B-2 is the US military's only low-observable long-range strike aircraft capable of penetrating high-threat areas. The Air Combat Command has indicated the B-2 may be losing its stealth advantage, noting that: "In 2018, the B-2 will be nearly

118 The "SDB II" is a 250 pound weapon with GPS/INS inflight guidance and a terminal guidance seeker to strike laser-designated fixed and moving targets from standoff ranges in excess of 60 nm. See "Small Diameter Bomb Increment II Backgrounder," April 2010, accessible online at http://www.boeing.com/defense-space/missiles/sdb/docs/SDBII_overview.pdf, and Northrop Grumman, "Precision-Guided Weapons Could Allow Aircraft to Attack Multiple Moving Ground Targets in Adverse Weather From Stand-Off Ranges," February 7, 2008, accessible online at http://www.irconnect.com/noc/press/pages/news_releases.html?d=135958/.

119 For the Air Force's explanation of these operational constraints, see *Bomber Roadmap* (Washington, D.C.: Department of the Air Force, June 1992) and *US Air Force White Paper on Long Range Bombers* (Washington, DC: Department of the Air Force, March 1, 1999), pp. 17–18, accessible online at http://www.fas.org/nuke/guide/usa/bomber/bmap99.pdf.

FIGURE 9. PENETRATING MISSION CONSTRAINTS

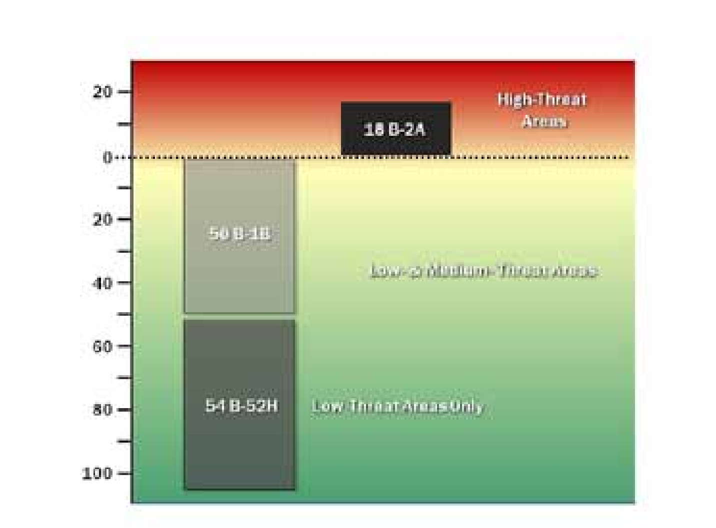

Image: CSBA

30 years old, and newer technologies are required to ensure access to denied areas in the 2015–2020 time frame due to rapid advances in foreign threats."[120] Without the B-2 as a penetrator, DoD would lose its only aircraft that can attack targets in A2/AD environments at distances exceeding the F-35's combat radius. This fact has led the Air Force to conclude that it needs to begin developing a new penetrating bomber.[121]

Although the current bomber force has sufficient service life to remain a viable *standoff* weapons delivery force for the next thirty years, it lacks the capabilities and capacity needed to strike target sets in future air campaigns that require penetrating contested airspace. The B-52s, B-1s and B-2s all have sufficient range and payload capacity to strike the full range of targets in low-threat and medium-threat areas. For long-range manned strike missions into high-threat areas, however, the United States must rely on a total of just sixteen B-2s until they too lose their ability to penetrate. Even with the B-2's large payloads, a mere sixteen aircraft will not provide air campaign commanders the capacity needed to strike thousands of deep targets. Moreover, unless B-2s are upgraded, the bomber force will remain incapable of striking the growing number of moving targets deep

[120] See IRIS Independent Research brief, "Long Range Strike: Options and Alternatives," January 3, 2008, p. 10, as published by Clark A. Murdock, *U.S. Air Force Bomber Modernization Plans: An Independent Assessment* (Washington, DC: Center for Strategic and International Studies, January 25, 2008) pp. 20–26. These "newer technologies" refer to future stealth platforms, since it is infeasible to significantly increase the B-2's survivability by changing its structure or materials. See Anthony Murch, "The Next Generation Bomber: Background, Oversight Issues, and Options for Congress," p. 6.

[121] See remarks by General T. Michael Moseley at the Air Force Defense Strategy and Transformation Seminar Series, Washington, D.C., April 4, 2006, published in Rebecca Grant, Return Of the Bomber (Arlington, VA: Air Force Association, February 2007) p. 20: "We need to be able to penetrate. We need to be able to capitalize on those attributes of an Air Force, which are range and payload and persistence. So this takes us to a new bomber."

TABLE 3. PROGRAM-OF-RECORD BOMBER CAPABILITY STRENGTHS AND SHORTFALLS

Strengths	Shortfalls
> Sufficient range, large payloads > Able to conduct independent operations using on-board sensors > Viable as standoff weapons carriers for 30+ years > Can penetrate low- to medium-threat environments > Capable of attacking fixed and mobile targets in low- and medium-threat environments	> With the exception of B-2s, unable to penetrate and persist in high-threat environments > Insufficient strike capacity to support air campaigns with thousands of DMPIs in high-threat environments > Unable to locate, track, and strike mobile targets in high-threat environments

in contested airspace. DoD's program-of-record bomber force's strengths and capability gaps are summarized in Table 3.

FILLING THE GAP: A NEW PENETRATING BOMBER

During testimony to the House Armed Services Committee earlier this year, Secretary Gates stated that the question of the next bomber was not so much a matter of "whether" as it was "what" it should be. While the exact details being considered for the Air Force's next bomber program remain classified, based on information discussed in public over the last several years they may appear to include the following:[122]

> Manned or optionally manned cockpit;

> Unrefueled combat range of at least 4,000 nm (2,000 nm-plus combat radius);

> Broad-band, very low-observable with improved low-observability materials;

> AESA radar;

> Capable of carrying air-to-air missiles;

> Conventional and nuclear-capable;

> Between 20,000 and 40,000 pounds of payload; and

> Affordable enough to procure around one hundred aircraft.

Analysis in preceding chapters supports developing a new bomber with the capabilities listed in the first five bullets, with the additions of all-aspect, broad-band low-observable characteristics and the capability to conduct independent strikes on mobile, relocatable, and hardened/deeply buried targets. The following section assesses the last three bullets regarding payload alternatives and size of a new bomber buy, as well as options to reduce a new bomber's cost.

[122] See Jeremiah Gertler, "Air Force Next-Generation Bomber: Background and Issues for Congress," Congressional Research Service, December 22, 2009, p. 5, accessible online at http://www.fas.org/sgp/crs/weapons/RL34406.pdf; Clark A. Murdock, *U.S. Air Force Bomber Modernization Plans: An Independent Assessment* (Washington, DC: Center for Strategic and International Studies, January 25, 2008), p. 5; and Jefferson Morris, "Future Long-Range Bomber Likely Won't Replace B-2, Northrop Says," *Aviation Week*, November 29, 2006, accessible online at http://www.aviation-week.com/aw/generic/story_channel.jsp?channel=defense&id=news/B211296.xml.

FIGURE 10. RELATIONSHIP BETWEEN EMPTY WEIGHT AND COST OF A NOTIONAL BOMBER

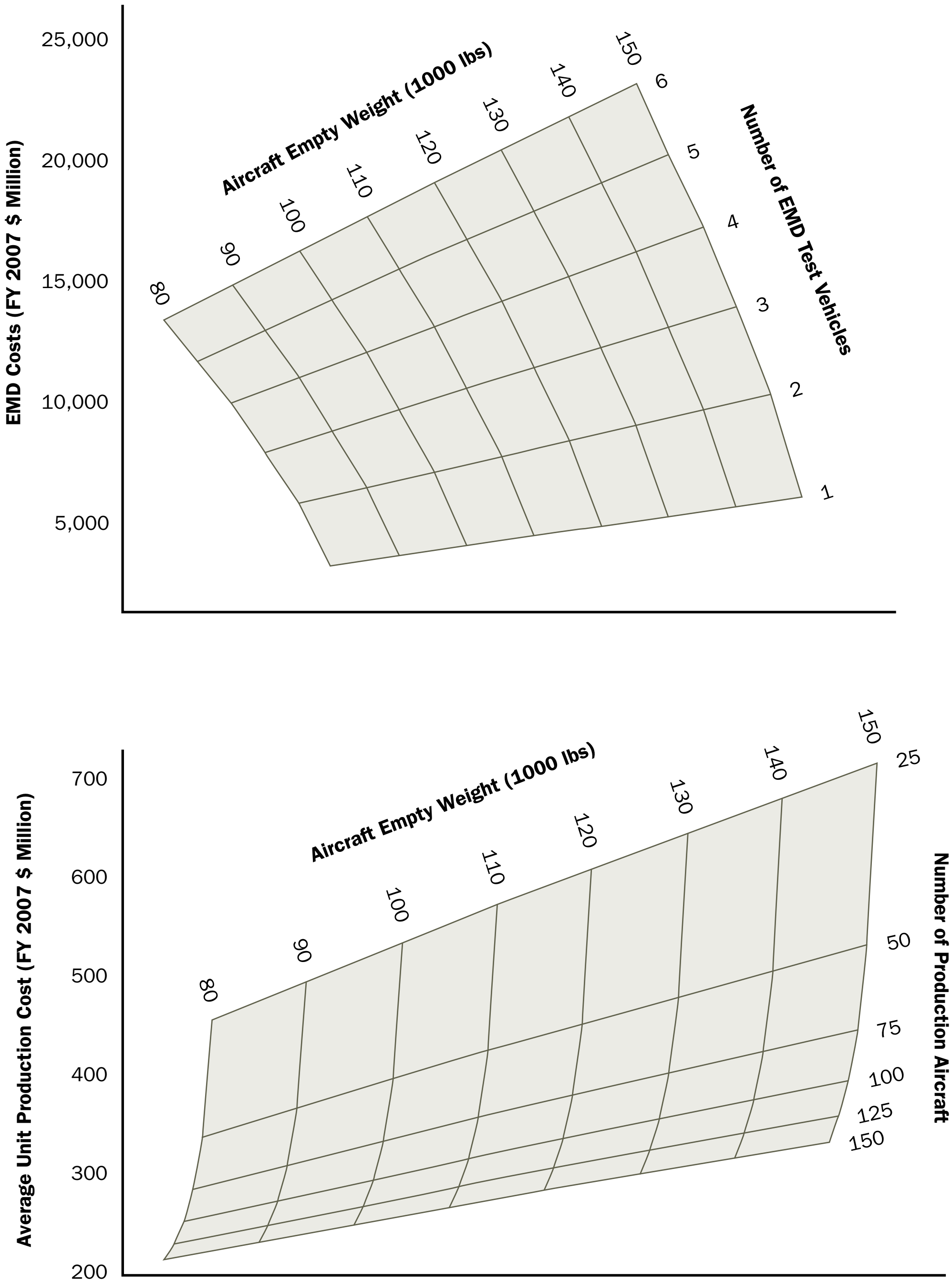

Image: CSBA

THE BOMBER PAYLOAD/COST/FLEET SIZE RELATIONSHIP

In the midst of last year's debate over the need for a new long-range strike platform, Secretary Gates announced that DoD intends to avoid paying so much for a new bomber or buying so few that it would severely limit how the US military might plan to use them in future conflicts:

> What we must not do is repeat what happened with our last manned bomber. By the time the research, development, and requirements processes ran their course, the aircraft, despite its great capability, turned out to be so expensive — $2 billion each in the case of the B-2 — that less than one-sixth of the planned fleet of 132 was ever built. Looking ahead, it makes little sense to pursue a future bomber — a prospective B-3, if you will — in a way that repeats this history. We must avoid a situation in which the loss of even one aircraft — by accident, or in combat — results in a loss of a significant portion of the fleet, a national disaster akin to the sinking of a capital ship.[123]

Sixty-six to one hundred new bombers would give DoD a sizable capacity for conducting penetrating long-range strikes compared to today's relatively small B-2 force.

The total size of a new bomber program will be determined by DoD's assessment of its operational needs, projected cost and available resources. If DoD decides to replace or augment the Air Force's remaining seventy-six B-52s or sixty-six B-1s with a new penetrating bomber, the total number procured could be less than one hundred aircraft. In either case, sixty-six to one hundred new bombers would give DoD a sizable capacity for conducting penetrating long-range strikes compared to today's relatively small B-2 force.

For DoD to afford fielding a large number of new bombers, it will need to pursue a design with a reasonable average unit cost. Defense experts have noted that it may cost $10 billion or more to develop a new penetrating bomber, assuming that the program takes advantage of systems and technologies from other programs.[124] As Figure 10 illustrates, the bomber's total EMD cost will be dependent on its empty weight, number of test aircraft procured and capabilities desired

[123] See a transcript of the speech by Secretary of Defense Robert M. Gates, Gaylord Convention Center, National Harbor, Maryland, Wednesday, September 16, 2009, accessible online at http://www.defense.gov/Speeches/Speech.aspx?SpeechID=1379.The cited $2 billion per B-2 includes total development and procurement costs. Of course, the average unit cost of a B-2 would have been significantly less than the quoted $2 billion if DoD had procured 132 aircraft. In 1990, the USAF estimated the B-2's program unit cost (that is, including development and procurement) at $516 million for each of 132 aircraft. Corrected for inflation, this would be $810 million in FY2011 dollars. See Headquarters USAF, *The Case for the B-2: An Air Force Perspective* (Washington, DC: Department of the Air Force, June 1990), p. 19.

[124] See Murch, "The Next Generation Bomber: Background, Oversight Issues, and Options for Congress," p. i.

for each test aircraft.[125] A new program's procurement costs would be driven by the same factors. Empty weight, in turn, is a function of an aircraft's mission requirement — its size, shape, payload and number of engines.

Based on the EMD and production cost plots in Figure 10, it would cost about $44 billion to buy fifty new 40,000-pound payload penetrating bombers compared to $46 billion for one hundred bombers that would carry a 20,000-pound payload.[126] Moreover, the unit cost for each of the fifty larger bombers — $840 million — is nearly twice the $440 million unit cost of the smaller aircraft. Part of this cost difference would be due to the number of engines required by each design, since two engines should suffice for a 20,000-pound payload bomber in contrast to four engines for a 40,000-pound payload aircraft such as the B-2.

Looking at the fleet size/payload tradeoff from an operational perspective, DoD should consider developing a penetrating bomber with a payload of around 20,000 pounds. Opting to buy one hundred of the smaller bombers would give air campaign commanders twice the area capacity to search for mobile and relocatable targets as compared to a fleet of fifty aircraft. Furthermore, in an era where smaller and increasingly lethal weapons are replacing the mass previously

[125] Entry into EMD is the formal beginning of a new acquisition program. EMD is used to develop a new system, integrate the system's components, develop a viable manufacturing process, and other activities that are critical to moving a new system into production. The B-2 program procured six test aircraft which were upgraded to operational configuration. EMD costs will not vary by the total number of operational aircraft that are eventually procured.

[126] The plots in Figure 10 were developed using Breguet's range equation and assumes a notional aircraft lift-to-drag ratio of 18, aircraft velocity of 430 knots (Mach 0.75) and a specific fuel consumption of 0.68 pounds of fuel consumed per pound of thrust produced per hour, (lbs/hr/lbf), yielding representative comparisons.

TABLE 4. NOTIONAL BOMBER COST COMPARISON

	40,000 lb Payload	20,000 lb Payload
Empty Weight	126,000 lb	100,000 lb
Total EMD (assume 6 test vehicles)	$19.7 billion	$16.2 billion
Total Production		
50 aircraft	$24.1 billion	$20 billion
100 aircraft	$36.2 billion	$30 billion
Total EMD + Production	**$44 billion for 50 aircraft** $56 billion for 100 aircraft	$36 billion for 50 aircraft **$46 billion for 100 aircraft**
Total Program Average Unit Cost	**$840 million for 50 aircraft** $540 million for 100 aircraft	$680 million for 50 aircraft **$440 million for 100 aircraft**

needed to achieve desired effects on a target, sheer payload tonnage is not as important as the *number of targets* that can be attacked with precision by a single aircraft. This shift toward precision strike weapons has had a revolutionary impact on air warfare. During the Second World War, approximately 1,500 B-17 sorties and 9,000 gravity bombs were needed to hit a fixed target with a high probability of success.[127] The lack of precision forced bombing campaign commanders to use sequential massed attacks to ensure the destruction of high-value targets. Today, the opposite is true. A penetrating bomber with a 20,000-pound payload could, potentially, carry up to seventy SDB II weapons or eight GBU-31 2,000-pound JDAMs.[128] As a comparison, sixteen B-2s based in Guam could attack approximately 180 targets in a Western Pacific target area per day with GBU-31s, compared to 448 GBU-31s delivered per day by a fleet of eighty new active-inventory penetrating bombers with payloads of 20,000 pounds each.[129] Moreover, the eighty bombers would allow the US military to conduct multiple simultaneous strikes deep into an enemy's territory from many different axes of attack or better support "swing" operations between different theaters if required.

Sheer payload tonnage is not as important as the *number of targets* that can be attacked with precision by a single aircraft.

Aside from the tradeoffs between fleet size, payload and cost, it also makes a great deal of sense for DoD to design future weapons to accommodate the weapons bays of a new bomber, rather than design a new bomber to carry legacy weapons. For example, if a new bomber is designed to carry even one of the Air Force's 30,000-pound penetrating MOPs, its unit cost will be significantly higher than the 20,000-pound payload bomber cited above.[130] Conversely, if DoD designed a future penetrating weapon that achieves the same *effects* as a MOP but would have the size and weight of today's 5,000-pound GBU-28 penetrator, then a 20,000-pound payload bomber would be capable of striking four hardened or deeply buried targets in a single sortie.

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[127] See Colonel Gary Crowder, "Effects Based Operations Briefing," March 13, 2003, accessible online at http://www.defense.gov/transcripts/transcript.aspx?transcriptid=2067.

[128] See http://www.boeing.com/defense-space/missiles/sdb/index.html. The SDB II weighs 285 pounds and is carried on BRU-61/A bomb racks, each of which hold four weapons. The number of SDB II weapons that can be carried by a future bomber will depend on the aircraft's weapons bay volume as well as weight capacity.

[129] The example assumes both bombers fly equivalent mission profiles and have a daily sortie rate of 0.7 sorties per day. A B-2 can carry 16 GBU-31s. Therefore, 16 B-2s x 16 GBU-31s x 0.7 sortie rate = 180 targets per day (rounding up). For illustrative purposes, the example assumes a new 20,000 pound payload bomber will be able to carry 8 GBU-31s in one or more weapons bays. The example also makes a conservative assumption that only 80 of the 100 new bombers may be fully mission capable. See http://www2.hickam.af.mil/shared/media/document/AFD-060726-020.pdf , p. 20.

[130] Moreover, the Air Force may buy a very limited number of MOPs — a total of ten to twelve according to some reports. See "US trebles MOP "bunker buster" bombs order, wants them fast," DEBKAfile, September 8, 2009.

OPTIONS FOR IMPROVING A NEW BOMBER'S AFFORDABILITY

Although average unit costs for a penetrating bomber could be significantly less than the $2 billion paid for each B-2, finding $40–50 billion for a new program will still be a difficult challenge for DoD, especially in today's economic climate. There are, however, options that could reduce program cost growth and spread needed investments over a period of years to lessen the impact on the defense budget:

> Avoiding requirements creep;

> Fully resourcing competitive prototyping and EMD;

> Taking advantage of technologies and systems developed for other programs; and

> Delivering capability in increments.

Requirements creep is one of the most significant drivers of the cost growth typical of major military aircraft acquisition programs.[131] Simply stated, requirements creep occurs when it is necessary to make unplanned changes to an aircraft's design or major systems during its development. These changes are driven by a number of factors, such as new requirements added by the Air Force or actions to those needed to address contractor design flaws that are discovered during aircraft testing. In the case of the B-2, for example, the USAF decided three years after program start that the bomber, originally designed as a high-altitude penetrator, also had to be able to penetrate at low altitudes. This decision required a redesign of the aircraft planform and structure, and significantly delayed the program.[132] In addition, extensive low-level flight testing was then required, further adding to the B-2's development cost.

The Defense Department can reduce a new bomber's cost growth by avoiding requirements creep to the maximum extent possible. The first step is to ensure that the Air Force fully identifies requirements at the beginning of a formal bomber program, and then avoids changing them during EMD. Defining specific requirements is especially important for an aircraft's most expensive items, such as the size and shape of its planform, engines, radar, sensors, apertures, and avionics. Furthermore, the Air Force should avoid increasing requirements beyond what is absolutely essential to the aircraft's initial production, reversing the trend

131 Or any other major military acquisition program, for that matter. Secretary Gates has made the prevention of requirements creep a top priority for DoD. See Secretary of Defense Robert M. Gates, "Defense Budget Recommendation Statement," Department of Defense, April 6, 2009, accessible online at http://www.defense.gov/Speeches/Speech.aspx?SpeechID=1341.

132 See Oliver Boileau, "The B-2 Bomber: An Acquisition Case Study," Northrop Grumman, June 10, 1993, pp.4–5.

of defining hundreds of requirements which has plagued the development of other major defense acquisition programs. The Air Force must also avoid excessive testing and production concurrency that contributed to the many design reworks that were required during the B-2's development.[133] Typically, thousands of skilled engineers are needed to design sophisticated military aircraft. The longer this "standing army" is required to work multiple and recurring design changes, the more an aircraft development program will cost. Moreover, excessive overlap between testing and production can delay the discovery of defects until late in an aircraft's development phase or even after production. These defects are far less expensive to resolve if uncovered early in testing.

Exploit technologies and systems developed for other aircraft to the maximum extent possible.

This last concern points to another approach for reducing a new bomber program's cost growth: fully resource its EMD phase. This means avoiding the illusion of easy savings by terminating competitive prototyping early or reducing the number of test aircraft. Competitive prototyping typically funds aircraft prototypes from two or more contractors until the start of EMD. Down-selecting to a single contractor prior to the start of EMD would cut the army of design engineers by half, but it would also void the opportunity to "reduce technical risk, validate designs, improve cost estimates, evaluate manufacturing processes, and refine requirements" early in the program.[134] It may be similarly attractive to try to save during EMD by reducing the number of test aircraft. As illustrated by Figure 6, buying four test aircraft instead of six could reduce EMD by $4 billion. Of course, this could lead to the aforementioned problem of discovering defects late in the bomber's development cycle, causing program delays and increasing costs. Simply stated, DoD must cease this "penny wise" and "pound foolish" approach to modernization.

In addition to containing cost growth, DoD could reduce the cost of a new bomber program by taking advantage of off-the-shelf technologies and systems. Developing sophisticated military aircraft is an expensive proposition, especially for aircraft such as the F-22 or a new stealth bomber that push technology beyond the state of the art in multiple areas. One alternative involves exploiting technologies and systems developed for other aircraft to the maximum extent possible. The F-117 program adopted this acquisition strategy, using flight controls from the F-16, cockpit displays and F404-GE-F1D2 engines from the F/A-18, brakes

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[133] According to the GAO, "working on flight tests, aircraft production, and modifications concurrently has created the need for further corrections of deficiencies after fully capable [B-2] aircraft are delivered." See *B-2 Cost and Operational Issues* (United States General Accounting Office, GAO/NSIAD-97-181, August 1997), p. 5, accessible online at http://www.gao.gov/archive/1997/ns97181.pdf.

[134] See "DOD Weapons Systems Acquisition," US Office of Management and Budget, accessible online at http://www.whitehouse.gov/omb/expectmore/issue_summary/issue_4.html.

from the F-15 and a modified C-130 environmental control system.[135] Similarly, DoD could reduce a new bomber's development risk, the need for design reworks and program cost by relying more on integration and less on invention. Taking advantage of the F-22's stealth technologies and perhaps the F-35's Pratt and Whitney F-135 engine could reduce a new bomber's development cost. Moreover, if production of a new bomber and the F-35 overlap, using major components from the F-35 could allow both programs to take advantage of the benefits of economies of scale.

DoD could also mitigate a new bomber program's impact on the defense budget by pursuing a block upgrade acquisition strategy that delivers capability in increments and spreads costs over time. It is critically important to get a new bomber's size (which determines payload and range) and planform (which determines survivability) right during development, since changing them significantly after production would require major structural redesigns. Other capabilities may be added gradually through a series of planned block upgrades, such as the specialized components needed to deliver nuclear weapons. A block upgrade acquisition strategy would also allow DoD to integrate new technologies as they mature, such as coatings, leading edge treatments and advances in computer processing that would enhance aircraft survivability.

Pursue a block upgrade acquisition strategy that delivers capability in increments and spreads costs over time.

[135] See http://www.ausairpower.net/Profile-F-117A.html and http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=410.

FIGURE 11. ILLUSTRATIVE OFF-THE-SHELF SYSTEMS AND COMPONENTS FOR A NEW BOMBER

F-35 engines
F-35 mission computer
F-35 cockpit controls and displays
F-35 comm/nav systems
F-35 armament control system
F-35 environmental control system
B-2 AESA radar
B-2 landing gear and weapons bay doors
B-2 secondary power system
B-2 crew escape
F-15E electrical system
F-15E fuel system
F-15E fire suppression
F/A-18E/F hydraulics
B737 derivative landing gear

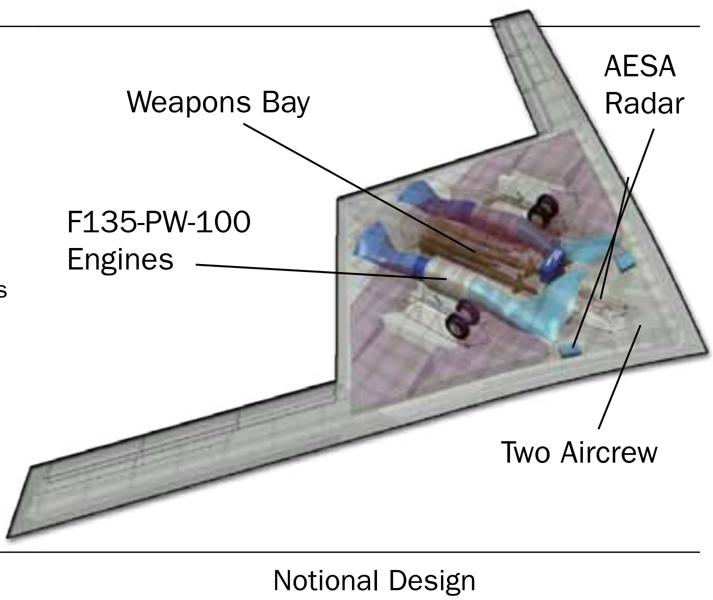

Image: CSBA

INCREASING CARRIER STRIKE REACH AND PERSISTENCE

In his address at the 2010 Navy League Sea-Air-Space Exposition, Secretary Gates noted that the nation's sea-based precision strike advantage is eroding. This is due, in part, to investments by potential adversaries in accurate anti-ship cruise and ballistic missiles that threaten aircraft carrier operations from over-the-horizon ranges.[136] Reversing this erosion will require the Navy to invest in a new generation of capabilities to increase the range, persistence and survivability of its carrier-based strike forces and better integrate with the Air Force during AirSea Battle operations to counter A2/AD battle networks.[137] The Navy will also need to integrate these new capabilities into the carrier air wing.

MOVING FORWARD OR IN THE WRONG DIRECTION?

Similar to the USAF's bomber force, the Navy's carrier air wings have become increasingly capable of delivering lethal effects over the last twenty years. Modernization programs to integrate advanced data links, sensors and precision-guided munitions on carrier aircraft have allowed the Navy to field carrier air wings with precision strike capabilities that are "more than 10 times greater than that of their late-1980s predecessors—making a single aircraft carrier battle group (CVBG) nearly twice as powerful as the six that combined to enable victory during Desert Storm."[138]

Even as precision weapons have allowed the Navy's strike aircraft to become more lethal, the "reach" and therefore persistence of carrier-based platforms have decreased significantly since the end of the Cold War.[139] This has been due, in part, to the Navy's lack of a perceived threat to carrier operations and its assumption that adversaries will have very little strategic depth. The F-35C will extend the reach of today's carrier air wings slightly, but will not recapture the reach lost when the Navy retired its last A-6 Intruder in 1997, nor will it provide

[136] Secretary of Defense Robert M. Gates, Gaylord Convention Center, National Harbor, Maryland, Monday, May 03, 2010, accessible online at http://www.defense.gov/speeches/speech.aspx?speechid=1460.

[137] CSBA's *AirSea Battle* Report proposes a list of initiatives to accomplish this objective. See Jan Van Tol with Mark Gunzinger, Andy Krepinevich and Jim Thomas, *AirSea Battle: A Point-of-Departure Operational Concept* (Washington DC: CSBA, 2010), pp. 81–94.

[138] Rear Admiral John. B. Nathman, "A Revolution in Strike Warfare," *SeaPower Magazine,* October 1999, accessible online at http://www.navyleague.org/seapower/revolution_in_strike_warfare.htm.

[139] For a more detailed discussion of this trend, see Thomas P. Ehrhard and Robert O. Work, *Range, Persistence, Stealth, and Networking: The Case for a Carrier-Based Unmanned Combat Air System* (Washington, DC: CSBA, 2008), p. 144. The report argues that the Navy accepted this decrease of range due, in part, to the perceived lack of threats to carrier and aerial refueling tanker operations following the end of the Cold War.

sufficient persistence to find and attack land-based mobile targets. Lack of reach will cause particular difficulty if long-range air and missile threats force Navy aircraft carriers to operate at 1,000 nm or more from an enemy's coastline.

Today, the Navy's F/A-18E/Fs provide the nation with a powerful instrument for precision strike in non-contested operating environments at very short ranges, or at longer ranges when enabled by aerial refueling. As for survivability, low-observable F-35s will be better able to operate in future contested environments compared to the F/A-18E/Fs that the Navy will continue to procure through FY 2013. Even when F-35s begin to join the fleet over the next several years, the Navy's air wings will be challenged to strike targets more than a few hundred miles from their carrier decks in contested environments, even if enemy threats do not prohibit aerial refueling. Thus, without changes to the program of record, US carrier air wings will lack the following attributes needed for high-end A2/AD scenarios:

> Sufficient range to outreach an enemy's land- or sea-based maritime strike systems;

> Persistence needed to find and attack mobile targets; and

> Longer-range platforms with all-aspect, broad-band low observability necessary to survive in advanced IADS environments.

Even when F-35s begin to join the fleet over the next several years, the Navy's air wings will be challenged to strike targets more than a few hundred miles from their carrier decks in contested environments.

FIGURE 12. DECREASING CARRIER AIR WING REACH

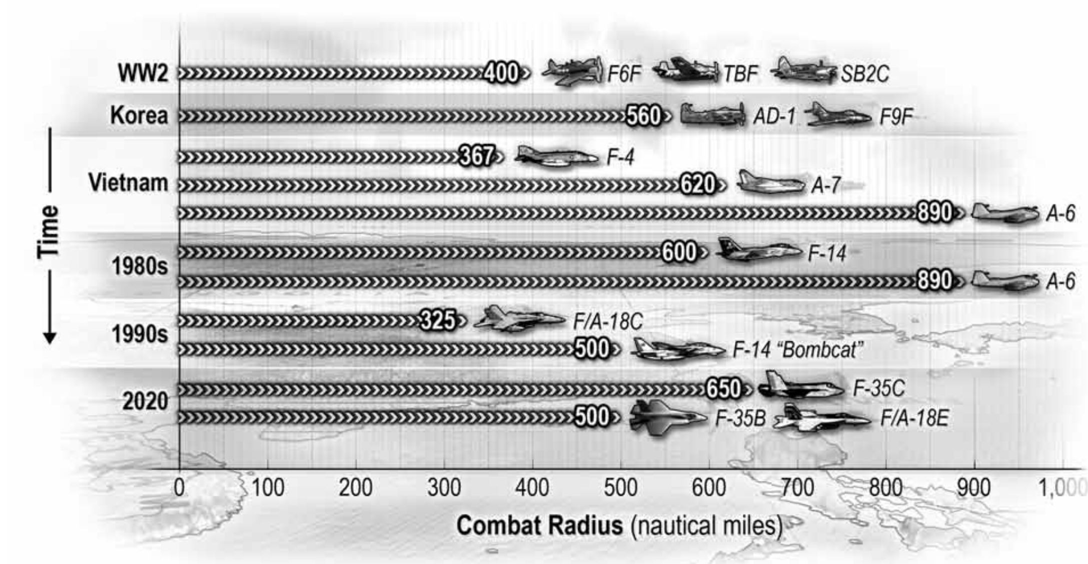

Image: CSBA

TOWARD THE FUTURE CARRIER AIR WING

The Navy has an opportunity to make a bold shift toward enabling effective strike operations.

The Navy is beginning to assess options for replacing the F/A-18E/F when it begins to retire.[140] This is a critical inflection point for naval aviation. If the decision is for more F-35s, US aircraft carriers will be locked into a concept of operations that is dependent on relatively benign, permissive environments. If the answer is a new platform, the Navy will have an opportunity to make a bold shift toward enabling effective strike operations against enemies with robust A2/AD battle networks, thereby ensuring that its future forward presence and immediately employable strike forces will remain effective.

In 2008, CSBA published a report that assessed how unmanned platforms might increase the range, persistence and survivability of the Navy's carrier air

[140] See "Aircraft Investment Plan Fiscal Years (FY) 2011–2040," Department of Defense, p. 16. For information on the Navy's notional future carrier air wing, see http://nae.ahf.nmci.navy.mil/downloads/NAV2010_04_Future_carrier_CVW_amphib_ACE_sp.pdf, p. 32.

FIGURE 13. ILLUSTRATIVE CARRIER-BASED UAS PERSISTENCE

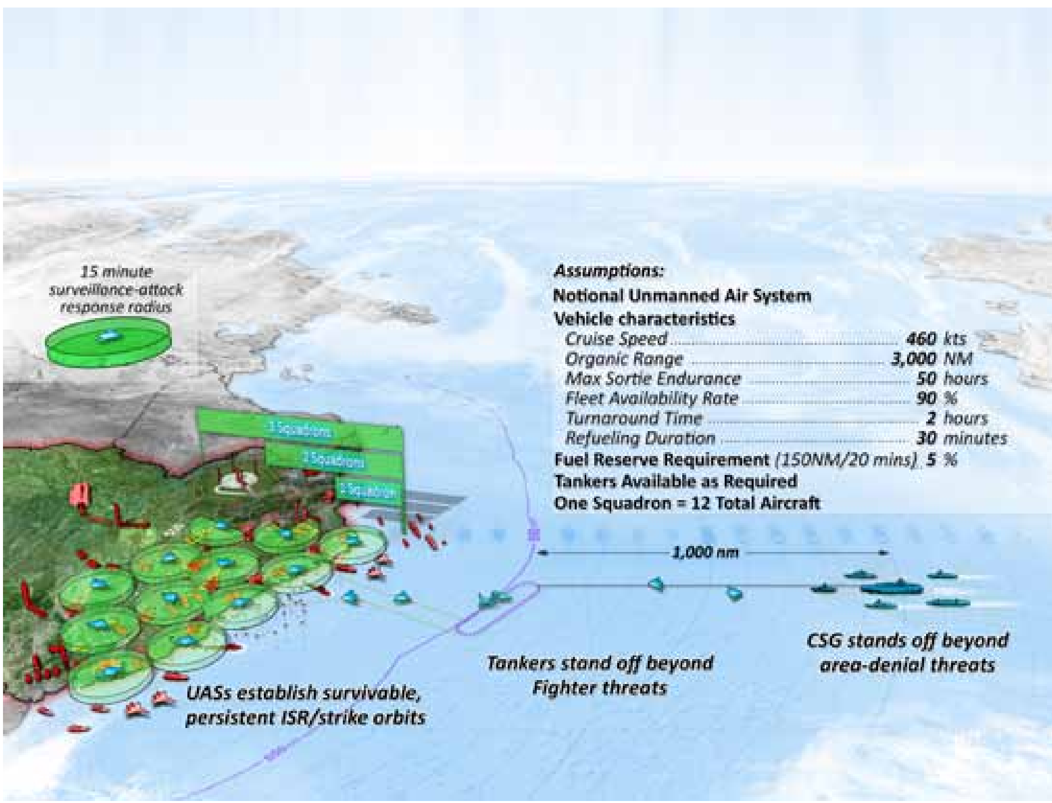

Image: CSBA

wings.[141] Unmanned aircraft with autonomous landing systems will be able to land on aircraft carriers without the need for a tail structure.[142] A tailless, flying wing design, such as the UCAS-D X-47B demonstrator, has significant advantages in its lift-to-drag ratio and internal fuel fraction compared to manned fighters of equivalent size like the F-35.[143] Combined with autonomous aerial refueling, these attributes would give an unmanned platform significantly greater unrefueled range and mission persistence than a manned fighter. For example, a carrier squadron of twelve X-47B-based aircraft could sustain five orbits along an enemy's coastline to search for mobile targets or provide supporting electronic attack, or two-plus orbits five hundred miles inland, even if the carrier were based 1,500 nm from the coast, assuming sufficient tankers were available 500 nm from the coast. Each orbit is depicted in Figure 13 with a 200 nm-diameter circle representing the distance that an aircraft at the center of the orbit could travel within fifteen minutes (estimated conservatively at approximately 100 nm for an aircraft cruising at 460 knots). This metric is used to approximate the geographic rapid-response "coverage" of an aircraft persisting in the operational area. Removing the tail structure is also critical to achieving a low-observable RCS needed to penetrate and persist in contested airspace.

141 See Ehrhard and Work, *Range, Persistence, Stealth, and Networking*.

142 Aircraft without tails and high lift devices require a steeper angle of attack when landing than do tailed aircraft. This increased angle of attack makes over the nose visibility challenging for manned aircraft.

143 An aircraft's fuel fraction, defined as the weight of the aircraft's fuel divided by its takeoff gross weight, is a key metric for determining how far an aircraft can fly without refueling.

TABLE 5. THE US NAVY'S NOTIONAL FUTURE CARRIER AIR WING

44 strike fighters	F/A-18E/F F-35 F/A-18E/F replacement
5 electronic attack aircraft	EA-18G EA-18 replacement
5 airborne early warning aircraft	E-2D
19 helicopters	MH-60R/S or replacement
2 future carrier onboard delivery aircraft	

The Navy is taking its first steps toward developing an unmanned carrier aircraft. By 2013, the Navy will have invested another $750 million in the UCAS-D program to demonstrate that unmanned platforms can take off and land on carrier decks and conduct autonomous air refueling operations. Another $7 billion is projected to be invested by 2020 with the goal of fielding four to six Unmanned Carrier Launched Airborne Surveillance and Strike (UCLASS) platforms that are "optimized for Irregular and Hybrid Warfare scenarios."[144]

While it appears the UCLASS is a good first step toward developing a future carrier aircraft with increased range and persistence, some of the architects of the Navy's air forces — naval aviators who came from fighter cockpits — may not champion the kind of unmanned platform required for high-end A2/AD scenarios.[145] One promising alternative involves capitalizing on current UCAS-D program investments by developing a derivative of the X-47B. The Institute for Defense Analyses studied this option and determined that "a derivative of the X-47B proved most cost effective" for a UCAS-sized aircraft that could persist in defended airspace.[146] Rather than start afresh with an untested design, an approach that builds on what is known could reduce development time and stem the erosion of the Navy's strike capability.

Due to their operational limitations and high cost relative to other munitions, long-range standoff cruise and ballistic missiles are best used in limited numbers against high-value fixed targets.

FUTURE LONG-RANGE STANDOFF MUNITIONS

Standoff munitions extend the reach of penetrating strike platforms and provide a means for commanders to strike targets without placing an aircrew in harm's way. Due to their operational limitations and high cost relative to other munitions, however, long-range standoff cruise and ballistic missiles are best used in limited numbers against high-value fixed targets. Given these considerations, several concepts for a future cruise missile and prompt global strike munitions could expand the standoff strike options available to future commanders.

For example, DoD could develop a new cruise missile that would provide a wider range of Air Force and Navy aircraft with a standoff strike capability. Today, the Air Force is about to initiate an analysis of alternatives for a "Follow-on Long-Range Stand-off Vehicle" to replace its aging ALCM and CALCM subsonic cruise

144 See "Aircraft Investment Plan Fiscal Years (FY) 2011–2040," p. 17, and "A-RFI Request for Information for Unmanned Carrier launched Airborne Surveillance and Strike (UCLASS) System Key Capabilities," May 3, 2010, Department of the Navy, p. 1.

145 Generically, a tailless, stealthy system with 3,000 nm unrefueled range, 4,500 weapons payload and 3,000 pound sensor payload would be well-suited to these scenarios. See Ehrhard and Work, pp. 211–217.

146 See "Tactical Systems and Missile Defense," Institute for Defense Analyses, accessible online at https://www.ida.org/researchareas/systemevaluations/tactical%20systems%20and%20missile%20defense.php.

missiles.[147] Instead of developing a new cruise missile that can strike targets that are 1,000 or more nautical miles away, a missile with a range on the order of the JASSM-ER, a little over 500 nm, would reduce the total cost per missile and increase the number of Air Force and Navy strike platforms that could carry it. A new cruise missile with a shorter range would also spend less time in flight, improving the weapon's effectiveness against targets that can relocate. On the downside, shorter-range cruise missiles would require their launch platforms to penetrate deeper into an enemy's airspace, increasing the potential for aircraft attrition.

Increasing the speed of standoff weapons is another approach for improving their effectiveness against time-critical targets. DoD is investigating technologies to develop aircraft-delivered supersonic cruise missiles with ranges up to 1,000 nm or more.[148] Hypersonic missiles that travel beyond Mach 5 could strike time-critical targets such as TELs or mobile SAMs that are located 700 nm from launch in a little less than thirteen minutes compared to the hour and a half it would take for a Tactical Tomahawk to fly the same distance.[149] While missiles traveling at supersonic or hypersonic speeds have the potential to overcome the time/distance limitations of subsonic standoff weapons, the engine and missile body technologies needed for flights at these speeds will increase their unit cost well above the $1–2 million required for a current-generation long-range cruise missile. Moreover, the engines and fuel required to sustain flight at hypersonic speeds may reduce the missile's useful warhead payload significantly. Considering these tradeoffs and likely high cost, it is hard to envision DoD investing in a large arsenal of super or hypersonic weapons, although they could be an important niche capability for strikes against very-high-value targets.

Other options for defeating "time-urgent regional threats," such as a rogue state's impending use or transfer of WMD, include conventional prompt global strike (CPGS) weapons.[150] CPGS concepts include conventional variants of

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147 See http://www.fas.org/blog/ssp/2010/03/newnukes.php. Also see Adam J. Herbert, "Strike Command Steps Up," *Air Force Magazine,* June 2010, Vol. 93, no. 6, accessible online at http://www.airforce-magazine.com/MagazineArchive/Pages/2010/June%202010/0610strike.aspx.

148 The Defense Threat Reduction Agency is interested in developing a Supersonic Cruise Missile that could deliver 2,000 pound warheads in less than 6 minutes on targets 600 nm from launch. See http://www.globalsecurity.org/ military/systems/munitions/jsscm.htm. As part of this development effort, the Air Force Research Laboratory is experimenting with a Mach 6 X-51A platform that could be launched from a bomber and carry various submunitions. See John Reed, "Boeing Could Expand Hypersonic Follow-on Efforts," *Defense News*, April 13, 2010, accessible online at http://www.defensenews.com/story.php?i=4581322.

149 For an excellent summary of the history and potential applications for hypersonic weapons, see Richard P. Hallion, *Hypersonic Power Projection* (Arlington, VA: Mitchell Institute Press, June 2010).

150 See *2010 Nuclear Posture Review Report* (Washington, DC: Office of the Secretary of Defense, April, 2010), which will be referred to hereafter as the *2010 NPR Report*, p. 34: "These capabilities [conventional prompt global strike] may be particularly valuable for the defeat of time-urgent regional threats."

CPGS capabilities would provide future commanders with a new tool for striking time-critical targets.

the Navy's Trident D-5 SLBM (Conventional Trident Modification) and the Air Force's Minuteman-III ICBM. The Air Force's Conventional Strike Missile (CSM) is one such experimental system in early development. The CSM concept marries a Minotaur IV missile derived from the Minuteman-III with a payload delivery vehicle that is capable of hypersonic speeds. The payload delivery vehicle, based on the Hypersonic Test Vehicle-2 (HTV-2) developed by Lockheed Martin for the Force Application and Launch from Continental US (FALCON) program, would be capable of dispensing a variety of conventional sub-munitions over a target area. The first CSM demonstration may occur as early as 2012.[151]

CPGS capabilities would provide future commanders with a new tool for striking time-critical targets, such as IADS battle network nodes in the opening minutes of an AirSea Battle campaign or a high-value counter-terrorism target. Similar to supersonic and hypersonic cruise missiles, however, the CPGS's high cost would limit it to a niche capability for strikes against only the highest-value targets.[152]

[151] For CSM information, see "Hypersonic Payload Delivery Vehicle," US Air Force Space Command, accessible online at https://www.fbo.gov/index?s=opportunity&mode=form&id=1d1080264a884f332528a8057 ec2c1f2&tab=core&_cview=0. Also see "Moving Forward on Conventional Strike Missile," *Air Force Magazine,* July 6, 2009, accessible online at http://www.airforce-magazine.com/DRArchive/Pages/2009/July%202009/July%2006%202009/MovingForwardonConventionalStrikeMissile.aspx.

[152] Vice Chairman of the Joint Chiefs of Staff General Cartwright observed "if you have more time, then there are better systems [than CPGS] out there and more affordable systems." See Elaine M. Grossman, "U.S. Military Eyes Fielding 'Prompt Global Strike' Weapon by 2015," Global Security Newswire, July 1, 2009, accessible online at http://gsn.nti.org/gsn/nw_20090701_5635.php.

FIGURE 14. HTV-2 ARTIST'S CONCEPT

Image: DARPA

As an example, the Minotaur IV used for the CSM is capable of lifting payloads of about 3,800 pounds into low earth orbit.[153] Subtracting the weight of the HTV-2, one CSM could deliver, at best, several thousand pounds of conventional weapons to a target area, even if allowing for the heavier payloads a Minotaur may be capable of lifting into a suborbital flight profile. These few thousand pounds of weapons would be expended at a considerable cost. For comparison purposes, Minotaur and Trident D-5 missiles, without the expense of a hypersonic vehicle payload, may cost at least $15 million and $31 million, respectively.[154]

Beyond their high cost, there are also concerns that launching conventional ballistic missiles from an SSBN or from missile silos in the United States may be misinterpreted by Russia, China, or other nations as a nuclear launch.[155] Moreover, CPGS systems that spend more than 50 percent of their time in ballistic flight will count against the New START Treaty's warhead limits. Although DoD intends to retain "a margin above the minimum required nuclear force structure for the possible addition of non-nuclear prompt-global strike capabilities," it is highly unlikely that the available margin would permit the fielding of more than one hundred conventional ballistic missiles.[156]

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[153] See the fact sheet released by the Air Force's 30th Space Wing Public Affairs Office, accessible online at http://www.vandenberg.af.mil/library/factsheets/factsheet.asp?id=4674. A Minotaur would probably be capable of lifting more than 3,800 pound payloads into a sub-orbital flight profile.

[154] For the cost of a Trident-II missile, see the US Navy fact sheet "Trident Fleet Ballistic Missile," accessible online at http://www.navy.mil/navydata/fact_display.asp?cid= 2200&tid=1400&ct=2. DoD's latest Selected Acquisition Report for the Trident II lists an average unit cost of $93 million. DoD does not publish a projected cost of a CSM, a Minuteman III or its Minotaur derivative. However, a 1996 Air Force fact sheet on the original Minuteman-III listed a unit cost of $7 million. Updated for inflation, this would be approximately $10 million in FY2011 dollars. A 2004 report indicated a Minotaur may cost approximately $13 million, which equates to $15 million in FY2011 dollars after adjusting for inflation. See Jeff Foust, "Reducing launch costs: a lower limit?," The Space Review, September 27, 2004, accessible online at http://www.thespacereview.com/article/233/1.

[155] See Secretary Gates' comments in "US Faces Choice on New Weapons for Fast Strike," *The New York Times,* April 22, 2010, accessible online at http://www.nytimes.com/2010/04/23/world/europe/23strike.html. This study assumed current treaty limitations on the use of conventional long-range ballistic missile systems. Absent these treaty limitations, such systems could provide significant complementary capability to the family of systems described in this paper. Further study is warranted to examine how conventional ballistic missile systems, and their derivatives, could further enhance the nation's long-range strike capability.

[156] Realistically, the number of CPGS weapons procured by DoD may be significantly less than 100. The New START treaty establishes a combined limit of 700 deployed ICBMs, SLBMs and nuclear-capable bombers, and 800 deployed and non-deployed ICBMs, SLBMs and nuclear-capable bombers. To meet treaty limitations, DoD is expected to retain up to 60 nuclear-capable bombers, 420 ICBMs and 14 submarines carrying up to 240 SLBMs. See Robert M. Gates, "The Case for the New START Treaty," *Wall Street Journal,* May 13, 2010, accessible online at http://online.wsj.com/article/SB10001424052748703339304575240164048611360.html?WORDS=gates. The CSM may not count against New START, since it will spend more than 50% of its profile in maneuvering flight.

FUTURE AIRBORNE ELECTRONIC ATTACK

The Defense Department has determined that AEA capabilities will remain critical to the survivability of long-range strike weapons and platforms. The US military's AEA platforms include the standoff EC-130H, as well as fighter platform-based EA-6B "Prowlers" and EA-18G "Growlers" used to suppress or disable enemy radars. The Navy is investing in a total of fourteen Growler expeditionary squadrons to replace its Vietnam-era EA-6Bs to conduct AEA operations from aircraft carriers or forward land bases. In addition to these dedicated AEA platforms, long-range strike aircraft are able to carry dispensable systems such as the Miniature Air-Launched Decoy-Jammer (MALD-J) and towed decoys that can spoof and jam air defense radars.[157]

The EA-18G lacks the range, persistence and survivability to support US strike platforms that penetrate deep into an enemy's airspace.

While there is little question that an AEA force is needed to sustain DoD's long-range strike strategic advantage, EC-130Hs and Growlers are best suited for the kinds of relatively permissive air operations the US military has conducted over the last twenty years. The EC-130H, a derivative of the C-130 cargo aircraft, cannot fly orbits within reach of enemy long-range perimeter air defenses. The EA-18G, based on the two-seat F/A-18F fighter, lacks the range, persistence and survivability to support US strike platforms that penetrate deep into contested airspace. In an assessment of a 2012 Major Combat Operation, the Institute for Defense Analyses determined that the EA-18G was "not designed to survive within defended airspace" and thus must provide AEA from standoff distances, a concept of operations that is ill-suited for supporting penetrating strike platforms.[158]

Absent supporting AEA aircraft, penetrating strike platforms will have to rely on their on-board self-protection systems. Expendable decoy/jammers are part of the survivability solution, but their small size limits their flight endurance and the jamming power they can generate.[159] Furthermore, carrying large numbers of decoys and jammers will reduce a strike aircraft's payload of precision strike munitions.

As DoD assesses options for its future long-range strike family of systems, it should consider developing a new AEA platform with increased range, persistence and survivability compared to program of record aircraft. One option would be to design a completely new, dedicated penetrating AEA aircraft. Similar to other major aircraft programs, such a platform would likely require ten years or more to develop and field. Another option would be to build on an existing

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157 The Navy also employs Tactical Air-Launched Decoys (TALD) that simulate fighter/attack sized aircraft.

158 See "Tactical Systems and Missile Defense," Institute for Defense Analyses, accessible online at https://www.ida.org/researchareas/systemevaluations/tactical%20systems%20and%20missile%20defense.php.

159 Towed decoys such as Raytheon's ALE-50 can act "as a preferential target that lures enemy missiles away by providing a much larger radar cross section than the aircraft." The ALE-50 is carried by B-1Bs. See http://www.raytheon.com/capabilities/products/ale50/.

developmental platform that would meet Secretary Gates' objective to field "75 percent solutions" more quickly rather than wait for 99 percent, exquisite and far more expensive solutions that will compete for resources with other needed long-range strike programs.[160]

A derivative of the aforementioned UCAS-D may be a viable "75 percent solution" candidate for a carrier-based AEA aircraft that has the increased range and persistence needed to support a long-range strike force. Boeing is testing a developmental "Phantom Ray" unmanned aircraft that might be an option for a future AEA platform. The Phantom Ray, which is based on a prototype developed for the Joint-UCAS program, will be capable of carrying eight small diameter bombs or other mission packages in its two internal weapons bays. With a 1,400 nm unrefueled combat radius, a low-observable Phantom Ray AEA variant could help enable long-range strike platforms to penetrate perimeter air defenses. Lockheed Martin's heretofore classified, but recently acknowledged, low-observable RQ-170 ISR platform might also be adapted to AEA missions.

While there is a synergy achieved by operating AEA and penetrating stealth strike aircraft in tandem, there are drawbacks to attempting to reduce the cost of the next long-range strike family of systems by trading new AEA capabilities for less stealthy strike aircraft designs. As mentioned in Chapter 2, stealth aircraft are not invisible. When combined with tactics, techniques and procedures for evading enemy air defenses, stealth technology prevents those defenses from gaining a target-quality track on the aircraft. Viewed from this perspective, AEA systems can enhance the survivability of penetrating stealth aircraft by jamming

160 See Jim Garamone, "Procurement Reform Must be Government Priority, Gates Tells Senate," American Forces Press Service, January 27, 2009, accessible online at http://www.defense.gov/news/newsarticle.aspx?id=52838.

FIGURE 15. PHANTOM RAY

Source: Wikipedia

enemy radars trying to track them. In order to "cloak" a bomber that has a larger RCS, an AEA platform must be capable of generating even more power to degrade the enemy's radar effectively.[161] This requirement to generate more power would translate to an AEA aircraft design that has more internal space and cooling capacity, and thus would be more expensive. In other words, trying to cut the cost of a penetrating bomber by making it less stealthy would simply increase the cost of fielding an effective AEA aircraft, and may also prohibit using another developmental platform as the basis for the AEA aircraft's design.[162]

DoD should consider "off-the-shelf" options that will lead to a lower-cost AEA aircraft that could be fielded over the next decade.

Summarizing these insights, DoD has the opportunity to develop future AEA capabilities that will enhance the survivability of the US military's long-range strike systems. As it does so, DoD should consider "off-the-shelf" options that will lead to a lower-cost AEA aircraft that could be fielded over the next decade to support legacy long-range strike aircraft and munitions as well as the next long-range strike family of systems.

SUSTAINING THE AIR LEG OF THE NUCLEAR TRIAD

> The Air Force needs to have a plan for a land-based strategic deterrent replacement and for sustainment of the air leg of the nuclear deterrent force.
>
> — General Chilton, Commander, US Strategic Command[163]

The 2010 Nuclear Posture Review (NPR) determined that DoD must maintain a nuclear triad in order to sustain the nation's strategic deterrence posture, provide extended deterrence to US allies and partners, and hedge against changes in the security environment or unforeseen technological failures of one or more triad legs.[164]

Despite the NPR's conclusion, the nuclear triad is on a glide-slope toward a "dyad" of SLBMs and ICBMs. The Defense Department's nuclear-capable bomber force program of record consists of twenty penetrating B-2s and seventy-six

161 For an excellent discussion of this relationship, see Rebecca Grant, *The Radar Game* (Arlington VA: IRIS Independent Research, 1981), p. 44, accessible online at http://72.52.208.92/~gbpprorg/mil/radar/The_Radar_Game.pdf.

162 Of course, designing new penetrating strike aircraft with less stealth would also reduce their capability to operate independently.

163 See Adam J. Herbert, "Global Force Worries," *Air Force Magazine*, January 2010, accessible online at http://www.airforce-magazine.com/MagazineArchive/Pages/2010/January%202010/0110worries.aspx.

164 *2010 NPR Report*, April 2010, p. ix.

standoff B-52s.[165] When the B-2 loses its ability to penetrate, the air leg of the triad will be reduced to B-52s equipped with nuclear-tipped standoff ALCMs that are approaching the end of their service life and are unsuited for attacking relocatable targets such as road-mobile ICBM launchers of the type being fielded by China, Iran and Russia.[166]

There are options that will permit DoD to sustain a nuclear-capable bomber force and hedge against uncertainty. First, DoD should develop a new nuclear-capable cruise missile capable of surviving advanced air defenses. Unlike the ALCM, the new missile should be able to carry conventional as well as nuclear warheads and to be launched from a variety of Air Force and Navy aircraft. A smaller, more versatile cruise missile with a range of 500–600 nm that can be carried by fighter-sized aircraft as well as bombers would permit DoD to take advantage of the economies of scale via a larger procurement and increase the overall size of the standoff missile magazine.

Second, the Defense Department should design a new bomber to preserve this option for delivering nuclear weapons. Under New START, the Air Force has the latitude to incorporate basic nuclear weapons requirements into a new bomber design without fully equipping, testing, certifying, and declaring it as nuclear-capable. With this in mind, a new bomber should:

> Withstand the effects of nuclear weapons (blast/shock, thermal effects and EMP);

> Incorporate wiring and weapons management systems that are compatible with nuclear weapons and can be certified to meet nuclear safety requirements at some future date; and

> Provide space and power for components needed to control and release nuclear weapons.

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165 To meet New START Treaty limitations, DoD is expected to decrease nuclear-capable bombers to 60 or fewer by converting some aircraft, most likely non-penetrating B-52s, to carry conventional weapons only. See Robert M. Gates, "The Case for the New START Treaty," *Wall Street Journal*, May 13, 2010, accessible online at http://online.wsj.com/article/SB10001424052748703339304575240164048611360.html?WORDS=gates. DoD will also retain up to 420 ICBMs, 14 submarines carrying up to 240 SLBMs. The Air Force's 66 conventional-only B-1s are not limited by the New START Treaty.

166 DoD's budget for FY2011 explains the current ALCM "is experiencing obsolescence of parts [and] components…missile components and support equipment are becoming non-supportable." Also see the *2010 NPR Report,* p. 24: "In addition, the Air Force will conduct an assessment of alternatives to inform decisions in FY 2012 about whether and (if so) how to replace the current air-launched cruise missile (ALCM), which will reach the end of its service life later in the next decade."

The first design factor is desirable for *all* military aircraft that may have to operate in environments where an enemy could use nuclear or EMP weapons.[167] If a new bomber may someday be required to replace the B-2 and B-52 in the nuclear triad, an ability to withstand the electromagnetic pulse, blast/shock and thermal effects of nuclear weapons should be included in its initial design. If not, and a post-production decision is made to make a bomber nuclear-capable, DoD would be forced to develop and procure new airframes. Essentially, the Defense Department would have to buy new aircraft at a significantly higher cost than had it simply designed the bomber to withstand these effects in the first place.

This insight applies to the next two criteria as well. If a new bomber is not designed and wired to accept specialized components to maintain positive control over nuclear weapons and the dedicated channels required to communicate with nuclear weapons, DoD would have to develop another airframe with these capabilities if it decides to recapitalize the nuclear-capable bomber force.

As a rough rule of thumb, developing a new bomber to survive nuclear weapons effects may increase its EMD cost by as little as 6 to 8 percent.[168] This 6 to 8 percent is relatively inexpensive compared to the cost of returning to the design stage and building another airframe. Reduced to the most basic terms, DoD does not need to make an immediate policy decision to fully equip and certify a new bomber as nuclear-capable. Instead, the Defense Department should design any new bomber to hedge against this eventuality.

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[167] DoD's "MIL-STD-464 Military Standard, Electromagnetic Environmental Effects, Requirements for Systems" establishes the design margin required to survive environmental effects such as lightning strikes.

[168] R.C. Webb, Lew Cohn, Joan Pierre, and Al Constantine, "The Cost Differential to Radiation Harden DoD Space Assets," Defense Nuclear Agency presentation to American Defense Preparedness Association C4I symposium, U.S. Air Force Academy, March 27, 1996. Also see Joan Ma Pieere, R.C. Webb, Lew Cohn, Les Palkuti, Al Costantine, "The Cost of Radiation Hardening Systems," January 24, 2001.

CHAPTER 4 > **INITIATIVES AND IMPLEMENTATION**

> We also believe the United States must be able to deny an adversary sanctuary by providing persistent surveillance, tracking, and rapid engagement with high-volume precision strike. That is why the Panel supports an increase in investment in long-range strike systems and their associated sensors.
>
> —The Final Report of the Quadrennial Defense Review Independent Panel[169]

Preceding chapters have presented the case that since World War II the United States has derived a major competitive advantage from its military's ability to conduct large-scale long-range strike operations. This advantage has paid big dividends in deterring would-be rivals and defeating enemies in war. The ongoing efforts of existing and potential rivals now threaten to dilute this advantage, if not eliminate it entirely. The Defense Department's current program of record is insufficient to sustain the US military's long-range strike strategic advantage. Consequently, DoD leaders, faced with a major strategic choice of whether or not to retain this advantage, have wisely chosen to do so. The question thus becomes: How?

The Defense Department's current program of record is insufficient to sustain the US military's long-range strike strategic advantage.

This chapter summarizes a number of key initiatives designed to close the gap between DoD's programmed force and a family of systems that will sustain the US military's ability to conduct long-range strike operations in non-permissive operational environments. Chapter 4 also offers insights into how these initiatives should be prioritized to address the most pressing capability shortfalls first and reduce the overlap between new programs. A final section briefly summarizes defense industrial base issues which DoD should consider as it defines a plan for developing its next long-range strike family of systems.

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[169] See *The Final Report of the Quadrennial Defense Review Independent Panel, The QDR in Perspective: Meeting America's National Security Needs In the 21st Century* (Washington DC: United States Institute for Peace, 2010), p. 60, accessible online at http://www.usip.org/files/qdr/qdrreport.pdf.

Assessed against the alternative framework proposed in Chapter 1, DoD's program of record long-range strike family of systems has the following shortfalls:

> Land-based bombers, with the exception of the small B-2 force, lack the ability to penetrate and persist in high-threat air defense environments;

> US carrier air wings lack the range, persistence and survivability to support long-range strike operations in A2/AD environments, especially if enemy threats induce carriers to operate beyond effective ranges for strike operations;

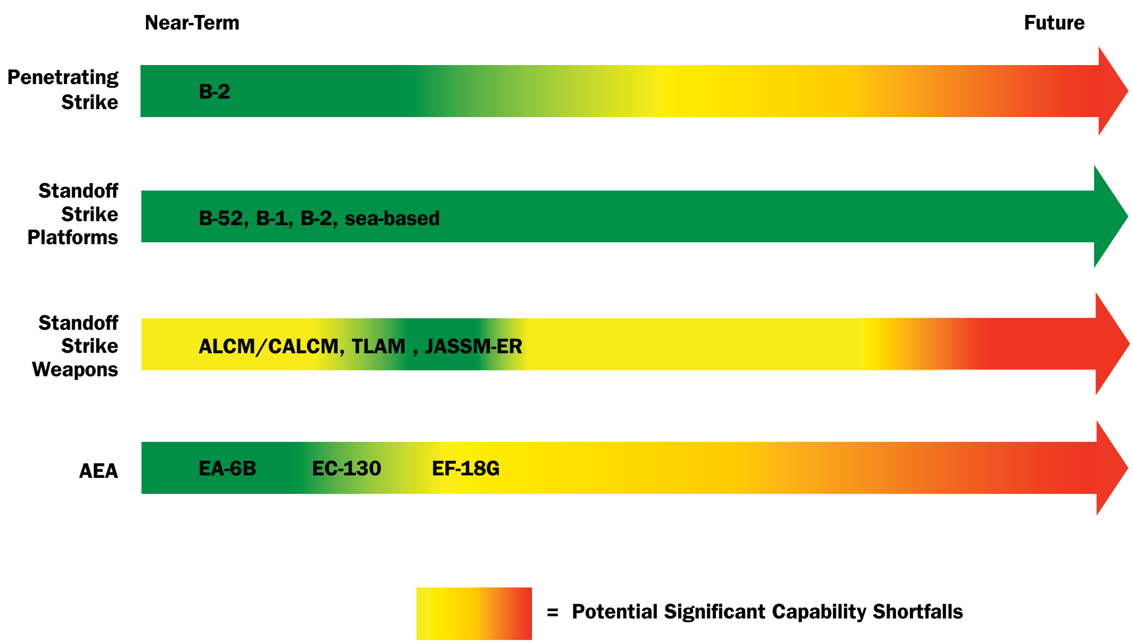
> Land-and sea-based strike systems lack the capability and capacity to strike large target sets that are increasingly mobile, relocatable, time-sensitive, hardened, deeply buried, and located deep in contested areas;

> Longer-range ALCM and CALCM air-launched cruise missiles are reaching the end of their service lives;

> Standoff weapons lack the ability to strike time-sensitive targets and are very expensive compared to direct attack PGMs; and

> Airborne electronic attack platforms lack the range and survivability needed to support long-range strike operations in contested airspace.

FIGURE 16. PROGRAM-OF-RECORD LONG-RANGE STRIKE CAPABILITY SHORTFALLS



SEQUENCING LONG-RANGE STRIKE INVESTMENTS OVER TIME

This section assesses four alternatives for prioritizing investments over time to meet DoD's known and emerging long-range strike capability shortfalls. Since each option proposes fielding an unmanned carrier strike platform as soon as technology and budget realities permit, assessments focus on the implications of developing new land-based bombers, standoff weapons and a supporting AEA platform with increased range and persistence.

OPTION 1: DEFER A NEW BOMBER. This option, which involves deferring a bomber decision until the mid-2020s would allow DoD to mature or invent new technologies that could lead to a more capable penetrating aircraft, such as advanced stealth, more efficient engines and improved automatic target recognition systems. It would also permit the Defense Department to procure a smaller and potentially less expensive AEA aircraft in the near term with sufficient range and persistence to support carrier UCAS operations. Of the four alternatives, Option 1 may have the greatest potential to reduce *near-term* investments needed for new long-range strike capabilities, an important consideration given the prospect of decreasing defense budgets.

However, Option 1 would find DoD's capability and capacity shortfalls for striking mobile, hardened, deeply buried, and geographically deep targets in progressive—and perhaps irreversible—decline.[170] To *partially* compensate for

[170] This assumes that a program initiated in the mid-2020s would not field a new bomber for 10 to 15 years.

TABLE 6. OPTIONS FOR SEQUENCING DEVELOPMENT OF THE NEXT LONG-RANGE STRIKE FAMILY OF SYSTEMS

Option 1: Defer a New Bomber	Option 2: Standoff Strike +	Option 3: Penetrating Strike +	Option 4: One Bite at the Apple
> Continue to upgrade the current bomber force > Defer a new bomber decision until mid-2020s > New air-launched standoff cruise missile, limited CPGS > New carrier UCAS > Develop a smaller AEA platform	> Field a new standoff bomber first > Defer fielding a new penetrating bomber until 2040s > New air-launched standoff cruise missile, limited CPGS > New carrier UCAS > Defer AEA platform until 2040s	> Field a new penetrating bomber first > Defer fielding a new standoff bomber until 2040s > New air-launched standoff cruise missile, limited CPGS > New carrier UCAS > New AEA platform	> Field a new penetrating bomber to replace the entire bomber force > New air-launched standoff cruise missile, limited CPGS > New carrier UCAS > New AEA platform

this shortfall, DoD would likely find itself compelled to procure a larger number of longer-range (1,000 nm or greater) and highly expensive standoff weapons. In the context of an air campaign, using primarily standoff weapons to strike tens of thousands of targets would be cost-prohibitive. Option 1 would, in effect, impose significant constraints on the conduct of future air campaigns and would not support implementing an AirSea Battle concept of operations for defeating A2/AD capable adversaries. Moreover, a bomber program that begins in the mid-2020s will not produce new "rubber on the ramp" until the very late 2030s or early 2040s, by which time DoD would need to begin replacing the entire bomber force, increasing the overall cost of a new program.

OPTION 2: MOVE TO AN ALL-STANDOFF STRIKE FORCE. Option 2 calls for developing a new standoff bomber without, however, the stealth and supporting systems needed to survive in contested airspace. This approach would reduce the bomber's cost. As in Option 1, deferring a penetrating bomber for another two decades would allow new aircraft technologies to mature.

The disadvantages inherent in this course of action, however, may far outweigh the advantages. In pursuing this option, the Defense Department would not take full advantage of the remaining service lives of its legacy — and fully paid for — bombers if it begins replacing them with a new standoff platform in the next ten or fifteen years. DoD would have to significantly increase its investments in long-range standoff weapons to compensate (if only partially) for the loss of its capability to conduct air campaigns with large numbers of less expensive direct-attack PGMs. Furthermore, DoD's ability to strike hard and deeply buried targets located in high-threat areas with large (5,000 pounds or more) direct-attack penetrating weapons would be lost for several decades after the B-2 transitions to standoff attack missions. In terms of cost, Option 2 would likely create a significant overlap between standoff bomber procurement and the long-lead development of a follow-on penetrating bomber, resulting in an undesirable program funding "bow wave."

OPTION 3: DEVELOP NEW PENETRATING STRIKE CAPABILITIES FIRST. Option 3 calls for according priority to developing a new penetrating bomber. This would take full advantage of the B-2's, B-1's and B-52's remaining service lives as standoff strike platforms. Assuming DoD initiates a development program within the next several years, a new penetrating bomber could join the active force before the B-2 loses its capability to penetrate. A penetrating bomber would enable DoD to enlarge its PGM magazine by procuring less expensive munitions, including a joint cruise missile with a range of 500–600 nm, while limiting CPGS weapons to a very small inventory needed for strikes against extremely high-value, time-sensitive targets.

Option 3 is not without its downside. The Defense Department may need to begin modernizing its standoff strike platforms in the final years of a penetrating bomber procurement program. However, the magnitude of this overlap would almost certainly be significantly smaller than the bow wave created in Option 2, and could be mitigated or nearly eliminated if DoD chose a non-stealth variant of the penetrating bomber as its follow-on standoff aircraft. This "one planform, two variants" approach would also allow DoD to exploit the economies of scale. Moreover, a significant degree of commonality between the two variants could reduce the cost of sustaining a future bomber force. Another approach would be to develop a new penetrating bomber as the first phase of a two-step spiral. The new bomber could have low-observable characteristics superior to the B-2 and with provisions (external hard points, power and data bus) to carry weapons externally. When the Defense Department is ready to proceed with the second spiral, it could convert the spiral one bomber to a standoff attack platform while procuring new penetrating bombers based on the same planform (and using most of the same production tooling) with updated stealth features and perhaps new, more efficient engines.

OPTION 4: ONE BITE AT THE APPLE. Procuring one penetrating bomber to replace the Air Force's entire long-range strike force could be the most expensive of the four postulated options. DoD would pay a very high cost to replace its non-LO standoff strike platforms, which could equate to a smaller total bomber force. Moreover, procuring an advanced stealth platform to conduct strike operations against target sets in low- and medium-threat environments would be a case of capability overkill.

TOWARD A BALANCED LONG-RANGE STRIKE FAMILY OF SYSTEMS

Of the four postulated options, Option 3 appears to offer the most balanced approach for sustaining the nation's long-range strike strategic advantage over the next thirty years. The mix of standoff and penetrating long-range strike capabilities called for in Option 3 would create multi-dimensional challenges for future adversaries while hedging against an unanticipated failure of one or more US long-range strike systems. Since DoD's most immediate long-range strike shortfall is the lack of platforms and weapons that can penetrate and persist in non-permissive threat environments to strike fixed and mobile targets, it is reasonable to assign addressing this capability gap the highest priority in a plan to develop the next family of long-range strike systems. Moreover, Option 3 would go a long way toward avoiding "stacking" programs to recapitalize the Defense Department's

Since DoD's most immediate long-range strike shortfall is the lack of platforms and weapons that can penetrate and persist in non-permissive threat environments to strike fixed and mobile targets, it is reasonable to assign addressing this capability gap the highest priority.

bomber force, while taking full advantage of the remaining service lives of the B-2, B-1 and B-52.

In summary, the following initiatives are needed to address DoD's highest priority long-range strike capability shortfalls:

1. PENETRATING, PERSISTENT BOMBER. The Air Force's next budget submission should initiate a new program to procure up to one hundred new optionally manned penetrating bombers with all-aspect, broad-band stealth; a payload capacity of approximately 20,000 pounds; and a range of 4,000 nm to 5,000 nm. The bomber should have on-board surveillance and self-defense capabilities to permit independent operations against fixed and mobile targets in degraded C4ISR environments.

2. STANDOFF STRIKE PLATFORMS. Given the expected service life and viability of the Air Force's current bomber force to perform standoff attack missions, DoD should defer procuring a new standoff strike platform until production of a penetrating bomber is nearly completed.

3. CARRIER AIR WING STRIKE. The Navy should develop an air-refuelable naval UCAS with a 1,500 nm combat radius and the all-aspect, broad-band low-observable characteristics required to survive in the face of advanced air defense networks.

4. AIR-LAUNCHED STANDOFF STRIKE CRUISE MISSILE. In lieu of a new standoff attack platform in the near- or mid-term, the Navy and Air Force should invest in a joint cruise missile that could be launched from long-range and short-range strike platforms and be capable of carrying either conventional or nuclear warheads.

5. PROMPT GLOBAL STRIKE WEAPONS. DoD should consider developing a small inventory (a hundred or fewer) of conventional prompt global strike weapons to support limited strikes against very-high-value targets requiring a total response time measured in hours.

6. AIRBORNE ELECTRONIC ATTACK. In addition to advanced decoys and other self-protect systems for new long-range strike platforms, DoD should field a manned or unmanned AEA platform to support long-range strike operations, leveraging other DoD programs and off-the-shelf technologies to reduce program development time and cost.

7. AIR LEG OF THE NUCLEAR TRIAD. The Air Force should design its new penetrating bomber to have the potential to carry nuclear weapons to sustain the air leg of the nuclear triad and hedge against uncertainty.

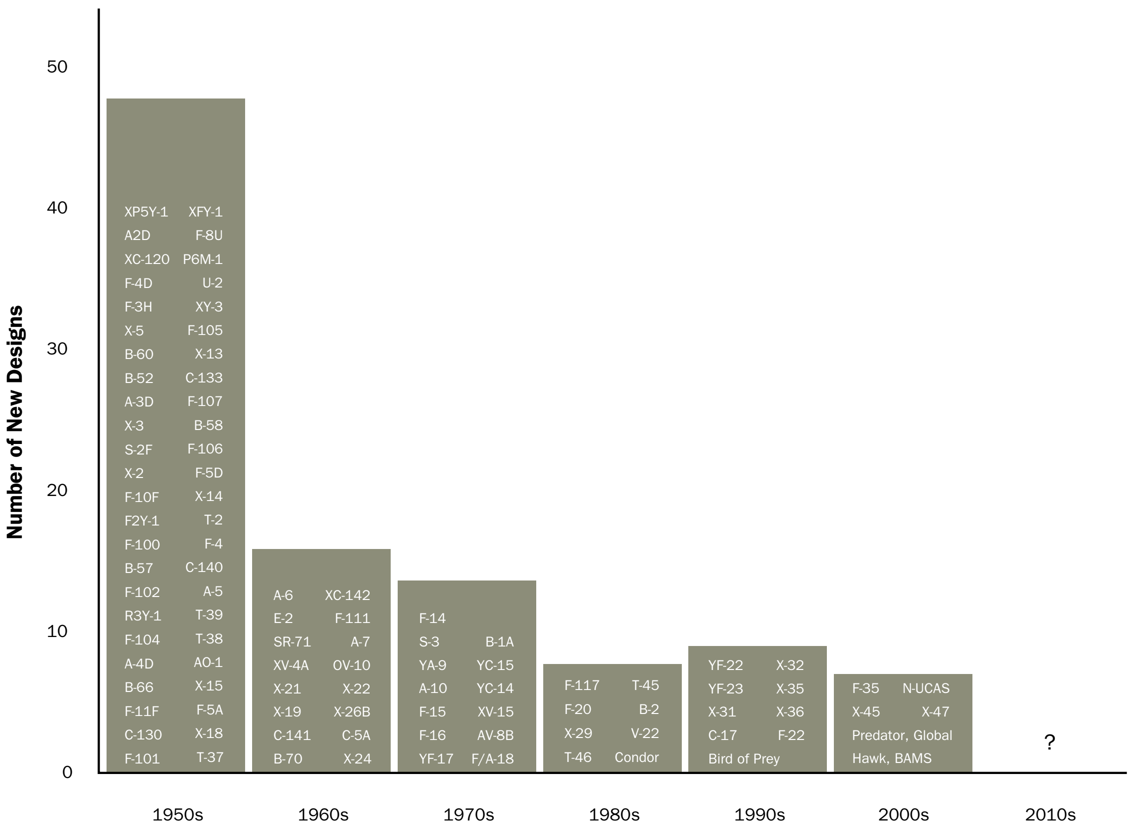
THE DEFENSE INDUSTRIAL BASE

Sustaining America's long-range strike strategic advantage extends beyond procuring specific platforms and weapons systems. It also depends on the human element: a workforce that understands sophisticated technologies and has the requisite skill-sets for designing, developing and building future military aircraft.

There are significant concerns with the long-term viability of the US military aircraft industrial base. Over the last forty years, DoD has had between seven and thirteen major aircraft under development. In 2010, with the possible exception of the Navy's UCAS-D program, there is not a single new major US military aircraft in development.

Sustaining America's long-range strike strategic advantage depends on sustaining a skilled industrial base.

FIGURE 17. HISTORICAL US MILITARY FIXED-WING AIRCRAFT DEVELOPMENT[171]



[171] Adapted from a figure developed by RAND Project Air Force. See Jeffrey A. Drezner, Giles K. Smith, Lucille E. Horgan, Curt Rogers, and Rachel Schmidt, *Maintaining Future Military Aircraft Design Capability* (Santa Monica CA: RAND, 1992), p. 30.

Image: CSBA

This trend, if it continues, runs a high risk of "hollowing out" the industrial base—long a key source of advantage for the United States against both existing and would-be threats. Aerospace engineering teams hone their skills by actually designing, developing, and testing new aircraft. Without new programs, industry will lose its most experienced military aircraft design and production teams as well as its capacity to train their replacements.[172] Moreover, fewer military aircraft development programs will, over time, reduce the workforce's breadth and depth of experience. While an aerospace engineer joining the workforce in the 1960s might expect to contribute to six or more major aircraft programs over a forty-year career, an engineer starting a career today might hope to participate in two or maybe three programs.

A less experienced industry workforce will, inevitably, increase the time needed to develop future long-range strike aircraft. In 1992, RAND determined that "a declining experience level has been a contributing factor to the problems we observe in many recent aircraft programs."[173] Since the mid-1990s, DoD has not developed a single new long-range strike platform, and has sent mixed signals on its intent to do so. This benign neglect of the industrial base "has led to considerable reductions in LRS [long-range strike] design and development capabilities" which will require considerable time and enormous cost to regenerate in the event DoD decides to defer beginning a new bomber program until mid-decade or later.[174] Moreover, further procrastination runs the risk that its development and production will require longer than the ten to twelve years originally projected for the now-cancelled Next-Generation Bomber, creating a "window of vulnerability" in a key area of the military competition.[175] And since "time is money,"

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172 Funding aircraft technology development alone, absent a real program, will not sustain the military aircraft industrial base. In 2009, Paul Meyer, Vice President and General Manager for Northrop Grumman's Advanced Programs and Technology Division, was quoted as saying "a small workforce needed for continuing science and technology development would be insufficient for sustaining a major defense company. See "Uncertain Skies for U.S. Industrial Base," *Defense News*, June 15, 2009, accessible online at http://www.defensenews.com/story. php?i=4138504. Mr. Meyer also observed "Once F-35 development ends pretty soon, there isn't another program coming in behind it."

173 *Maintaining Future Military Aircraft Design Capability*, p. 16.

174 "The Unseen Cost: Industrial Base Consequences of Defense Strategy Choices," Aerospace Industries Association, June 2009, p. 20, available online at http://www.aia-aerospace.org/assets/report_industrial_base_consequences.pdf. Following DoD's 2009 cancellation of the Next Generation Bomber program, Ashton Carter, Under Secretary of Defense for Acquisition, Technology, and Logistics observed if DoD were to allow this highly skilled workforce to erode, it "would be difficult to rebuild." See "Carter: Protect U.S. Industrial Base," Vago Muradian and John T. Bennett, Defense News, September 7, 2009 accessible online at http://www.defensenews.com/story.php?i=4266169.

175 Ibid, p. 21.

adding even a few years to a new aircraft's development schedule would likely cost the American taxpayer billions of dollars. [176]

At the industry level, the loss of one or more of the few remaining firms that are capable of acting as prime contractors for designing and developing new military aircraft would seriously compromise DoD's ability to rely on the private sector as a wellspring of invention and innovation. In 1965, eleven separate companies were capable of acting as prime contractor for new fighter or bomber aircraft. Today, at best a bare three remain: Boeing, Lockheed Martin and Northrop Grumman. If one of these three decided it was unable to continue to absorb the annual cost—approximately $80 million to 100 million—to sustain its aircraft design and development teams while awaiting DoD's decision for a new program start, it would diminish the DoD's ability to "harness the power of competition" that is essential to long-term innovation in major defense acquisition programs.[177]

In summary, sustaining the nation's long-range strike strategic advantage is more than a question of developing new technologies or procuring new platforms. It will also require the Defense Department to deliberately and effectively manage program investments to ensure its industry partners sustain a highly skilled workforce upon which, ultimately, the US military's future capabilities depend.

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176 "Carter: Protect U.S. Industrial Base." "Of the three primary factors that shape weapon programs —cost, schedule and performance—he [Carter] said he views the second as most critical." Also see "Advance Questions for Ashton Carter, Nominee to be Under Secretary of Defense for Acquisition, Technology, and Logistics," pp. 17–18, accessible online at http://armed-services.senate.gov/statemnt/2009/March/Carter%2003-26-09.pdf.

177 For a summary of this linkage between competition and innovation, see Mark Lorell, *The US Combat Aircraft Industry 1909–2000* (Santa Monica CA: RAND, 2003).

GLOSSARY

A2/AD	Anti-access/area-denial
AEA	Airborne Electronic Attack
AESA	Active Electronically Scanned Array
ALCM	Air-Launched Cruise Missile
AMRAAM	Advanced Medium-Range Air-to-Air Missile
ASAT	Anti-Satellite
ASBM	Anti-Ship Ballistic Missile
ASCM	Anti-Ship Cruise Missile
ASuW	Anti-Surface Warfare
ATP	Advanced Targeting Pods
BUR	Bottom-Up Review
C2	Command and Control
C2ISR	Command, Control, Intelligence, Surveillance, Reconnaissance
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance
CALCM	Conventional Air-Launched Cruise Missile
CG	Guided Missile Cruiser
COCOM	Combatant Commander
CONUS	Continental United States
CPGS	Conventional Prompt Global Strike
CSM	Conventional Strike Missile
DAWMS	Deep Attack Weapons Mix Study
DDG	Guided Missile Destroyer
DMPI	Desired Mean Point of Impact
DNI	Director of National Intelligence
DoD	Department of Defense
DRFM	Digital Radio Frequency Memory

EMD	Engineering and Manufacturing Development
EMP	Electromagnetic Pulse
GBU	Guided Bomb Unit
G-RAMM	Guided Rockets, Artillery, Mortars, Missiles
IADS	Integrated Air Defense System
ICBM	Intercontinental Ballistic Missile
ISR	Intelligence, Surveillance, Reconnaissance
JASSM	Joint Air-to-Surface Standoff Missile
JDAM	Joint Direct-Attack Munition
LACM	Land-Attack Cruise Missile
MRBM	Medium Range Ballistic Missile
MRC	Major Regional Contingency
NASIC	National Air and Space Intelligence Center
NGB	Next-Generation Bomber
nm	Nautical mile
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OTHR	Over-the-Horizon Radar
PGMs	Precision-Guided Munitions
PLA	People's Liberation Army
PLAN	People's Liberation Army Navy
PLANAF	People's Liberation Army Navy Air Force
PNT	Precision Navigation and Timing
PRC	People's Republic of China
QDR	Quadrennial Defense Review
RCS	Radar Cross Section
SAM	Surface-to-Air Missile
SATCOM	Satellite Communications
SEAD	Suppression of Enemy Air Defenses

SLBM	Submarine-Launched Ballistic Missile
SRBM	Short-Range Ballistic Missile
SSGN	Nuclear-powered guided missile submarine
SSK	Diesel-electric powered attack submarine
SSN	Nuclear-powered attack submarine
TACTOM	Tactical Tomahawk Cruise Missile
TEL	Transporter Erector Launcher
TLAM	Tomahawk Land-Attack Missile
UAS	Unmanned Air System
UCAS	Unmanned Combat Air System
UCLASS	Unmanned Carrier-Launched Airborne Surveillance and Strike
UHF	Ultra-High Frequency
VHF	Very-High Frequency
WMD	Weapons of Mass Destruction

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