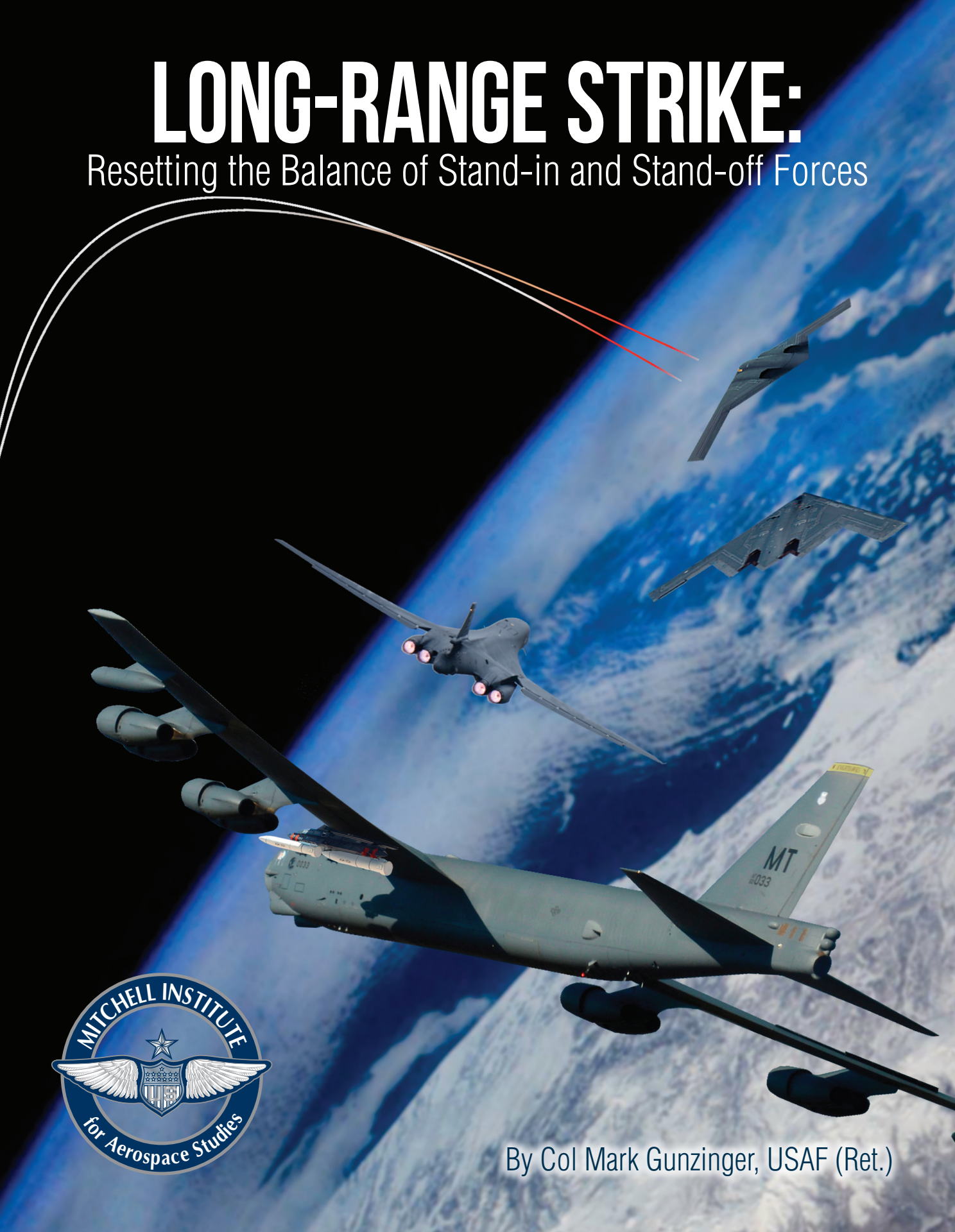
LONG-RANGE STRIKE:

Resetting the Balance of Stand-in and Stand-off Forces



MITCHELL INSTITUTE for Aerospace Studies

By Col Mark Gunzinger, USAF (Ret.)

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By Col Mark A. Gunzinger, USAF (Ret.)

The Mitchell Institute for Aerospace Studies
Air Force Association
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Brigadier General William L. Mitchell, United States Army Air Service

About the Author

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Foreword

Over the last 30 years China and Russia set out to modernize their strategies, operational concepts, and military technologies to negate the advantages of the American way of war showcased during Operation Desert Storm. Recognizing this reality, the Department of Defense (DOD) has undergone a strategic awakening that is now codified in the U.S. national defense strategy acknowledging that an era of peer conflict has reemerged. It has occurred at a moment in time when all of the services are struggling to make critical force modernization choices needed to regain the upper hand in deterring, and if necessary, prevailing in any great power contingency.

While many of the legacy ways and means wielded by the services require a major, if not complete, redesign to effectively compete with China and Russia's rising military prowess, a number of key capabilities in the nation's arsenal remain enduring. Chief among these tools is global *long-range strike*—the ability to attack targets anywhere, at any time. When paired with an effective campaign strategy aimed at vital targets on which an enemy's military enterprise greatly depends, long-range strike is one of the most effective methods available to America's military commanders. Decisions will soon be made that will reshape the balance of how DOD will conduct long range strikes in the future. Without analysis to inform those decisions there exists great danger that tightly constrained defense resources may be misspent.

Mark Gunzinger brings forward critically needed analysis on how DOD could strike the right balance between *penetrating strike*, also known as *stand-in* strike using the stealth bomber force resident in the U.S. Air Force, and *stand-off* strike—the launching of long-range missiles from aircraft, ships, submarines, and land emplacements. The analysis reveals that shifting the balance in favor of long-range stand-off systems does not make sense for the Air Force from either operational or cost-per-effect perspectives and would likely lead to over-investments in the Pentagon's overall stand-off strike capacity. Instead, this report recommends the Air Force should significantly increase its penetrating long-range strike capacity to provide American leadership the most cost-effective military capability for formulating credible options against great power aggression.

Lt Gen David A. Deptula, USAF (Ret.)
Dean, The Mitchell Institute for Aerospace Studies
June 2020

Executive Summary

America has long relied on using its bomber force as a premier means to project power globally. Since the Cold War, the Department of Defense (DOD) sized and shaped its bombers and other force structure for conflicts against rogue states similar to Operation Desert Storm in 1991. It now intends to build a future military that will have more capacity, the right mix of capabilities, and incorporate new operational concepts needed to defeat great power aggression and other 21st century threats. This new strategic focus will require DOD to take a hard look at its future ability to conduct missions critical to prevailing against these threats, including rapidly striking a large number of targets over long ranges in increasingly contested operational environments.

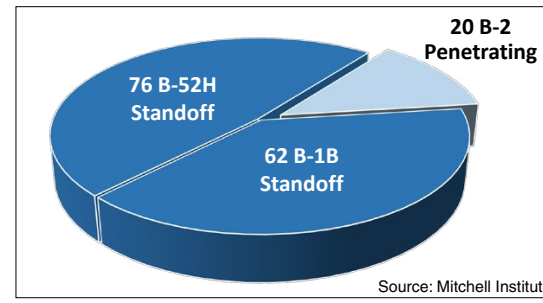
Given DOD's increased emphasis on preparing to conduct long-range, precision strikes against peer adversaries, now is a crucial time to reevaluate the U.S. Air Force (USAF) bomber force mix. This report assesses the strengths and limitations afforded by two facets of DOD's long-range strike forces—stealth bombers that can deliver munitions on targets from inside Chinese or Russian anti-access/area-denial (A2/AD) envelopes, and non-penetrating bombers that must stand-off from A2/AD threats to launch their weapons. The ability to conduct stand-in and stand-off strikes is not an either-or proposition, but instead constitutes a balanced approach to fighting future wars. This is exactly the dynamic General David Goldfein referred to when he recently discussed capabilities needed to prevail in great power conflicts: "The only force that can actually win…is a hybrid force" of long-range aircraft that can operate inside contested areas and from stand-off distances.[1] Goldfein cited multiple analyses that have shown neither an all stand-off force nor an all stand-in force would win in a host of conflict scenarios. Instead, it comes down to using a balanced force mix.

The future bomber force will also be critical to assuring and defending America's allies and partners that live under the A2/AD umbrellas of potential adversaries. For example, Russia's A2/AD complex now covers most of Poland, all of the Baltic states, and much of the Baltic Sea. USAF bombers and other combat air forces must be able to penetrate these contested areas to fight alongside America's allies on day one of a conflict, rather than slowly build-up a massive ground force in theater before launching a so-called "combined arms" effort similar to Operation Desert Storm. The latter approach in a future war would give China and Russia the time and freedom of action in the battlespace they need to win.

The 2020 Bomber Force

Although this report is focused on the USAF bomber mix, it is important to know that DOD as a whole has tremendous stand-off strike capacity and limited depth in its stand-in strike forces. The U.S. military's long-range stand-off strike forces include the USAF's 76 B-52H and 62 B-1B bombers plus Navy, Marine Corps, and Army long-range fires consisting of artillery, ballistic missiles, and cruise missiles, while its current stand-in strike capacity consists of a mere 20 Air Force stealth B-2s. This mix must be rebalanced in favor of stand-in capabilities as the Air Force modernizes and increases the size of its bomber force.

It is also important to understand how and why the bomber force has changed over the last 30-plus years. The Air Force's 158 bombers are a shadow of the force of 411 bombers it operated toward the end of the Cold War, the last period of great power competition. Since 1990, the Air Force made a series of cuts to the size of its bomber force primarily for two reasons: to find savings in an era of shrinking defense budgets and to retire bombers that DOD did not believe were needed to defeat aggression by rogue states such as Iran and North Korea. An attempt to modernize the force by buying 132 stealth B-2s was capped at 21 aircraft by the Secretary of Defense in 1997 for similar reasons. The Air Force's FY2021 budget proposes to cut another 17 of its B-1Bs in the hope that it will generate savings that can be used to sustain B-1Bs that will remain in the inventory. The Air Force also plans to keep all of its B-52Hs in the force until the 2040 timeframe and buy at least 100 B-21 stealth bombers to gradually replace its remaining B-1Bs and B-2s.



As a result of 30 years of force cuts, inadequate modernization funding, and some shortfalls in sustainment funding, the USAF bomber force is the oldest and smallest since its founding as a separate service in 1947. Multiple studies have concluded it lacks the long-range strike capacity needed for a *single* conflict with a peer adversary and recommended growing the bomber force as quickly as possible to at least 220 aircraft. As the USAF does so, it will be even more critical to field the most effective and efficient future mix of stand-off and stand-in bombers. The wrong bomber mix could reduce long-range strike options available to America's theater commanders and waste resources by over-investing in stand-off strike capacity that other services are already procuring.

Advantages and Disadvantages of Stand-off and Stand-In Long-Range Strikes

Both long-range stand-off and stand-in strikes have advantages and disadvantages. Similar to penetrating systems, stand-off bombers and fighters can deploy within hours to launch long-range weapons at targets located inside contested areas. This early firepower is essential to achieving time-sensitive objectives for theater commanders such as rapidly halting a Chinese or Russian invasion of a U.S. ally. The use of stand-off strike platforms can also reduce U.S. force attrition early in a fight when enemy defenses are at full effectiveness. Force survivability is all-the-more important considering the diminished size of the USAF Combat Air Force (CAF) as a whole.

In comparison, stealth aircraft can penetrate contested areas and approach targets closely enough to use very short-range "direct attack" weapons against them. Direct attack weapons are generally smaller than long-range stand-off weapons that have ranges greater than 400 nm. To achieve long range, weapons such as cruise missiles typically need powerplants, wings that deploy after launch, one or more guidance systems, and other design features that increase their size and cost. These costly features are not needed by short-range weapons such as the Joint Direct Attack Munition (JDAM). Size matters, since the number of

weapons that can be delivered per aircraft sortie decreases as weapon size increases. Fewer weapons per sortie can increase the time needed to strike targets required by a theater commander, time that an enemy could use to its advantage. A better alternative is to seek a force mix that *increases* weapons per sortie—a mix that predominately consists of stand-in bombers—that will help theater commanders gain a decisive advantage.

Long-Range Stand-off Weapons
- Ranges > 400 nm, typically winged and powered to achieve range (Tomahawk, JASSM-ER)
- Enable non-stealth aircraft to launch long-range strikes while remaining outside contested areas

Short-Range Stand-off Weapons
- Ranges up to 400 nm, winged, powered or can glide to extend range (JSOW, SDB II)
- Enable penetrating aircraft to strike while remaining outside highest risk threat envelopes

Direct Attack Weapons
- Ranges of low tens of nm or less, typically unpowered (JDAMs, Quickstrike mines, etc.)
- Must be released close to targets

The potential for weapons to be intercepted or otherwise rendered ineffective by enemy air defenses is another factor that must be considered by bomber force mix assessments. China, Russia, and other adversaries have aggressively pursued countermeasures that are increasingly capable against U.S. precision strikes. These countermeasures include developing layered air defenses that can intercept incoming weapons; fielding increasingly mobile ground-based weapon systems to make it harder for U.S. ISR systems to locate and track; and hardening/deeply burying important installations to make them more difficult for weapons to destroy. Weapons destroyed or otherwise defeated by enemy air and missile defenses can increase the total number of weapons needed to kill a set of targets. In the past, the probability that a weapon would be intercepted after launch was very small. During the 2003 Operation Iraqi Freedom air campaign, coalition air forces used an average of 1.5 precision guided munitions (PGMs) per target, a weapon-to-target ratio that World War II airmen could have only dreamed.[2] Legacy U.S. cruise missiles and other weapons can now be located, tracked, and intercepted far more effectively by advanced air and missile defenses. If three, four, or even more PGMs must be launched to ensure at least one of them survives to strike a designated target, the total number of weapons and aircraft needed to attack tens of thousands of targets in a peer conflict would be far more than DOD can afford to procure.

While enemy countermeasures can increase the number of weapons needed to strike targets from all ranges, they can have a greater impact on long-range stand-off weapons. Non-stealth strike aircraft must stand-off hundreds of miles—possibly 500 to 700 nm depending on the threat—from advanced air defenses to ensure their survival. This requires them to use weapons with long ranges to attack targets located inside A2/AD envelopes. Flying hundreds of miles through enemy defenses increases the probability that long-range standoff weapons will be intercepted compared to direct attack weapons with flight times of a few minutes that reduce an enemy's ability to detect and respond to incoming strikes.

It is also more difficult to find, fix, track, and attack mobile/relocatable targets from long stand-off ranges compared to penetrating aircraft that have on-board sensors and other capabilities to complete the entire kill chain against time-sensitive targets. A subsonic (Mach 0.8) long-range cruise missile launched 500 nm from a target would need about an hour to reach it. Because aimpoint coordinates are generally programmed into stand-off weapons before they are released, this would afford an enemy with time to detect long-range stand-off attacks and counter them by changing the locations of their mobile/relocatable assets.

Source: USAF

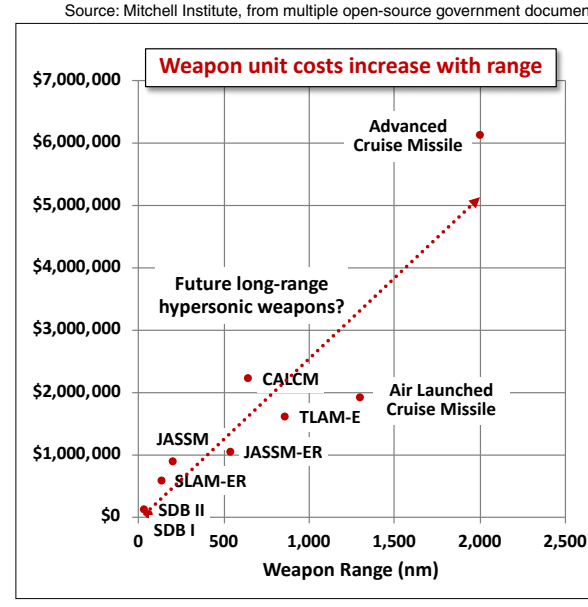
B-2 releasing a GBU-57A/B MOP

Stand-off weapons also cannot carry warheads that are large enough to kill targets that are structurally hardened or deeply buried, a tactic widely used by China, Russia, Iran, North Korea, and others to counter precision strikes. On the other hand, penetrating bombers can deliver very large direct attack weapons that are specially designed to have enough kinetic punch to kill these kinds of challenging targets. To cite two examples, B-2s can deliver 5,000-pound direct attack "bunker buster" weapons and even the 30,000-pound GBU-57A/B Massive Ordnance Penetrator on hardened targets. It is impractical to design weapons with these sizes and weights to also fly very long ranges.

Aircraft stand-off distances can also reduce the number of targets they can attack. An aircraft that must stand-off 800 nm from the Chinese coastline would need a weapon with more than 1,600 nm range after launch to attack a target located 800 nm inland. Non-line-of-sight flight profiles created to avoid enemy threats while inbound to a target would increase this range requirement well outside the 500 nm reach of the USAF's Joint Air-to-Surface Stand-off Missile-Extended Range (JASSM-ER). A weapon with 1,600 nm or more range would likely be so large that it would be impractical for most U.S. combat aircraft to carry them in significant numbers. Aircraft stand-off ranges can be a major constraint in a war with China or Russia, considering the depth of their landmasses and ability to deploy ballistic missile launchers, anti-satellite weapons, and other high-value assets deep in their interiors.

Then there is the matter of cost, a growing concern given the reality of flat or declining defense budgets. Weapons affordability is critical given the need to attack tens of thousands of aimpoints in a conflict with China or Russia. As a point of reference, allied air forces attacked about 40,000 aimpoints during Operation Desert Storm against a third-rate Iraqi military. Target lists in a major war with China or Russia could be multiples of this number. Using tens of thousands of very long-range stand-off weapons that cost a million dollars or more each is simply not affordable.

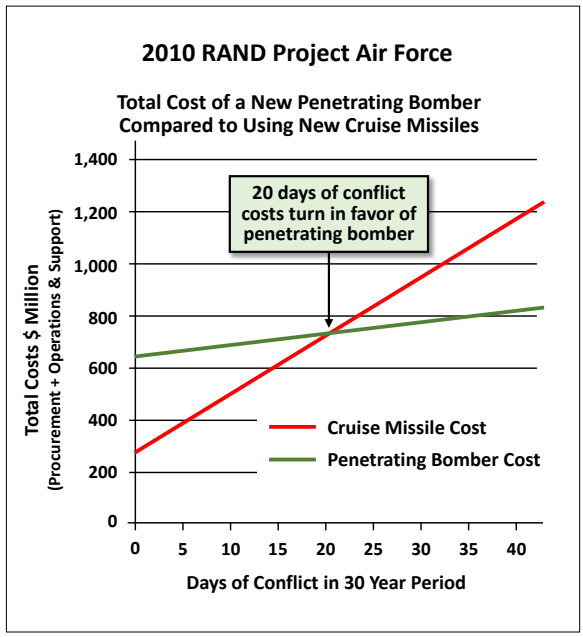
Source: Mitchell Institute, from multiple open-source government documents



Some have suggested the high cost of using long-range weapons could be offset by buying a new large

stand-off strike aircraft or "arsenal plane" that could be less expensive than a new penetrating bomber. This is not born out by analysis. A 2010 RAND Project Air Force study concluded a penetrating bomber delivering direct attack weapons for at least 20 days of combat would cost less than expending an equivalent number of more expensive stand-off cruise missiles.[3] To put this in context, **20 days of airstrikes is less than half the length of the 43-day Desert Storm air campaign** and is far less than the combined duration of all U.S. air campaigns over the last 30 years. This finding was instrumental in DOD's decision to begin the B-21 program. Assuming that buying and sustaining a new stand-off bomber would run into the hundreds of millions of dollars, the cost crossover point could be as short as 10 to 15 days of combat. In this light, investing in penetrating bombers instead of additional USAF stand-off strike capacity would be a bargain.

Source: RAND (see endnote 3)



Source: Mitchell Institute (see endnote 75)

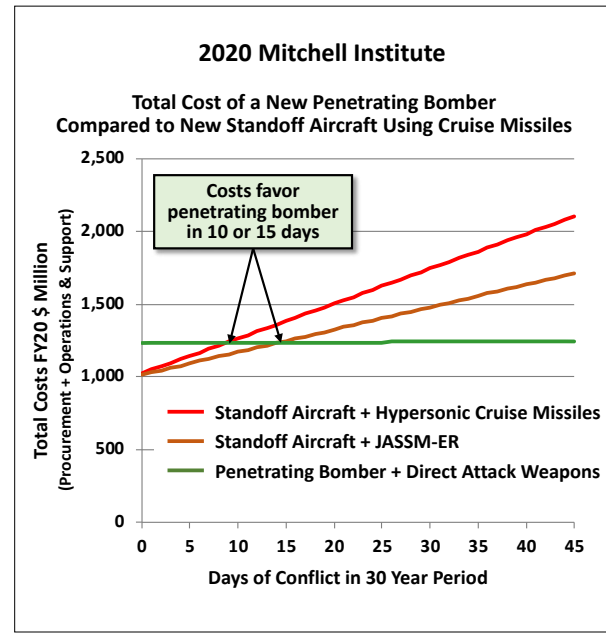


Figure 1: 2010 RAND and 2020 Mitchell Institute cost comparisons

The cost and operational impacts of Chinese or Russian countermeasures would be all the more consequential given that 87 percent of the USAF bomber force cannot penetrate A2/AD envelopes and would need to rely on long-range stand-off weapons. The service's remaining B-52H bombers rolled off the production line during the Kennedy administration, well before the introduction of stealth technologies. Similarly, the B-1B was designed to penetrate Soviet-era air defenses, not the modern integrated air defense systems (IADS) now fielded by China and Russia. Only the Air Force's 20 stealth B-2s are able to penetrate these threats, and **only 16 of these 20 are assigned to combat squadrons**.

Past these 16 primary mission B-2s, the rest of the bomber force would be limited to launching long-range weapons from outside contested areas during a conflict with a peer adversary. This reality invites China and Russia to field even longer-range air defenses that would drive USAF non-stealth bombers and other aircraft further out in the battlespace. This in turn would require the Air Force to invest in new stand-off weapons with even greater ranges and higher price points.

Considering the demands that the burgeoning threats pose by a resurgent Russia and an increasingly capable Chinese military, the USAF must increase the size of its bomber force. While classified studies and analyses are important in generating actual threat conditions based on current intelligence, the American public deserves to understand the force sizing approach to support the large investment that will be required to get to that objective bomber force. The Mitchell Institute paper, *The Force We Need: Key Factors for Shaping the Air Force for the Future*, provides a detailed discussion of such a methodology and how it directly relates to the U.S. national defense strategy.[4] The conclusion reached after the analysis conducted for this paper is that new B-21 squadrons should consist of 16 B-21s per unit. In cognizance with the force sizing construct outlined in the above paper, 10 squadrons of B-21s will be required to accommodate the national defense strategy amounting to 160 combat coded B-21s. Adding the nominal 25 percent for training and an additional 20 percent for attrition reserve and backup aircraft inventory amounts to an objective force level of 240 B-21s. Therefore, given the USAF's long-range penetrating strike shortfall, its future bomber force should consist of 76 B-52s and 240 or more B-21s for a total of at least 316 bombers. This total force is consistent with other independent bomber requirement studies that used different force sizing methodologies and is also approximately 25 percent less than the 411 bombers the Air Force had in its inventory near the end of the Cold War, an era where the United States was challenged by a *single* great power competitor.

It does not make sense for the Air Force to buy more stand-off bombers when it has a far greater shortfall in penetrating capacity. Despite evidence to the contrary, there is still interest in investing in a new stand-off aircraft that some believe could cost less than B-21s. These options include modifying military or commercial cargo aircraft to launch cruise missiles and even pursing a clean sheet new design for a stand-off bomber which some have called an "arsenal plane."

Assessments to determine the USAF future long-range strike requirements must consider the effectiveness as well as the cost of using stand-off and penetrating capabilities against realistic target sets in contested areas. Too much reliance on stand-off aircraft and weapons during peer-on-peer conflicts would constrain options available to theater commanders. As noted by Marine Corps Commandant General David Berger: "There is an argument to be made by some who feel that two great powers can stand off with long-range precision weapons and hold each other at bay…I am not in that camp."[5] In the end, it comes down to how the Air Force should invest its finite budget to field the most effective and efficient set of capabilities to support the U.S. national defense strategy.[6]

Recommendations

Based on assessments in this report and a mature body of evidence from related studies, the Mitchell Institute offers the following recommendations:

- **The USAF should significantly increase its long-range strike capacity.** A total force of *at least 316 bombers* is needed to support the national defense strategy, the vast majority of which should be B-21 aircraft. DOD's 1997 decision to stop buying stealth B-2s helped create a bomber force

that is now too small, too old, and over-weighted toward stand-off aircraft. While this force may have been adequate for past operations against lesser regional militaries, multiple analyses have concluded the Air Force should increase its capacity to conduct stand-in strikes in contested environments against peer adversaries. Doing so would require the USAF to buy at least 240 B-21 stealth bombers.

- **The Air Force should prioritize penetrating strike platforms.** Success in warfare comes down to inflicting rapid, overwhelming attacks against key targets, and sustaining such operations demands affordable means to conduct strikes. Today, B-1Bs and B-52Hs cannot penetrate the expanding Chinese or Russian IADS with an acceptable degree of risk, and the same is true for any non-stealth aircraft—old or new. The inability to penetrate limits bombers to using stand-off weapons to strike targets inside contested areas. The time needed for these weapons to fly hundreds of miles after launch reduces their effectiveness against relocatable targets such as missile transporter-erector-launchers, a weapons system favored by adversaries to launch attacks against U.S. forces. Past this, long-range weapons lack warheads capable of destroying very hard or deeply buried targets. The need to attack these challenging targets in contested environments was a primary reason that DOD chose to procure the B-21. Long-range weapons are also more expensive and can be carried in fewer numbers per sortie compared to smaller direct attack weapons. Finally, if facing a choice, the USAF must prioritize penetrating systems because it is the sole owner of these systems—other stand-off options and capacity exist. All of the other services seek to acquire new stand-off strike capabilities. To avoid redundancy the Air Force must ensure it can provide commanders with options to penetrate deep into contested areas and strike a large number of targets per sortie.

- **Hypersonic weapons are needed but will not be a panacea.** Enemy IADs are increasingly effective against legacy weapons such as subsonic Tomahawk Land Attack Missiles as well as non-stealth aircraft. Due to their speed, maneuverability, and other characteristics, hypersonic (Mach 5 or greater) weapons will be better able to survive in these threat environments. Using more survivable hypersonic weapons would help limit the total number of stand-off weapons needed to attack defended targets. However, hypersonic weapons launched from long stand-off distances will still be less effective against targets that can quickly relocate compared to direct attack PGMs that can reach targets in just a few minutes. Plus, hypersonic weapons are not cheap. Air-breathing hypersonic cruise missiles require powerplants, fuel, and other design features to fly long ranges which increases their size (decreases weapons per sortie) and cost. Similar to other stand-off munitions, investments in hypersonic weapons should be informed by tradeoffs between their survivability, size, weapons per sortie, effectiveness against challenging targets, and affordability.

- **Allocating modified airlift aircraft to conduct strike missions does not make operational sense.** There are already indications of a growing shortfall in the Air Force's capacity to provide heavy airlift to rapidly deploy and sustain forces. Schemas that would allocate some number of modified airlifters to strikes instead of their primary mobility missions could have a major impact on the U.S. military's ability to prevent China or Russia from achieving a quick victory.

- **Developing a new stand-off bomber is not a quicker and cheaper option.** There is a persistent myth that a new stand-off arsenal aircraft with large payload capacity could be developed quickly and for less cost than buying the B-21. Neither are true. Restarting a production line for a military airlifter like the C-17 would require years and billions of up-front program dollars. On top of this, modifying a C-17 or existing commercial cargo aircraft to carry stand-off weapons would require even more funding and time. Those who question this should consider the effort needed to develop the Navy's P-8 maritime patrol-strike aircraft from a commercial design and continued struggles surrounding the Air Force's KC-46A tanker. The resulting cost of a weapons-carrying widebody aircraft could equal or exceed the B-21's cost while providing a less operationally flexible, single-mission capability. It is likely that a clean-sheet design stand-off bomber would be even more expensive than a program that modifies a mature airlifter to launch weapons.

Introduction

America's global interests are being threatened like never before. China and Russia now pose security challenges that the United States has not confronted since the Cold War—some potentially existential in nature. At the same time, mid-tier powers like North Korea and Iran that have ballistic missiles and aspire to develop the ability to deliver nuclear warheads over long ranges remain an enduring threat to the United States and its allies. Added to this, non-state actors like Al Qaeda, the remnants of ISIS, and Hezbollah continue to plot attacks against the United States and its allies. The concurrency of these threats has stretched American military resources thin. With vital interests on the line, U.S. leaders must prioritize solutions that efficiently modernize America's military and ensure it will have the most effective tools available to execute the U.S. national defense strategy. The country simply lacks excess resources to invest in subpar or duplicative technologies.

Chief among these tools is global long-range strike—the ability to attack targets anywhere, at any time.

Chief among these tools is global *long-range strike*—the ability to attack targets anywhere, at any time. When paired with an effective campaign strategy aimed at vital targets on which an enemy's military enterprise greatly depends, long-range strike is one of the most effective tools available to America's military commanders. History offers decisive proof. When Allied forces stormed the beaches of Normandy in June of 1944, it took them a mere 11 months to reach Berlin and bring an end to the war. This occurred over the very same territory that opposing armies waged stalemated bloody trench warfare between 1914 and 1918. In contrast to World War I, Allied long-range strike bombers reduced Germany's ability to sustain its combat operations on the ground, in the air, and at sea. In the Pacific, long-range strikes executed by U.S. Twentieth Air Force B-29s and two atomic airstrikes were instrumental in achieving unconditional victory without a costly Allied invasion of Japan's home islands. Over the ensuing decades, technological innovations such as precision-guided munitions, improvements in aircraft range, and stealth technologies radically enhanced what single combat aircraft could achieve in the battlespace. Today, one stealth B-2 sortie can strike eighty individual targets with pin-point accuracy and do so without a large "package" of accompanying support aircraft to assure its survivability.

There are two basic approaches for conducting long-range strikes. One involves using aircraft to penetrate enemy defenses and release munitions in proximity to targets. This approach is called *penetrating* or *stand-in* strike and is classically associated with the stealth bomber force resident in the U.S. Air Force. The other approach is called *stand-off* strike, which is described as launching long-range missiles from aircraft, ships, submarines, and from land locations against targets.

Both approaches have their strengths and weaknesses, but recent debates about the nature of these two vectors have migrated toward going "all in" on investments for one or the other. Today, the Army and Navy are starting to bolster their strike capacity by procuring long-range stand-off missiles. In many ways, such investments are often viewed as a panacea for the defensive strategies used by our adversaries. Such thinking is simplistic and risks a broader set of challenges that will negatively impact options available to

U.S. commanders. It is often perpetuated by the failure to perform adequate analysis on issues such as the *feasibility* of buying sufficient stocks of expensive long-range missiles, the *cost* and *time* needed to develop a new stand-off attack "missile truck," and even the *suitability* of using long-range weapons against many tens of thousands of targets. It is also stoked by intra-service budget battles.

A key insight from post-Cold War government and non-government analyses is that both long-range stand-off and stand-in strike capabilities are necessary. General Dave Goldfein, Air Force Chief of Staff, recently noted that after a significant number of USAF wargames, the force that wins in DOD planning scenarios "has a combination of that which works from inside and that which works from outside…a balance" of penetrating and stand-off strike forces.[7] Goldfein also remarked on the need for analysis to inform decisions on future strike programs: "And as I've shared with other leaders who have talked about just shifting to an all-outside force…show me your analysis, this can't be a gut feeling for us in terms of investment."[8]

A key insight from post-Cold War government and non-government analyses is that both long-range stand-off and stand-in strike capabilities are necessary.

Past analyses have shown the optimum mix of DOD long-range strike forces should consist of USAF penetrating bombers and a balanced mix of other stand-off capabilities. As DOD implements its defense strategy, it should adequately size and modernize the USAF bomber force so it can meet the demands commanders will require of the long-range penetrating strike component of the U.S. military. Given that the Army and Navy are pursuing options to buy additional stand-off strike systems, the Air Force's stand-off bomber force is now sized about right, but its long-range penetrating bomber capacity—a total of 20 stealth B-2s today—is woefully inadequate. Attempting to buy additional USAF stand-off arsenal planes instead of focusing on the far greater need for more penetrating bombers would further unbalance the force. More importantly, it would deprive U.S. commanders with critical tools they will need to deter, and if necessary, defeat great power threats to America's security.

Trends and Challenges That Frame the Bomber Mix Debate

The diminished size of America's bomber force has plummeted to a level that has not been seen since the founding of the Air Force in 1947. Now the Air Force is proposing to retire another 17 B-1Bs in FY2021, which would leave a total of 141 bombers. This is particularly concerning, since 141 total bombers translates to about 86 primary mission aircraft that can generate between 30 to 50 long-range strike sorties per day—a capacity that will likely fall short of a theater commander's requirement in a conflict with China or Russia.[9] Similar to previous bomber draw-downs, this latest action is driven by budget constraints as the service struggles with massive modernization challenges, too many of which were deferred for too long and now require decisive action.

The imbalance between the Air Force's stand-off and stand-in bomber capacity is of even greater concern. Only the USAF's 20 B-2s—13 percent of its bomber force—are capable of penetrating advanced IADS. This stand-off/stand-in force imbalance is even more significant from a whole-of-DOD perspective since long-range fires now provided by the other services are all stand-off systems. Furthermore, only 16 of these 20 B-2s are assigned to combat squadrons so they can perform their warfighting missions. In other words, the USAF's 16 primary mission B-2s constitute the nation's long-range penetrating strike force. Even as special as the B-2 is in America's arsenal, the USAF's FY2021 budget cancels a program intended to maintain the B-2's ability to penetrate well into the future. Everything is now hedged on the capabilities of the new B-21 bomber—a stealth aircraft that will enter the inventory starting in the mid-2020s.

> Only the USAF 20 B-2s are capable of penetrating advanced IADS, of which 16 are assigned to combat squadrons so they can perform their warfighting missions. These 16 primary mission B-2s constitute the whole of the nation's long-range penetrating strike force. Assuming a mission capable rate of 63 percent that amounts to only 10 B-2s available to fight at any time.

Enemy advancements outpace our own. China, Russia, and other adversaries continue their long-term efforts to deploy advanced defenses that are effective against U.S. combat aircraft and weapons, improve the mobility of their forces to make them harder to target, build underground facilities that are protected by virtue of their depth and reinforced structures, and implement other measures to harden themselves against precision strikes. All of these actions could increase the time and number of weapons needed for U.S. forces to defeat an enemy in future strike campaigns.

The growing gap in the USAF's long-range strike capacity is all-the-more consequential considering that 87 percent of its bombers cannot penetrate contested environments. Non-stealthy bombers and ships must operate hundreds of miles from enemy defenses and use long-range stand-off weapons to strike targets. Broadly speaking, long-range stand-off weapons that must fly hundreds of miles through contested airspace have a greater potential of being destroyed by enemy defenses compared to short-range stand-off and direct attack weapons. Simply put, rebalancing the bomber force toward stand-in strike capacity would improve the odds of netting future warfighting objectives in a rapid, decisive, and affordable fashion.

Characterizing Stand-off and Stand-In (or Penetrating) Bombers

DOD's new focus on preparing to defeat aggression by China and Russia while maintaining a significant presence in the Middle East and other regions drives the need to fundamentally change the U.S. military's size and mix of capabilities. Preventing China or Russia from successfully invading their neighbors will require the U.S. military to engage their forces "from the very beginning of hostilities" rather than after many weeks of deploying ground forces to a theater similar to Desert Storm.[10] This operating concept change will require U.S. forces to attack on night one of a conflict. This involves striking "diverse targets inside adversary air and missile defense networks" such as ballistic missile launchers and other means that China, Russia, and others rely on to project power.[11]

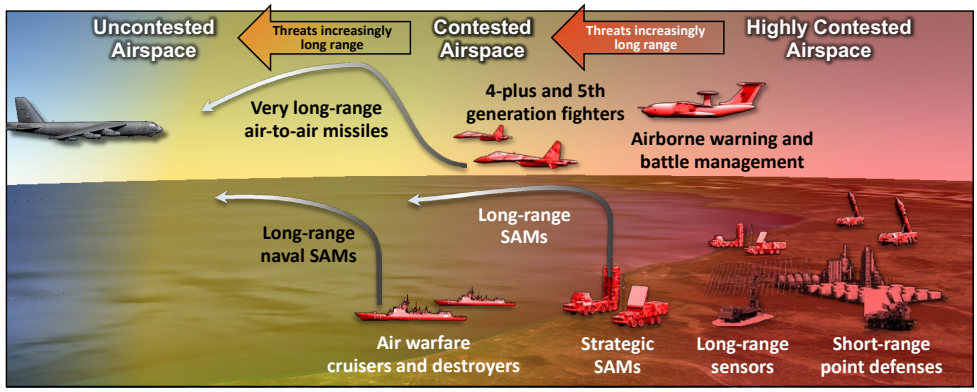


Figure 2: Illustrating an IADS designed to counter U.S. air operations

Source: Mitchell Institute

Long-range strikes—the ability to kinetically attack targets at range and at a time and place of a theater commander's choosing—are key to achieving these objectives. This mission can be accomplished by non-stealth platforms that launch weapons while remaining outside contested A2/AD environments (stand-off), and by stealth bombers that can penetrate contested areas to deliver their payloads (stand-in). Stand-off aircraft such as non-stealth bombers and fighters cannot penetrate areas covered by advanced IADS fielded by China, Russia, and other adversaries without excessive risk of an intercept, nor can ships at sea. IADS include long-range strategic surface to air missiles (SAMs), 4th and 5th generation fighters carrying very long-range air-to-air missiles, sea-based surface-to-air interceptors, and other threats with long ranges. These systems are complemented by short-range "point" defenses that are typically deployed around high-value targets. Air Force planners have used the terms contested and highly contested environments to describe the density and lethality of an IADS.

It is crucial to understand the different operational capabilities of the USAF's individual bomber types in these lethal threat environments. B-52Hs and B-1Bs designed many decades ago to penetrate Soviet defenses cannot operate in areas now covered by advanced IADS without excessive risk; they must use long-range weapons such as cruise missiles to strike targets located inside these areas. Their stand-off distances are dependent on a number of factors, including the range, density, and lethality of an enemy's IADS. A non-stealth B-52H or B-1B may have to stand off 500-700 nm or more from long-range air defenses during the opening stages of a conflict with a peer adversary.

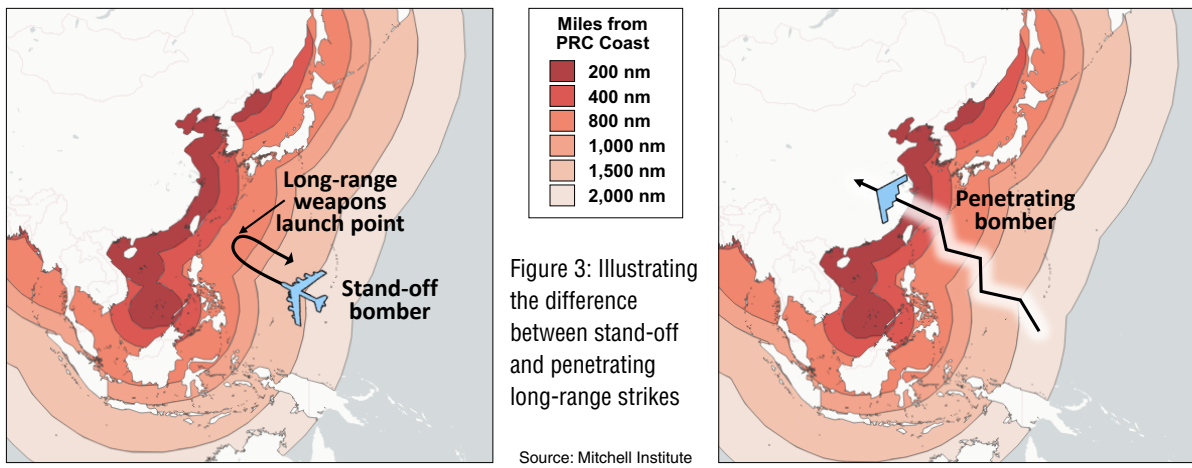


Figure 3: Illustrating the difference between stand-off and penetrating long-range strikes

Source: Mitchell Institute

In comparison, stealth B-2s were designed to survive in these environments, and next-generation B-21 bombers will advance the art of the possible even further. There is no "silver-bullet" solution to preventing an enemy from intercepting a penetrating aircraft. True stealth is the product of a balanced, interdependent approach. Early generation stealth aircraft like F-117 fighters that first flew in 1981 depended heavily on an aircraft design and the use of special materials to reduce an enemy's ability to detect it using radar and other sensors. Although the F-117 was a success story in Operation Desert Storm, its design was optimized to reduce radar returns from its nose and tail and at frequencies used by Soviet-era fire control radars. The F-117's radar signature was much greater from its side aspect and in other frequency ranges.

The ability of more advanced stealth aircraft such as B-2s and B-21s to survive inside the range of advanced IADS is the result of a multi-pronged approach that includes minimizing their signatures in multiple bands of the electromagnetic spectrum (low observability) and at all aspects. Aircraft with flying wing designs like the B-2 and B-21 do not have large surfaces such as vertical tails that reflect radar energy, giving them better low observability. All-aspect low observability combined with smart mission planning to avoid enemy defenses; onboard sensors and increased processing power to manage an aircraft's position relative to enemy sensors; and datalinks to receive threat updates increase a stealth aircraft's survivability. Despite similarities in the B-2 and B-21's smooth, blended flying wing shapes, B-21s will have more advanced next-generation stealth radar energy absorbing materials, increased processing power to fuse information from on-board sensors and external sources, and low probability of intercept/low probability of detection (LPD/LPD) datalinks that will maximize opportunities to collaborate with other penetrating weapon systems. The combination of all-aspect stealth in multiple frequency bands will enable B-21s to penetrate Chinese and Russian IADS well into the future.

It is quite reasonable to assume aerial operations will be executed under attack for the duration of the campaign.

A critical point to stress is that stealth does *not* make an aircraft invisible to enemy sensors; it denies an enemy information required to determine an aircraft's position, altitude, speed, and direction of flight with enough accuracy to launch a successful intercept. Many who criticize stealth as a waning advantage due to advances in air defense technologies fail to understand this point—it is not about completely avoiding detection but preventing an enemy from completing an intercept—dramatically increasing a stealth aircraft's probability of survival. U.S. advances in stealth technologies continue to outpace advances in air defense threats. In an era in which information is increasingly important to success in warfare, stealth will grow in importance as a means of denying critical information to adversaries. The need to stay ahead of evolving threats is also an important consideration for the USAF B-2s. While they are now capable of penetrating contested areas, over time the risk to B-2s will increase. This is a key reason why DOD chose to acquire B-21s with more advanced stealth technologies.

Some also argue there is less need for stealth aircraft because they believe multi-domain operations could quickly degrade an enemy's IADS and allow non-stealth aircraft to penetrate and survive. This school of thought is similar to what U.S. aircrews did in the past, where an initial wave of stealth aircraft could "knock down the door" of an enemy's defenses, thereby allowing lower technology aircraft not protected by stealth to operate at acceptable levels of risk. While it was possible in the past to quickly roll-back less

capable defenses such as those operated by Iraqi forces during Operation Desert Storm and Operation Iraqi Freedom, it is simply not feasible against China and Russia's far more advanced IADS. Their IADS have multiple layers of sensors and weapon systems that are highly mobile, are protected by camouflage and deception, and employ other measures to counter efforts to quickly defeat them. These systems are growing in number and geographic coverage. Attempts to knock-down an advanced IADS to the extent needed for non-stealth aircraft to survive would take a great deal of time—time that China or Russia could use to achieve their warfighting objectives. It is quite reasonable to assume aerial operations will be executed under attack for the duration of the campaign.

America's Bomber Force: A Community Under Stress

Although this report is focused on assessing the right balance of stand-off and penetrating bombers in the future force, it is important to understand that the bomber force is now smaller than what is needed for even a single great power conflict. Toward the end of the last extended period of great power competition—the Cold War—the USAF's bomber force totaled a little over 400 aircraft. Since then, it has declined to an all-time low of 158 total bombers. This decline was primarily due to DOD's desire to reduce budget expenditures and a belief that a smaller bomber force would be sufficient for contingency operations against rogue states such as Iran and North Korea. Bomber cuts continued into the 2000s, when the Air Force retired an additional 33 percent (32 of 93 tails) of its B-1Bs and 20 percent (18 of 94 tails) of its B-52Hs. Again, these retirements were done primarily for budgetary reasons, not because of a decline in operational demand for bombers which has actually steadily increased. As one USAF commander remarked: "Air Force Global Strike Command has gone from supporting one enduring combatant commander requirement to an average of 12 annually, a 1,100-percent increase."[12] Despite this demand growth, the Air Force flew these aircraft on near non-stop deployments for years. This hard use literally broke the B-1 fleet, with too few aircraft amortized across a high operational tempo.[13]

The Air Force now seeks to balance its books by retiring another 17 B-1Bs. It hopes that this and other proposed force structure divestitures will free up funding to sustain its remaining bombers and meet other modernization needs.[14] This would leave only 45 B-1Bs in the force, of which an estimated 26 will be primary mission aircraft assigned to combat squadrons.[15] Assuming a 52 percent mission capable rate, that means that only 13 B-1's could be expected to be ready to fly missions at any particular time.

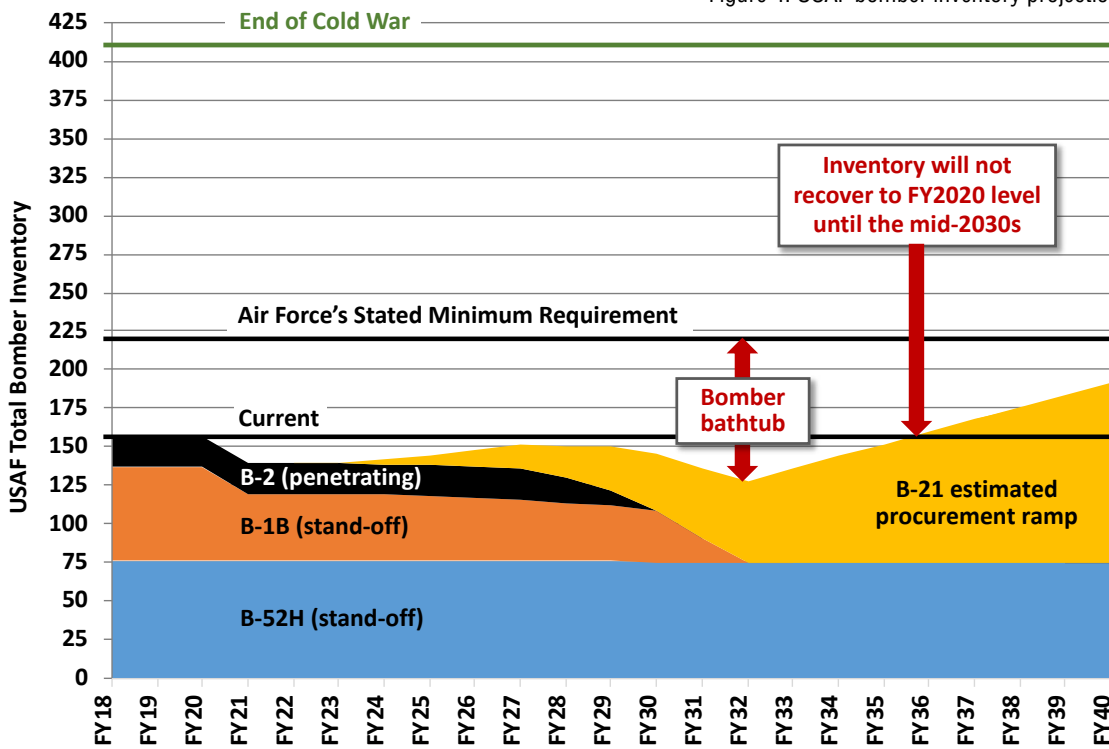
Bombers	FY2020		FY2021		Comments
	Total Inventory	Primary Mission	Total Inventory	Primary Mission	
B-52H	76	44	76	44	B-52Hs will receive new engines, radars, upgraded communications, and other systems[16]
B-1B	62	36	45	26	B-1s will retire as B-21s join the force
B-2	20	16	20	16	The FY2021 budget cancels the B-2 Defensive Management System-Modernization (DMS-M) program
Total	**158**	**96**	**141**	**86**	**The FY2021 force will be a new record low for the USAF**

Table 1: Bomber force breakdown based on the FY2021 budget

Source: Based on USAF statements and FY2021 President's Budget

From purely a budget perspective, some might think retiring 17 B-1Bs is a prudent approach to sustaining the USAF remaining bombers. In reality, it is simply the next step in a vicious cycle that has created a force in crisis. A chronic lack of sustainment and modernization funding after the Cold War led to decisions to divest older bombers to free-up resources to sustain remaining aircraft. These additive resources disappeared over time, and the remaining smaller bomber force was flown even harder to conduct real-world operations. This toxic combination led to more bomber mechanical challenges, which then helped drive the next round of force cuts. Arguments made in the early 2000s justifying the retirement of two dozen B-1s are *exactly* the ones being made today to rationalize another cut. This slippery slope which eroded the bomber fleet's health and capacity will only be arrested when resources are directed to ensure it can meet future operational demands. In short, if a fleet of 158 bombers was strained to the breaking point, how will the situation improve by further reducing the force? Maintaining a healthy bomber force is a matter of deliberate priorities.

Figure 4: USAF bomber inventory projection



Source: Mitchell Institute based on current inventory information provided by the USAF, data from the FY2021 President's Budget, and a Mitchell Institute estimate of a notional B-21 procurement ramp

The Air Force's budget-driven FY2021 choices will create a period of increased risk in its ability to conduct long-range strikes, including stand-in strikes due to the B-2 DMS-M cancellation. The B-21 program is the first opportunity for the Air Force to begin to correct its stand-off/stand-in strike imbalance and overall lack of bomber capacity. However, it will take years of B-21 acquisitions to offset thirty years of bomber divestments and decisions to forego buying more than a very small force of penetrating bombers. Assuming B-21 production can ramp to a modest five to ten aircraft per year by the late 2020s, less than 40 new next-generation stealth bombers could be on the ramp by 2030.[17] At this rate, the bomber inventory would not return to its present level for at least 15 years. In other words, it will be the mid-2030s before

the Air Force gains back the number of bombers that it is now surrendering, and it will be well into the 2040s before it reaches its stated requirement of at least 220 total bombers. Moreover, using other major acquisition programs as a guide, it will take some time before early production B-21s are certified as fully mission capable.

	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030
B-21 Deliveries	3	3	5	5	5	8	8
B-21 Total Inventory	3	6	11	16	21	29	37

Table 2: Notional B-21 delivery schedule through 2030

Source: see endnote 17

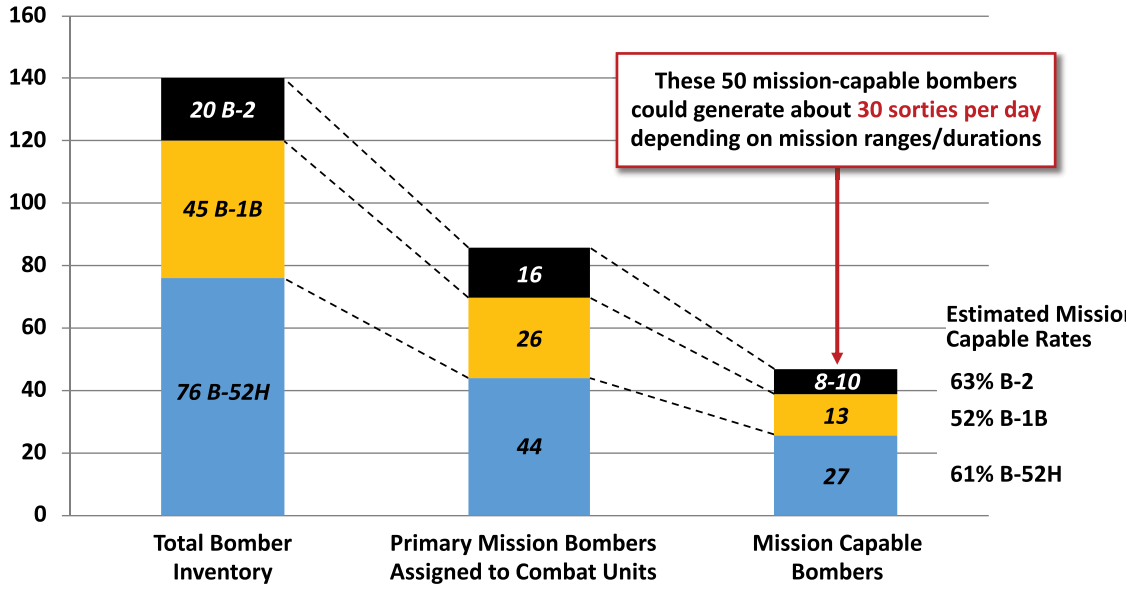
There is another action that could slow B-21 production: a decision to procure a new stand-off bomber (arsenal plane) developed from a commercial derivative or a clean sheet aircraft design, which would cost hundreds of millions of dollars each. Development costs alone would likely run into single-digit billions. This funding would need to come from somewhere, and in an era of flat or declining budgets it could threaten the B-21's delivery schedule. In other words, the start-up of an arsenal plane development program could delay fixing the shortfall in the USAF penetrating long-range strike capacity.

As we consider the size of the bomber fleet, sortie potential—the number of missions an aircraft is able to fly in a given period—is an even better measure of combat capacity. The success of a U.S. operation can come down to putting as many bombs on targets as possible and as quickly as possible. General Goldfein has described this as the need to complete "thousands of kill chains in hundreds of hours" during a conflict with a peer adversary.[18] This means keeping as many aircraft as possible on station and ready to strike targets. High bomber utilization rates yield maximum combat value to theater commanders.

After applying mission capable rates, up to 10 B-2s, 13 B-1Bs, and 27 B-52Hs in the FY2021 bomber force would be available to generate sorties. While this is already a small number, it is unlikely that each of these 50 bombers will fly a combat sortie every day if they must operate from bases located far from the battlespace. In a conflict with China, the need to reduce the threat of missile attacks on U.S. airbases in the Indo-Pacific theater may require Air Force bombers to operate from Guam, northern Australia, and other locations that are thousands of miles from potential target areas on the Chinese mainland. USAF bombers flew an average of 0.6 sorties per day during Desert Storm primarily because they operated from airbases located significant distances from Iraq.[19] Applying a similar rate to the USAF's 2021 mission capable bomber force would reduce its sortie generation potential to **30 or fewer sorties per day total**. The actual number of bomber sorties available per day could be even lower than 30, given the need for the Air Force to maintain some of its B-52H and B-2 nuclear-capable bombers in the U.S. homeland to meet nuclear deterrence commitments. For context, Air Force B-52s flew up to 50 sorties per day at the height of the Desert Storm air campaign against Iraq.[20] Far more than 50 bomber sorties per day would be needed in a major war with a peer enemy.

The start-up of an arsenal plane development program could delay fixing the shortfall in the USAF penetrating long-range strike capacity.

Figure 5: Sortie generation potential is a better measure of combat capacity (based on FY2021 inventory)



Source: Mitchell Institute based on current inventory information provided by the USAF, data from the FY2021 President's Budget, and Mitchell Institute's estimates of mission capable rates

With DOD's increased focus on the Indo-Pacific, it is crucial to understand that a given number of combat aircraft operating over extremely long distances will not bring the same volume of sustained force to bear as an operation such as Operation Desert Storm that was concentrated in a small region. Long round-trip mission distances will stretch an already small bomber force to the absolute limit in terms of affording commanders with the combat results they require within operationally acceptable timelines. Failing to strike enemy targets in a rapid, full spectrum fashion will ultimately result in a far more costly, longer, and risk-prone campaign. An enemy afforded the benefit of additional time and operational flexibility to act will disperse centers of gravity that are vital to its warfighting strategy. This would make it more difficult for the United States to prevail, especially against an adversary like China that has significant resources, territorial depth, and other "home field" advantages.

Differences: Long-Range Stand-off, Short-Range Stand-off, and Direct Attack Weapons

Debate over long-range stand-off versus penetrating strike bomber capacity is often focused on the right mix of non-stealth and stealth *aircraft* only. In reality, the range, size, survivability, and effectiveness of guided weapons against challenging targets in future conflicts must also be considered, since they impact the USAF's future force structure requirements. The kill chain is not complete until a weapon hits and destroys its intended target.

Similar to future U.S. surface-to-surface strike systems that could be located along the Pacific's first island chain or beyond, B-52H and B-1B bombers will need to use long-range stand-off weapons to attack targets on the Chinese mainland. Long stand-off distances will also be needed by U.S. non-stealth aircraft that launch strikes against Russian forces protecting by A2/AD umbrellas. From a budget perspective, it is

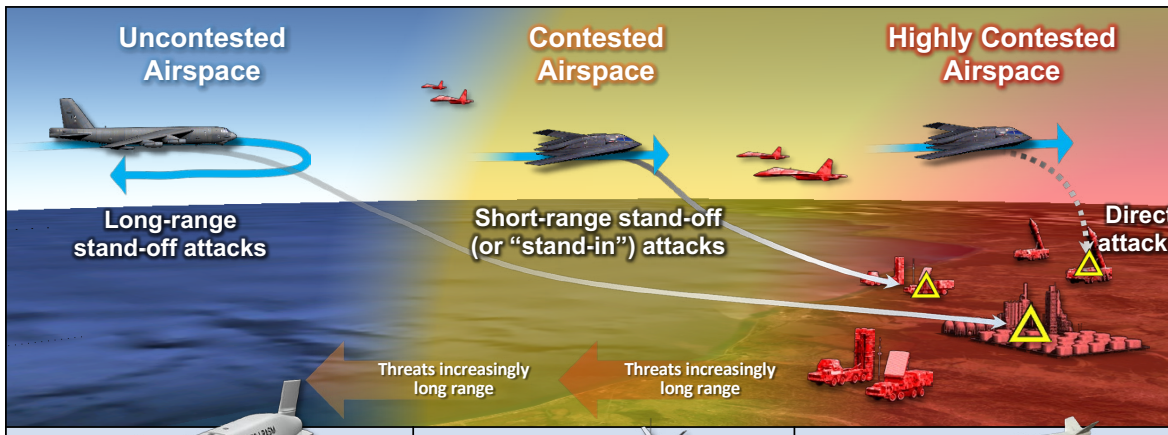
simply not feasible for the Air Force to quickly replace all of its existing 4th generation fighters, B-52s, and other non-stealth platforms with stealth aircraft. These platforms will provide additional strike capacity until the B-21 and F-35 programs can field the stealth systems needed to prevail against China and Russia.

For the purposes of this analysis, long-range stand-off weapons have ranges greater than 400 nm to over 1,000 nm. These weapons typically have some form of tail and wing structure, a powerplant and fuel to extend their ranges, navigation systems to guide them to target areas, possibly a datalink to communicate to other weapons and platforms, and even terminal seekers to locate and characterize individual targets. In a sense, long-range stand-off weapons such as cruise missiles are actually small, unmanned aircraft. None of these capabilities are inexpensive, especially given the fact that they can only be used one time.

For the purposes of this report, short-range stand-off weapons have a range of 400 nm or less. Penetrating aircraft can use short-range stand-off weapons to strike targets while remaining outside the most lethal air defense threat envelopes. Short-range stand-off weapons such as the Small Diameter Bomb II (SDB II) and Joint Stand-off Weapon (JSOW) are powered or can glide after launch to their targets.

Threat conditions permitting, penetrating aircraft can use even shorter range—25 nm or less—direct attack weapons that are typically unpowered. Direct attack precision guided munitions (PGMs) do not need powerplants, fuel, and other capabilities to extend their range, so they cost much less than their long-range counterparts.

Figure 6: Characteristics of long-range stand-off, short-range stand-off, and very short-range direct attack weapons



Long-Range Stand-off Weapons	Short-Range Stand-off Weapons	Direct Attack Weapons
Tomahawk cruise missile, JASSM-ER, etc.	SDB II, Joint Standoff Weapon, etc.	JDAMs, Quickstrike mines, etc.
• Ranges more than 400 nm • Typically powered to extend range • Enable attacks by non-stealth aircraft from outside contested areas	• Ranges up to 400 nm • Winged/glide capable, may also be powered to extend range • Enables attacks from beyond the most lethal ranges of some point defenses	• Ranges of single digit to low 10s of nm • Weapons are typically unpowered • Must be released close to targets

Source: Mitchell Institute

Adversary Advances: Complex Target Sets and Threats to Weapon Survivability

DOD's post-Cold War shift toward planning for lesser regional conflicts instead of a major war with the Soviet Union also provided it with a convenient rationale for cutting force structure and truncating force modernization initiatives such as the B-2 and F-22 programs. DOD assessments in the 1990s assumed that a smaller force of non-stealth B-1Bs and B-52Hs would be able to operate in relatively benign threat environments and strike targets without significant aircraft or weapons attrition. Neither of these fundamental assumptions would be true in a future conflict with China or Russia. DOD planners should also assume the number and kinds of targets that theater commanders would attack during peer conflicts will be very different than the past. A failure to adopt realistic assumptions on the nature of *future target sets* and the lethality of *advanced air defenses* could lead to poor decisions on the size and stand-off/stand-in mix of America's bomber force.

China now has the world's largest standing ground force, with some 915,000 active duty combat military personnel, 5,800 main battle tanks, and 9,000 artillery pieces.

Future target sets will be more complex. Target sets in a major conflict with China or Russia would have far more aimpoints and be distributed over much larger areas compared to targets attacked by U.S. air forces during post-Cold War operations in the Balkans, Iraq, Afghanistan, Libya, and Syria. Attacking these larger, more distributed targets sets would require a much larger force of penetrating bombers. Given the size of China and Russia's forces and military infrastructure, the number of targets that U.S. bombers and other combat aircraft would be tasked to strike could exceed the number of targets attacked during all U.S. air campaigns since the Cold War.

Iraq had an estimated 5,000 tanks, 3,000 artillery pieces, 700 combat aircraft, 200 short-range ballistic missiles (SRBMs) and hundreds of early generation SAMs at the start of Operation Desert Storm in 1991.[21] Coalition air forces struck over 40,000 aimpoints during the 43-day Desert Storm air campaign.[22] This was accomplished with a U.S. Air Force that was nearly three times the size of what it is today.

In comparison, China now has the world's largest standing ground force, with some 915,000 active duty combat military personnel, 5,800 main battle tanks, and 9,000 artillery pieces.[23] It also has the world's third largest air force with about 395,000 personnel, 2,700 total aircraft, and over 800 SAMs of which a growing number are advanced long-range "strategic" SAMs. China has the largest missile force in the world with 750-1500 SRBMs, 150-450 medium-range ballistic missiles (MRBMs), 80-160 intermediate-range ballistic missiles (IRBMs), 90 intercontinental ballistic missiles (ICBMs), and 270-540 ground-launched land-attack cruise missiles (LACMs).[24] Defeating this highly lethal force would require a tremendous number of strikes delivered in a rapid fashion.

Russia's military has a ground force with 280,000 personnel, 2,750 main battle tanks, and over 4,300 artillery pieces. The Russian Air Force is the second largest air force in world with 165,000 personnel and close to 4,200 total aircraft which includes over 1,200 combat aircraft and 2,100 Russian Army and Air Force SAMs. Russia has the largest number of advanced SAMs in the world and is pursuing foreign military sales of a number of its advanced capabilities.[25] Again, rapid, overwhelming force projection will be the key

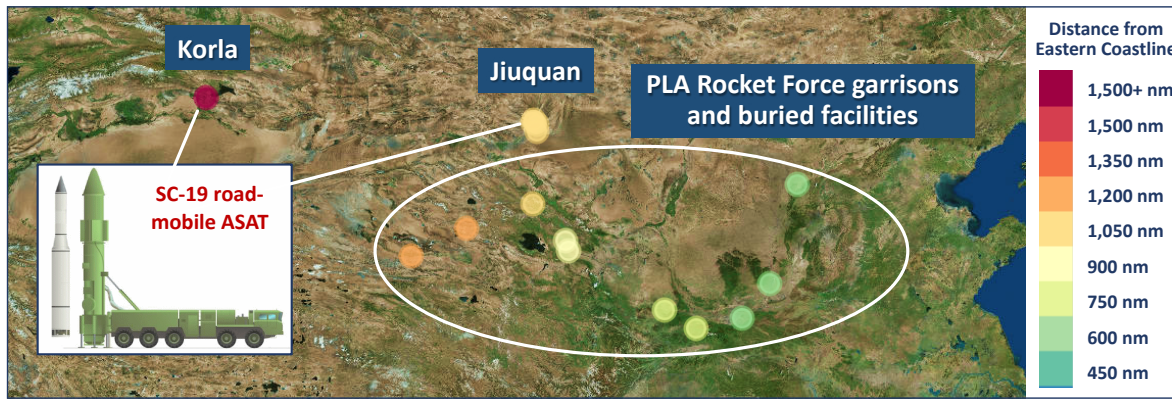
to victory against such a foe, which will also have a home field advantage during a conflict in the Baltic Sea region or elsewhere along its periphery.

Conducting high-tempo precision strike campaigns and other operations to quickly blunt a major Chinese or Russian military invasion of a U.S. ally will be critical to the security of the United States.[26] Defeating a peer adversary would require USAF combat air forces to strike many thousands, not hundreds of aimpoints in a few days to prevent enemy forces from achieving their campaign objectives. Such conflicts could be existential in ways not seen since the Cold War and World War II. This is a significant paradigm shift for the American public at large, who saw the United States fight wars in Iraq, Afghanistan, and Libya with no tangible effects that are recognizable to the average American citizen.

Depth and distribution. The great depth and distribution of potential target sets is another factor that should shape USAF long-range strike requirements. China is about 22 times the size of Iraq, over 14 times the size of Afghanistan, and is far more highly developed than both. Attacking targets located deep in the interiors of China and Russia is a difficult challenge, especially for non-penetrating strike aircraft that must use long-range weapons. For instance, the PLA has conducted test launches of its SC-19 direct ascent anti-satellite weapons from launch facilities located close to the cities of Jiuquan and Korla which are about 1,100 nm and 1,500 from China's east coast, respectively. The PLA Rocket Force's 666 Brigade, which operates DF-26 intermediate-range ballistic missiles, is stationed close to Xinyang China, which is about 400 nm to the west of Shanghai. Non-stealth bombers that must stand-off 500 nm or more from China's coast to ensure their survivability would need weapons with more than 1,000 nm of range to reach targets in these areas. To put this number in context, a 1,000 nm weapon range requirement is twice the distance between the northern and southern borders of Iraq.

Figure 7: Illustrative military forces and facilities located deep in China's interior

Source: Mitchell Institute



Advancements and countermeasures. DOD planners must consider how countermeasures employed by China, Russia, and increasingly other modern adversaries will change future strike requirements. Similar to aircraft, weapons must also survive in contested environments. Chinese and Russian advanced air defenses protecting their military forces and installations are capable of intercepting incoming weapons. Their IADS also include multiple passive measures such as camouflage and decoys that further reduce the effectiveness of U.S. guided weapons. A weapon that strikes a decoy is a net loss to the attacker.

Source: Mitchell Institute

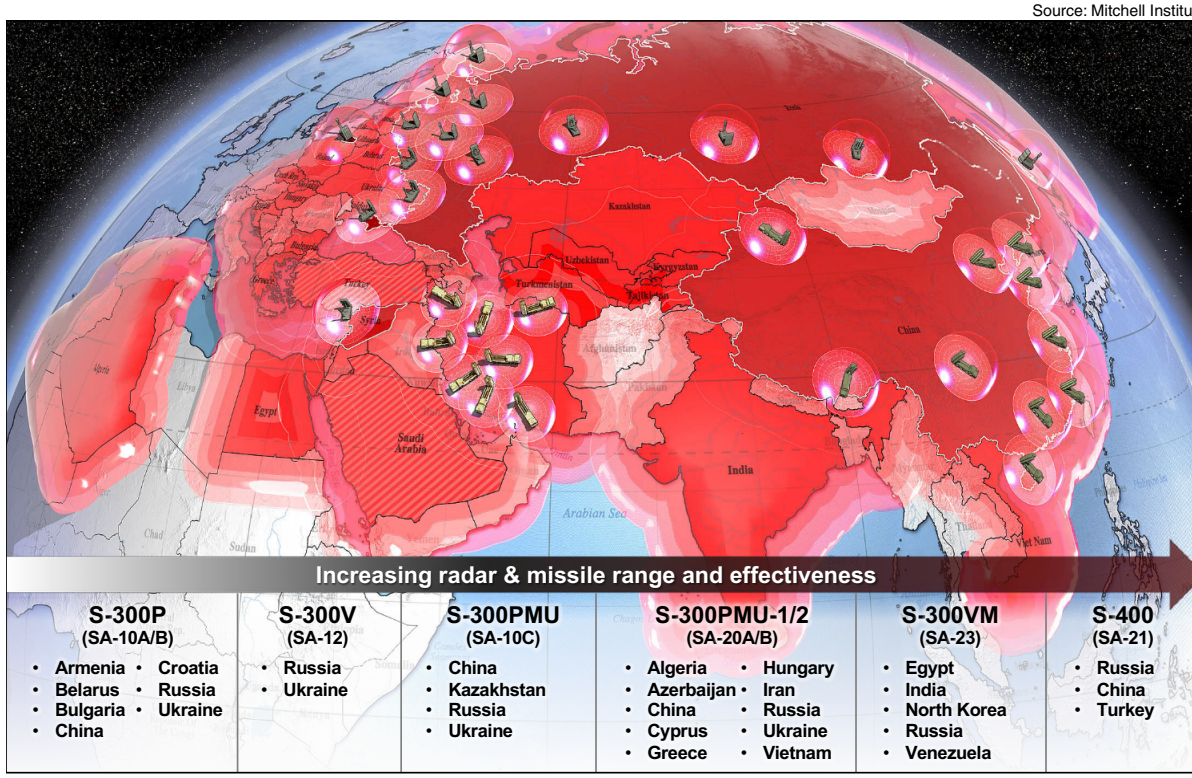


Figure 8: Examples of proliferating advanced air defense systems

While advanced defenses can be effective against most classes of weapons, in general long-range stand-off weapons may be easier to detect and intercept than direct attack weapons. Range requirements for stand-off weapons drive the need to design them with long fuselages and wing-body-tail configurations. Similar to aircraft, this form factor can reduce the survivability of weapons exposed to advanced air defenses compared to direct attack weapons that do not need these design features. Some contemporary stand-off weapons have the ability to fly at low altitudes and maneuver to improve their survivability. Future weapons will be able to fly at hypersonic speeds and could have data links to receive post-launch threat updates to improve their survivability. However, these and other advanced capabilities will increase the unit cost of stand-off weapons, a key factor in the number of weapons that can be procured. In addition, weapons that are reliant on data links to enhance their survivability and lethality may be significantly less effective against technically advanced adversaries that have sophisticated jamming capabilities.

Mobility is another tactic to degrade an attacker's ability to find, fix, track, and strike targets with precision. The ability to quickly relocate military forces such as batteries of mobile SAMs and missile TELs can reduce the likelihood that stand-off weapons will reach their designated aimpoints. Russian S-300/400 family of mobile SAMs can deploy to launch their weapons in five to ten minutes and then begin to reposition in a like amount of time. Similarly, many Chinese missile systems such as the DF-26—which are often called "carrier-killers" due to their ability to attack U.S. aircraft carriers as well as reach U.S. bases on Guam—are mounted on road-mobile launchers. These launchers could quickly disperse from their garrisons, increasing the difficulty to strike them from long-range stand-off distances. In the time required for a long-range stand-off weapon to arrive in a target area, its highly mobile target may have changed its location. The

ability of stand-in bombers to use passive and active sensors and other means to find, fix, track, target, and then attack highly mobile or relocatable targets deep in contested areas is one of their key advantages.

China, Russia, and other potential enemies are also hardening and/or deeply burying stationary targets to make it more difficult for guided weapons to disable or destroy them. Long-range stand-off weapons cannot carry warheads with enough size and kinetic "punch" to penetrate these reinforced targets. However, direct attack weapons can be larger and specially-designed with more structural features and greater explosive power to penetrate hardened and deeply buried targets.

Ultimately, the very large size, distribution, mobility, degree of hardening, and other characteristics of potential target sets in great power conflicts should have a significant impact on USAF requirements for its future long-range stand-off and penetrating strike force mix. Adversaries have observed U.S. military strategies for the last three decades and have taken steps to ensure their centers of gravity are resilient in the face of America's demonstrated ability to strike with precision. The U.S. must avoid overreliance on using too many costly stand-off weapons that can be intercepted by enemy air defenses, are ineffective when their targets move from the weapons' pre-programmed target coordinates, or cannot defeat hardened/deeply buried targets.

A Need to Increase the Size of the USAF Penetrating Bomber Force

In the face of the aforementioned threats, the Air Force's much-diminished bomber force, which is already "managed at peak utilization rates" to support the combatant commands, does not have the capacity to handle further growth in operational demand.[27] Some 65 to 70 percent of the USAF B-1B force was committed to supporting operations in Afghanistan and elsewhere in the U.S. Central Command's area of responsibility for "well over a decade."[28] Stresses placed on B-1Bs by the way they were operated during these missions combined with insufficient sustainment funding led to structural issues that greatly degraded their mission readiness.[29] Overall, the strains of years of operations in Afghanistan as well as Iraq were borne by B-1Bs and B-52Hs primarily because of the very low risk of using them in permissive threat environments.

Long-range stand-off weapons cannot carry warheads with enough size and kinetic "punch" to penetrate these reinforced targets.

B-1Bs and B-52Hs would not operate this way in a conflict with China, Russia, or others who have fielded state-of-the-art air and missile defenses. In these scenarios, the USAF's small B-2 force would fall far short of providing penetrating strike capacity needed by threat commanders—optimistically only eight to ten B-2 sorties a day. This will be the nation's only long-range penetrating strike capacity until the B-21 reaches its initial operational capability (IOC) threshold at some point in the future. Even the B-2's current penetrating sortie capacity could be at increased risk, since the Air Force's FY2021 budget cancels the DMS-M program to improve the bomber's ability to detect and avoid advanced air defense threats.[30] According to DOD, the B-2's current Defensive Management System Threat Emitter Locator System (TELS) has shortcomings that "limits overall B-2 operational capability and survivability."[31]

Simply put, *a larger bomber force is needed*. This is especially true for the stand-in portion of the force—a mere 13 percent of the 2020 bomber inventory. General Timothy Ray, Commander of the Air Force Global Strike Command, has said the Air Force requires a future force of 225 bombers to support the national defense strategy.[32] Chief of Staff of the Air Force General David Goldfein has testified: "Our assessment—and that's been backed up by independent assessments—that a moderate risk force is 220 bombers of which 145 would be B-21s."[33] This objective force assumes that all B-52Hs will remain in the inventory for another 30 years as planned.[34]

One of the USAF's assessments determined its 2030 force—which it calls "The Air Force We Need"—should have 14 operational bomber squadrons, an increase of 5 squadrons from 2020. The Air Force based its study on fighting a single great power conflict plus deterring a second lesser regional aggressor nearly simultaneously. Two parallel independent studies directed by 2018 National Defense Authorization Act were completed by the MITRE Corporation and the Center for Strategic and Budgetary Assessments. MITRE's proposed bomber force was similar to the Air Force's, with the exception that it recommended keeping all B-1Bs in the inventory until 50 operational B-21s were available.[35] CSBA's study recommended the Air Force field 24 bomber squadrons (383 total bombers) based on its assessment of USAF capabilities needed to defeat Chinese and Russian aggression nearly simultaneously.[36] While this is a larger force than recommended by the USAF and MITRE's studies, it would still be less than the number of bombers that were in the inventory toward the end of the Cold War.[37]

A future force of 383 total bombers would still be less than the 411 bombers that were in the USAF's inventory toward the end of the Cold War.

Independent studies by the Mitchell Institute have mirrored these findings. Retired Air Force Lt Gen Michael Moeller recommended a force of 160 combat-coded bombers, which would require the Air Force to buy more than 150 B-21s.[38] A second Mitchell Institute report co-authored by retired USAF Lt Gen David Deptula and Douglas Birkey recommended the USAF would need a total force of at least 270 bombers to meet the future demands of the combatant commands.[39] It is also worth emphasizing that while many of the conflict scenarios and operational assumptions underpinning these bomber assessments were different, they all concluded the USAF's future bomber fleet should be significantly larger and better capable of penetrating contested environments.

America's bomber force provides policy options for global strike and other missions that no other element of the U.S. military can provide.

In summary, America's bomber force provides policy options for global strike and other missions that no other element of the U.S. military can provide. Should the remaining bomber fleet implode due to overuse in the near-term and if the force does not grow to meet mission requirements in the long-term, some of these options will not be available. Furthermore, the future mix of stand-off and penetrating bombers is even more critical than the total number of bombers. The current force is unbalanced in the sense that only a fraction of its aircraft can penetrate Chinese and Russian A2/AD threat envelopes The only sound approach to reinforcing the bomber force is to rapidly procure the B-21 and ensure the USAF's other bombers are maintained at a level that will maximize their utilization rates.

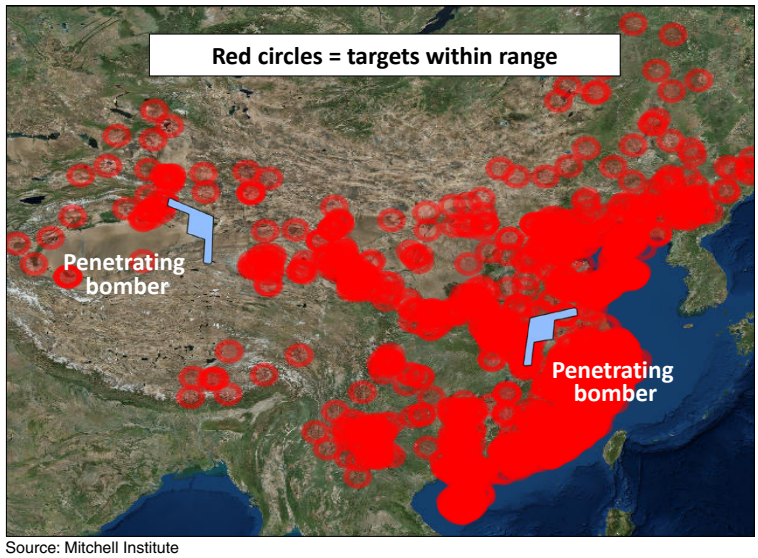
Assessing Long-Range Strike Weapon Tradeoffs

A USAF future force design approach should account for the advantages and disadvantages of weapons as well as aircraft that will be needed to conduct stand-off and stand-in strikes. This section provides evidence that the Air Force *must find the optimal mix* of both stand-off and stand-in bombers based on five of the most important factors in long-range strike operations: stand-off ranges, weapon flight times and the need to strike moveable targets, hypersonics, payload limitations, and cost.

Long Stand-off Ranges Decrease Number of Reachable Targets

Non-stealth bombers and other stand-off platforms must use long-range weapons (often air-launched), which have limits to how far they can reach into contested battlespace. Since air-launched weapons only have so much range, the distances they must fly after launch limit the number of targets they can reach. In contrast, stealth bombers can penetrate contested areas, which increases the number of targets they can attack.

This can be illustrated by using a notional set of military targets distributed across China derived from unclassified sources.[40] A penetrating bomber with a B-2-like combat radius of at least 2,500 nm (5,000 nm between air refuelings) could physically reach any of these targets using short-range and direct attack weapons.[41] In this case, coverage of a target set is a function of the range of the penetrating bomber, not the range of its weapons. A Congressional Budget Office report concluded a bomber with a 2,000–2,500 nm combat radius that is refueled prior to penetration "would fully cover all countries" in the world.[42] Furthermore, the combination of survivability and long ranges enable stealth bombers to attack deep targets from multiple axes, which complicates an enemy's ability to defend against them.



Source: Mitchell Institute

Figure 9: All notional targets can be reached by stand-in bombers that have long ranges

To remain survivable, non-stealth bombers and other stand-off platforms must use long-range weapons to strike targets on the Chinese mainland. The number of targets these weapons can physically reach on the mainland will depend on how far the bombers must stand-off from Chinese IADS combined with the ranges of the weapons they launch.[43] The JASSM-ER, which has an acknowledged

range after launch that exceeds 500 nm, is carried by USAF bombers and fighters. JASSM-ER-like weapons launched by a non-stealth bomber standing off 550 nm from China's coastline could reach targets located about 50 nm or slightly more inland. In this case, targets held at risk on the Chinese mainland by the stand-off bomber would be a much smaller percentage of targets held at risk by penetrating bombers.[44] Further increasing the bomber's stand-off range to avoid Chinese threats would further reduce the number of targets its JASSM-ER-like weapons could reach, possibly to the point that no targets are in range. This example highlights how relying on long-range stand-off attacks alone could create operational sanctuaries for anti-satellite weapons, ballistic missile brigades, and other weapon systems that are located deep in China's interior.

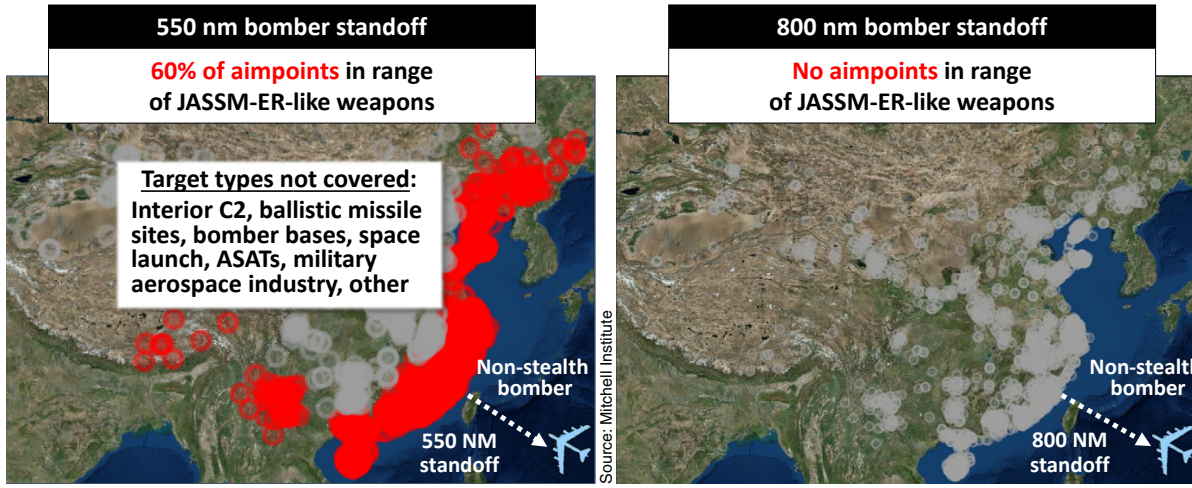


Figure 10: Aimpoints in a notional target set that could be reached by weapons with JASSM-ER range launched 550 nm or 800 nm from the Chinese coastline

While weapons with even longer ranges could enable stand-off aircraft to attack deeper targets, increasing range without changing a weapon's outer mold line would require tradeoffs such as reducing the size and weight of its warhead, which could reduce the weapon's effectiveness against some targets. The alternative is to use larger weapons with longer ranges, but this can reduce the number of weapons delivered per sortie. To illustrate this, a B-2 bomber can carry up to 80 short-range stand-off Small Diameter Bombs, and only 16 much larger JASSM-ERs.[45]

Enemy Countermeasures Require Stand-in Bombers

China, Russia, and other adversaries seek to degrade the effectiveness of U.S. precision strikes by increasing the mobility of their military systems, using camouflage and deception to complicate U.S. ISR and targeting operations and hardening or deeply burying critical facilities to make them more difficult to kill. These countermeasures have a greater negative impact on long-range stand-off aircraft.

Attacking mobile or relocatable targets. Adversaries are increasing the mobility of their forces to complicate the U.S. military's ability to find, fix, track, target, and attack them with precision-guided weapons. For instance, Russia's family of S-300 and S-400 long-range SAMs are reportedly able to engage

targets within 5 to 10 minutes after moving to a new location, and then tear down and begin to move in a similar amount of time.[46]

While target movements can reduce the effectiveness of strikes from all ranges, they can have the greatest impact on long-range stand-off strikes. Stand-off weapons are usually pre-programmed with their target coordinates before they are launched. A cruise missile flying at a high subsonic speed (0.8 Mach) launched by a non-penetrating aircraft standing off 550 nm from a target would have a flight time to impact of slightly more than 60 minutes. This is well outside the time needed for a mobile target such as an S-400 SAM to relocate. While the cruise missile may strike its preprogrammed coordinates with great accuracy, the weapon will be a net loss to the attacker if its target is no longer there. While some may argue that more advanced weapons can be retargeted in flight, it is also important to recognize that enemy electromagnetic spectrum defenses may degrade the ability of U.S. systems to communicate in a real-time, on-demand fashion. It is useful to have the option of a shorter kill chain.

Penetrating aircraft can deliver cheaper short-range stand-off and direct attack weapons with flight times of a few minutes that reduce the time available for enemy to detect and react to strikes.

In contrast, penetrating aircraft can deliver cheaper short-range stand-off and direct attack weapons with flight times of a few minutes that reduce the time available for enemy to detect and react to strikes. Moreover, penetrating aircraft with sensors that can actively or passively locate targets or receive information from off-board sources can update their weapons before launching them. This also increases strike effectiveness against highly mobile/relocatable targets.

Attacking hardened or deeply buried targets. Building hardened and underground facilities to shelter weapons of mass destruction, military command and control centers, ballistic missile launchers, fighters, and other high-value capabilities is a widespread practice. These measures provide protection against guided weapon attacks and help conceal operations from an adversary. China initiated a major effort to create advanced underground facilities (UGFs) in the 1980s. The success of U.S. precision strike operations during Operation Desert Storm convinced China to accelerate its UGF building program. Today, "China has thousands of UGFs and it continues to construct more each year."[47] While Russia's UGF program is not as ambitious as China's, its Cold War-era investments in hardened and deeply buried facilities are well known.

PLA Air Force J-8 fighters entering an underground shelter

Source: Air Power Australia, https://www.ausairpower.net/APA-PLA-Fighters.html

Large conventional warheads that are specially designed to penetrate to some depth before they detonate are typically needed to create desired effects on hardened

or deeply buried facilities. The AGM-158B JASSM-ER carries a 1,000-pound penetrating warhead that is capable against some types of reinforced targets. Harder targets require even larger penetrating weapons such as the 2,000-pound class GBU-31 JDAM that has a BLU-109/B penetrator, the 5,000 pound-class GBU-28 laser-guided bomb, or even the 30,000-pound GBU-57A/B Massive Ordnance Penetrator "bunker buster" bomb. While they vary in size and sophistication, large munitions designed to penetrate very hard/deeply buried targets are direct attack weapons. It is difficult and cost prohibitive to design stand-off weapons that are able to fly long ranges *and* carry warheads large enough to penetrate the most fortified targets.

Negative impact of mobile/relocatable and hardened/deeply buried targets. China, Russia, Iran, North Korea, and other potential adversaries have aggressively employed hardening/deeply burying and mobility countermeasures to decrease the effectiveness of U.S. precision strikes. These countermeasures can significantly reduce the number of targets that are suitable for long-range stand-off strikes.[48] This would then require a joint force commander to commit additional costly assets to strikes or accept delays that could give an enemy the time it needs to prevail.

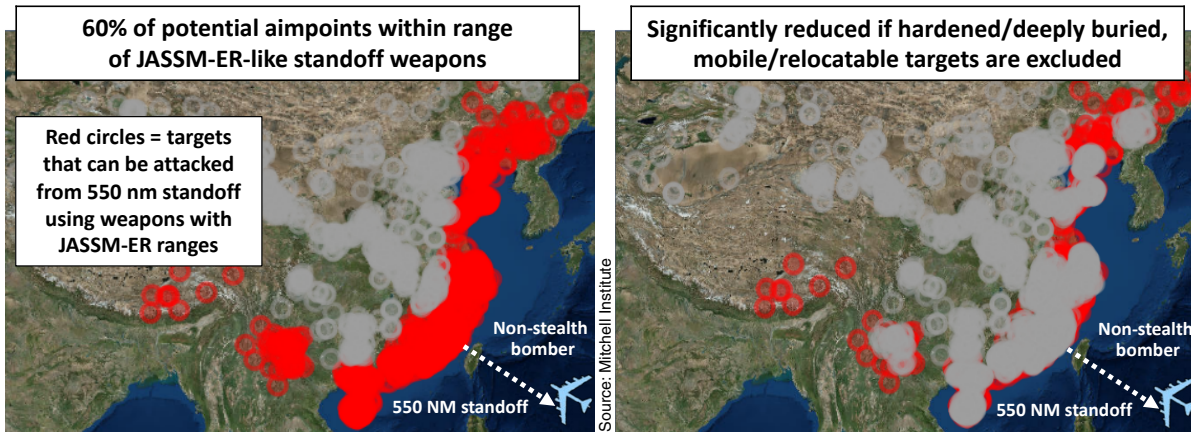


Figure 11: Mobility and hardening/burying countermeasures reduce targets suitable for stand-off attacks

On the other hand, penetrating strike aircraft can carry large payloads of direct attack weapons that are better suited for killing hardened/deeply buried and mobile/relocatable targets. This can reduce time and resources needed to attack challenging targets required by theater commanders. It is important to recognize that tremendous costs would be sunk in expensive stand-off weapon technologies that, by definition, self-destruct at the end of their mission. A stand-in bomber, by comparison, can reuse its various technologies to strike targets over an operational lifespan of decades. Buying a delivery system once and amortizing its cost across many missions represents basic common sense.

Hypersonic Weapons Are Needed, but Will Not Be a Panacea

It is possible to compensate for some target movements by using weapons that are capable of detecting, identifying, and then maneuvering to strike targets that have relocated. JASSM-ERs have imaging infrared (IIR) terminal seekers and can store a number of three-dimensional models of targets to help them locate

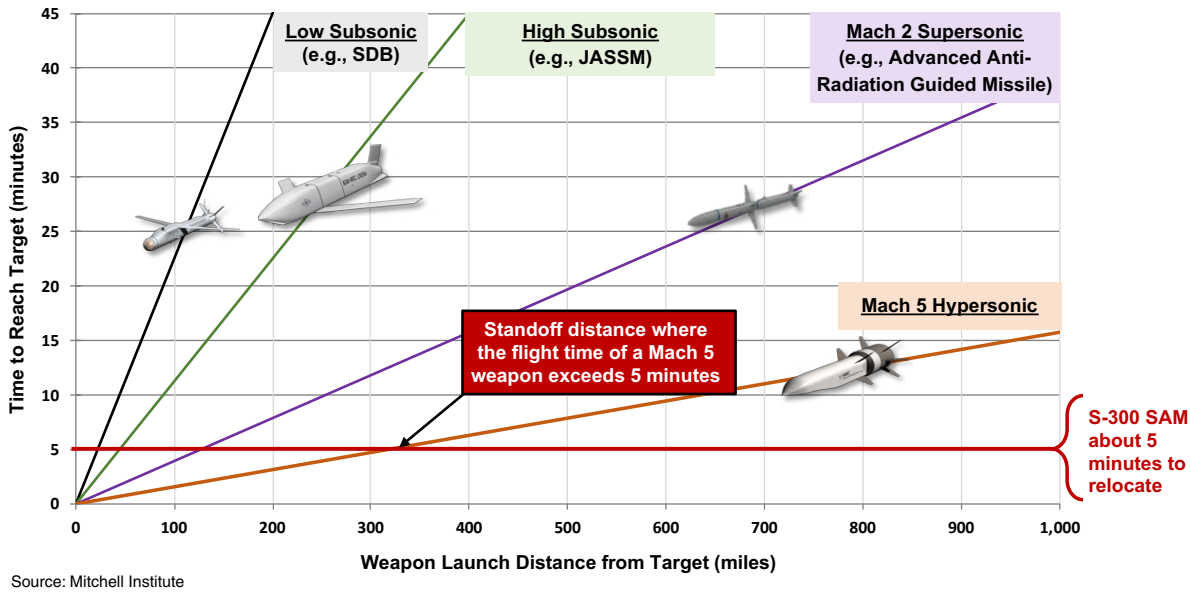
and guide to their aimpoints with precision. A JASSM datalink has also been successfully tested. However, enemy jamming can disrupt line-of-sight and beyond line-of-sight datalinks, and the use of multi-spectral camouflage can mask a target's IR signature from a weapon's seeker. These and other countermeasures can increase the total number of weapons needed to ensure required targets are killed.

Another approach would be to increase the *speed* of long-range stand-off weapons after launch, which would reduce the time needed for them to reach time-sensitive targets. DOD is spending billions of dollars to rapidly prototype, test, and acquire multiple variants of weapons capable of hypersonic (greater than Mach 5) flight. However, these weapons are likely to be costly on a per-unit basis.

There are two general classes of hypersonic weapons: boost/glide weapons that can be launched by aircraft or from surface launchers, and "air breathing" missiles that are equipped with a ramjet or scramjet engine to sustain flight at hypersonic speeds.[49] The Air Force is developing hypersonic weapons in both classes. The USAF's AGM-183 Air-Launched Rapid Response Weapon (ARRW) will carry a hypersonic glide vehicle payload, and the Hypersonic Air-breathing Weapon Concept (HAWC) will be a scramjet-powered weapon.[50] Hypersonic speeds can reduce weapon flight times after launch, which can improve the Air Force's ability to attack time-sensitive targets.

Increasing missile speeds beyond Mach 5 would reduce flight times to targets, but similar to other stand-off weapons, higher speeds can increase the sophistication and cost of hypersonic missiles. Hypersonic weapons that must travel very long distances may also need datalinks to receive in-flight target updates and terminal seekers to compensate for target location errors caused by target movements—technology that in some cases has yet to be proven to be operationally reliable. These capabilities would further increase the cost of hypersonic weapons compared to less sophisticated, shorter-range munitions launched by aircraft that can penetrate closer to defended targets.

Figure 12: Kill chain latency is still a factor for very long-range hypersonic weapon attacks



Source: Mitchell Institute

Weapons Range/Size Affect Number Delivered on Targets

Long-range stand-off weapons enable non-stealth aircraft to conduct strikes into contested areas on day one of a conflict, but due to aircraft payload capacity constraints, the number of large, long-range weapons stand-off aircraft can deliver per sortie are limited. In contrast, stealth bombers can penetrate closer to targets located in contested areas and deliver larger numbers of smaller short-range and direct attack weapons per sortie. Increasing weapons delivered per sortie during an air campaign can have a critical impact on the time needed to achieve a theater commander's objectives.

AGM-183 ARRW launched by a B-52H

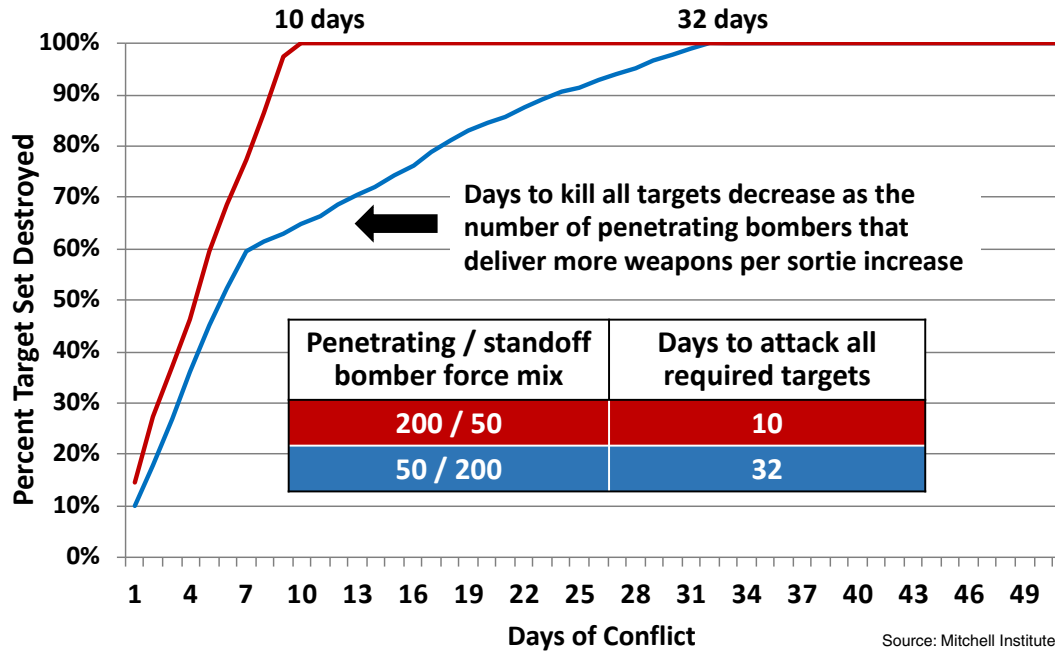
Source: Artist's rendering courtesy of Lockheed Martin

The size and weight of a long-range stand-off weapon is dependent on the warhead it carries; the need to be equipped with a powerplant, fuel, and wings to extend its flight; its guidance systems; and other required features. For instance, the B-2 can carry up to 16 long-range stand-off JASSM-ERs or up to 80 JDAMs in its internal weapon bays. Maximizing weapons per sortie is one reason the Air Force chose to continue developing the hypersonic AGM-183 ARRW instead of the Hypersonic Conventional Strike Weapons (HCSW): "The reason we went with ARRW was not that HCSW was bad, but ARRW is smaller; we can carry twice as many on the B-52."[51]

Given the importance of putting large numbers of bombs on targets during a strike campaign, weapons delivered per sortie can afford a clear choice regarding operational value realized. For the sake of argument, assume a future force of 250 bombers has a mix of 200 penetrating aircraft that can each carry 80 direct attack weapons, and 50 stand-off aircraft that can carry only 20 long-range cruise missiles each. This force

mix would deliver more weapons per sortie and destroy a larger percentage of targets in less time than a mirror opposite force of 50 penetrating and 200 stand-off bombers. To illustrate this point, Figure 13 shows the 200 penetrating/50 stand-off force could theoretically kill all targets prioritized by a commander in as little as 10 days (red line), and its opposite force mix of 50 penetrating/200 stand-off bombers (blue line) would require more than three times the amount of time—32 days—to do the same.[52] The success or failure of a theater air campaign can hinge on the Air Force's ability to maximize the numbers of weapons it can place on targets in the shortest amount of time possible.

Figure 13: Illustrating the relationship between weapons per sortie & time to attack targets



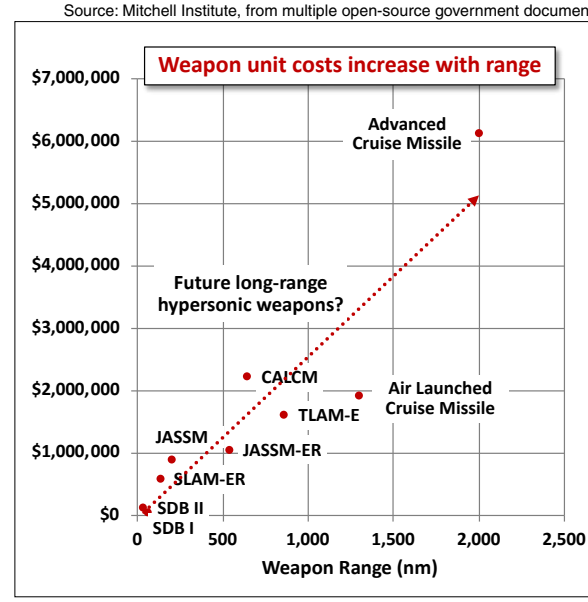
Weapon Costs Increase with Range

Weapons cost is another factor that must be considered by DOD force planners. Broadly speaking, the unit costs of weapons increase with their range. This is due to the need to design weapons with aerodynamic bodies, wings that can extend after launch, powerplants, fuel, guidance systems, and other capabilities to extend their range. The advanced technologies of long-range hypersonic weapons will likely increase their unit costs into the millions. Procuring very large numbers of these expensive long-range stand-off weapons would constrain the total number of weapons of all classes the Air Force can afford to procure. Affordability is a critical consideration, given the very large size of potential Chinese or Russian target sets.

The unit costs of various air-to-surface weapons are roughly proportional to their range. Very long-range advanced precision-guided weapons can cost millions of dollars each, which can reduce the total number the Air Force can afford to procure and use. This is a major problem given the number of concurrent threats facing the United States. It should also be recalled that U.S. stocks of stand-off weapons were reduced to low levels by regional operations like Operation Odyssey Dawn in Libya; major operations against China or Russia would be far more taxing.

Source: Mitchell Institute, from multiple open-source government documents

Figure 14: Illustrating the relationship of weapons unit cost to weapons range[53]



Allied aircraft flew on average over 1,200 strike sorties per day, and attacked roughly three to four times that number of aimpoints or 4,800 target aimpoints per day during Operation Desert Storm in 1991.[54] Most of the weapons used were short-range stand-off and direct attack munitions because the threat environment permitted non-stealth aircraft to operate with near impunity in the battlespace. This would not be the case in a conflict with China and Russia; non-stealth bombers and fighters would need to use long-range stand-off weapons such as JASSM-ERs to attack targets in contested areas. JASSM-ERs have a flyaway unit cost of approximately $1.05 million. It would cost over $50 billion to buy enough JASSM-ERs to launch them at a rate of 4,800 per day similar to Desert Storm for as little as ten days. On the other hand, less expensive direct attack weapons such as $29,000 per unit GBU-32 JDAMs delivered by penetrating bombers at a rate of 4,800 per day for 10 days would cost less than 3 percent the total cost of the JASSM-ERs.[55] Moreover, using JASSM-ERs at such a high rate is infeasible from an inventory perspective, since the USAF does not plan to buy anywhere near that number of JASSM-ERs—about 6,500 total through FY2025—nor would it be affordable given budget pressures that will impact DOD in the wake of COVID-19 response efforts.

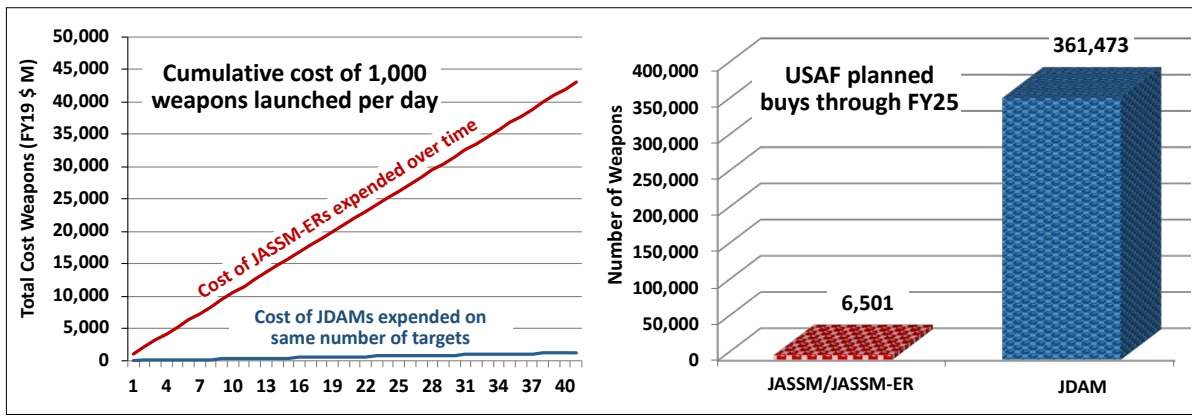


Figure 15: Comparing the cost of using long-range stand-off and direct attack weapons

Source: Mitchell Institute (see endnote 55)

This does not mean the Air Force should not buy JASSM-ERs which have tremendous capabilities. The point is, technical sophistication and long ranges increase the cost of weapons, and high weapon costs can reduce the number available to theater commanders. It is simply not feasible to assume that stand-off weapons costing millions of dollars will be available in very large quantities. This is exactly what would be required if the Air Force's mix is not rebalanced in favor of penetrating aircraft. More broadly, these cost-benefit calculations must be assessed from a joint, theater-wide power-projection perspective given the Army and Navy's planned investments in stand-off weapons, which will be the topic of a future Mitchell

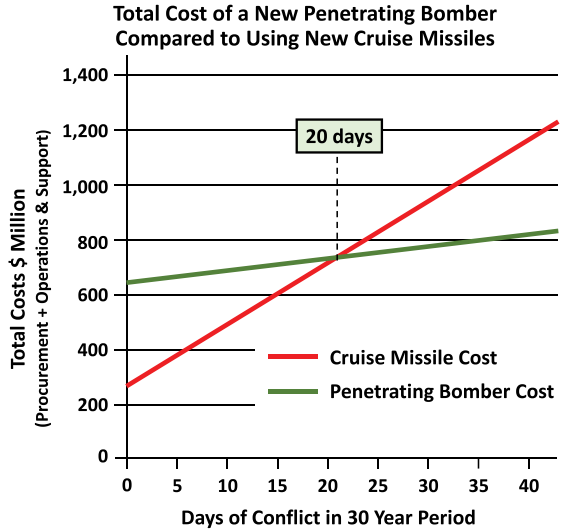
Institute assessment. In summary, investing in affordable capabilities to strike with precision and mass over long ranges will be key to defeating great power aggression. The next section expands this comparison to include the cost of procuring a new stand-off arsenal plane for long-range strikes.

Developing Alternatives: Quick and Cheap?

Alternatives to buying more B-21 bombers are to: a) purchase more long-range cruise missiles for existing stand-off aircraft; b) increase standoff strike capacity by modifying an existing cargo aircraft to launch cruise missiles; or c) create a new stand-off bomber from scratch. This section analyzes each of these alternatives according to their cost, cost effectiveness, and priority capability gaps, factors that ultimately led to DOD's decision to buy the B-21.

Expendable Long-Range Cruise Missiles Cost More Than Reusable Stand-in Bombers

DOD completed an exhaustive joint study that considered a spectrum of stand-off and penetrating strike aircraft and weapons prior to its decision to proceed with the B-21. The results were clearly in favor of the course chosen by the Air Force and Secretary of Defense. While these analyses are highly classified, one RAND Project Air Force report commissioned by DOD to support this effort is not. The 2010 study compared the cost of procuring and operating a new penetrating bomber over a thirty-year period with the cost of using long-range cruise missiles in future operations. It concluded if these capabilities are used in air campaigns "for 20 days or more over the next 30 years, penetrating stealth bombers cost less than expendable missiles for similar missions."[56]



Source: RAND (see endnote 56)

Figure 16: 2010 RAND Project Air Force cost comparison

RAND's analysis is a classic example of how a reusable capability like a penetrating bomber that can employ less expensive direct attack weapons is a better value than expending more expensive one-time-use stand-off cruise missiles. The 20 days of strikes over a thirty-year period cited by the study is not unrealistic, considering it is less than half the duration of the Desert Storm air campaign in 1991, and far less than the total number of days the USAF has conducted airstrikes over the last 30 years. More importantly, RAND's assessment emphasizes why it is critical to focus on the relative cost of different capabilities to achieve mission effects over some period of time rather than just the unit cost of a new penetrating bomber.

Assessing the Potential Cost of a New Stand-off Arsenal Plane

Some believe it may be possible to reduce the cost of a new stand-off weapons carrier by modifying existing airlift aircraft to carry large payloads of cruise missiles.[57] General Ray has expressed interest in a exploring the potential to build a clean sheet "…low cost, very simple bomb truck to increase our stand-off weapons capacity" by "leveraging existing technologies, instead of it being a full blown, highly integrated, stealthy platform."[58] Based on evidence from other DoD large commercial aircraft derivative programs (Navy's P-8 from a B-737 and the Air Force's KC-46 from a B-767) and clean sheet aircraft design programs, a new arsenal plane would be costly and require years to develop.

Potential cost of a C-17 derivative arsenal plane. There has been some speculation that it could be less expensive to modify an existing mature military airlift aircraft such as a C-17 to launch stand-off weapons. The Air Force's C-17s can carry up to 170,900 pounds in its cargo bay and has an unrefueled range of 2,700 nm.[59] Following depressurization, C-17s can airdrop paratroopers, palletized cargo, and other mission loads from its aft ramp.[60] After factoring in the cost to restart a C-17 production line and modify the aircraft to do what it was never designed to do—routinely launch long-range stand-off cruise missiles inflight—it would be a more expensive option than procuring additional penetrating B-21s.

C-17s already are in high demand for their primary air mobility missions, and it is unlikely the U.S. Transportation Command would be willing to allocate some of its existing C-17s to conduct stand-off strikes in a conflict with China or Russia rather than airlift or airdrop missions.[61] General Ray agrees that modifying existing C-17s would not be the best approach, since it would pit them in "a competition for other airlift requirements."[62] This leaves the question of the cost and feasibility of manufacturing new C-17s that are modified to launch stand-off weapons.

Based on evidence from other DoD large commercial aircraft derivative programs (Navy's P-8 from a B-737 and the Air Force's KC-46 from a B-767) and clean sheet aircraft design programs, a new arsenal plane would be costly and require years to develop.

A 2012 RAND Project Air Force study concluded non-recurring costs to restart production of an C-17 airlifter could range between $2.7-3.1 billion in FY2011 dollars and up to $7.3 billion for a modified C-17.[63] In 2009, the Air Force estimated it could require three years to restart a C-17 line, assuming a restart decision was made by 2010 and the C-17's production plant and tooling were still available. Since Boeing has divested both, starting a production line for a modified C-17 standoff strike platform would likely require more than three years and high single-digit billions of dollars.

In 2008, the U.S. Government Accountability Office estimated a new C-17A would cost $278 million in procurement costs only - $345 million in FY2020 dollars.[64] Modifications needed for a C-17 to carry and launch cruise missiles would significantly increase its unit cost beyond this. Structural changes may be needed to allow C-17s to depressurize and release weapons at altitudes greater than 25,000 feet, its current certified ceiling for airdrops.[65] Unlike manned bombers, C-17s were not designed with a pressurized crew compartment separate from its payload section. Without a pressurized cabin, aircrews would need to fly

for some period of time in an unpressurized environment to conduct multiple weapon launches. This could reduce the aircraft's permissible operating altitude, range, and mission duration.[66] The C-17's speed during a weapons release would also need to allow for weapons to achieve stable flight and initiate an engine start, although weapons could be modified with a rocket that boosts them to higher speeds and altitude if necessary. More significantly, a C-17 arsenal plane would need an internal system that can hold a large number of weapons, move them to launch position, then eject them while airborne. This system would need sufficient cooling and power to operate, a means to quickly transfer mission data to weapons before launch, and other supporting capabilities.

Modifying an airliner to carry weapons internally could be even more technically challenging than a C-17 option, would take years to develop and test, and could end up costing somewhere in the range of $300-500 million each.

In summary, while an arsenal plane derived from a C-17 may be feasible from a technical perspective, completing its extensive engineering, manufacturing, and development phase, opening a new production line, and then begin procurement could drive its unit cost into the $400 million or more range. After factoring in the higher cost of the long-range stand-off weapons a non-stealth C-17 would need to use, this option would not compete well with a new penetrating bomber from a unit cost or cost effectiveness perspective.

Potential cost of a commercial derivative. Modifying an airliner to carry weapons internally could be even more technically challenging than a C-17 option, would take years to develop and test, and could end up costing somewhere in the range of $300-500 million each. Like the C-17 option, it would not be a quicker or cheaper alternative to buying additional B-21s, nor would it help fix the critical imbalance between the USAF's long-range stand-off and stand-in strike capacity.

Developing a cruise missile carrier aircraft (CMCA) from a commercial aircraft is not a new idea. After the Carter administration cancelled the B-1A, DOD completed multiple studies on the feasibility of modifying commercial aircraft to launch cruise missiles.[67] Concepts for a CMCA have included using an internal carousel to sequentially move multiple rotary launcher assemblies that eject cruise missiles through an aft cargo door or other aircraft aperture.[68] Figure 17 is an artist's concept for a modified Boeing 747 equipped with rotary launch assemblies that carry up 72 long-range cruise missiles.[69]

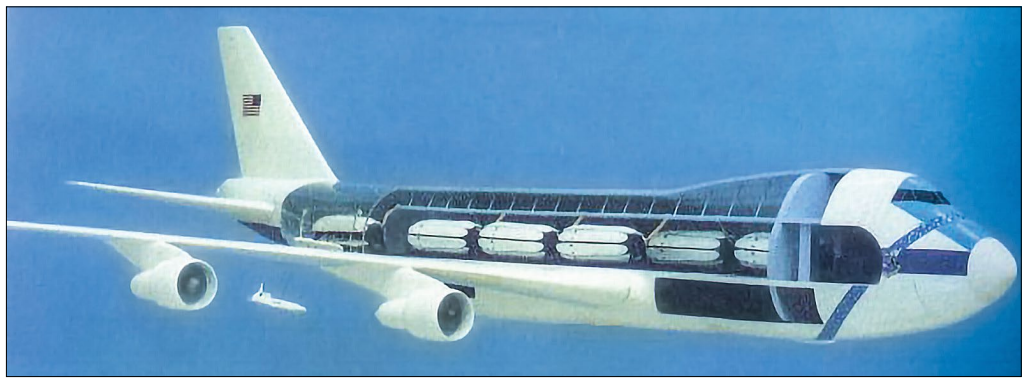


Figure 17: Artist's concept of a modified B747 cruise missile carrier aircraft

Source: "Why Boeing's Design For A 747 Full Of Cruise Missiles Makes Total Sense," (see endnote 68)

Significant modifications to commercial aircraft would be needed to compensate for depressurization and vibro-acoustic effects created by opening a door inflight at high subsonic speeds.[70] Major modifications may also be needed to aircraft engine gearboxes and bleed air systems to provide electricity, hydraulic power, and cooling air to a moving carousel of rotary launch assemblies. Unlike passenger and freight carrying airliners, a CMCA would have to quickly shift its fuel or use other means to compensate for changes to its center of gravity created by launcher movements and missile releases.

Modifying an airliner to carry weapons externally would be just as challenging. The outside skin of an airliner is part of its structure (semi-monocoque design) and would require a major redesign to support weapon hardpoints. It would also require extensive modifications to allow an airliner to carry weapons on wing-mounted pylons like a B-52, since airliner wings are designed to be lightweight to improve fuel efficiency. Other upgrades could include equipping a CMCA with secure communications, threat warning receivers, and other electronic warfare systems to give them some means of countering long-range air-to-air threats, the ability to refuel inflight, and hardening against electromagnetic pulses from directed energy weapons.

Buying and then upgrading commercial aircraft with these capabilities would be an expensive proposition. The U.S. Navy has procured P-8A Poseidon aircraft to conduct maritime surveillance, anti-submarine warfare, anti-surface warfare, ISR, and other missions. P-8As are B737-800s modified with sensors, a weapons bay, and external pylons to carry anti-ship weapons.[71] The Royal Australian Air Force has procured airborne early warning and control aircraft called "Wedgetails" that are based on B737-700s modified with electronically scanned array radars, crew stations, electronic warfare self-protection capabilities, and C2 systems.[72]

Source: Boeing

Figure 18: U.S. Navy P-8A Poseidon and RAAF E-7A Wedgetail

After modification, average procurement unit costs for the P-8A Poseidon and E-7A Wedgetail were 105 percent and 23 percent higher respectively than the base cost of B737s from which they were derived.[73] Modifications needed to carry and release weapons were a key driver behind the higher cost of P-8As. Based on these precedents, Table 3 assumes large cruise missile-carrying aircraft derived from four large freight aircraft could cost 40 percent or more than the list prices of their base aircraft.[74]

Large Commercial Freight Aircraft	Cargo Capacity (x 1,000 lbs.)	Notional Rotary Launch Assemblies	2018 List Price Without Modifications	Estimated Cost (+40%) With CMCA Modifications
B767F	115.7	3	$220 million	$330 million
A330-200F	143.3	4	$241 million	$338 million
B777F	224.9	7	$339 million	$508 million
B747-8F	303.7	9	$403 million	$565 million

Table 3: Illustrative costs to buy and upgrade commercial freight aircraft to CMCAs

Source: see endnote 74

The time and cost to develop a clean sheet arsenal plane. A clean-sheet stand-off arsenal plane would need a launch system located in a depressurized compartment or an area that could routinely depressurize, secure communications for command and control and to receive targeting information, a weapon stores management system that provides target information to weapons, and possibly threat warning receivers. The latter could be necessary because stand-off aircraft may be at risk of attack by future Chinese or Russian long-range interceptor aircraft. A clean-sheet design may not require active sensors to support strike operations, since they would remain well outside of radar range of their potential targets. While the lack of a radar would reduce a clean sheet aircraft's unit cost, other required capabilities would drive its unit cost into the hundreds of millions. The potential for lower unit costs is one of the reasons the Air Force and other services created programs to derive new weapon systems from commercial aircraft—a clean sheet approach is unlikely to yield greater savings.

Source: Mitchell Institute

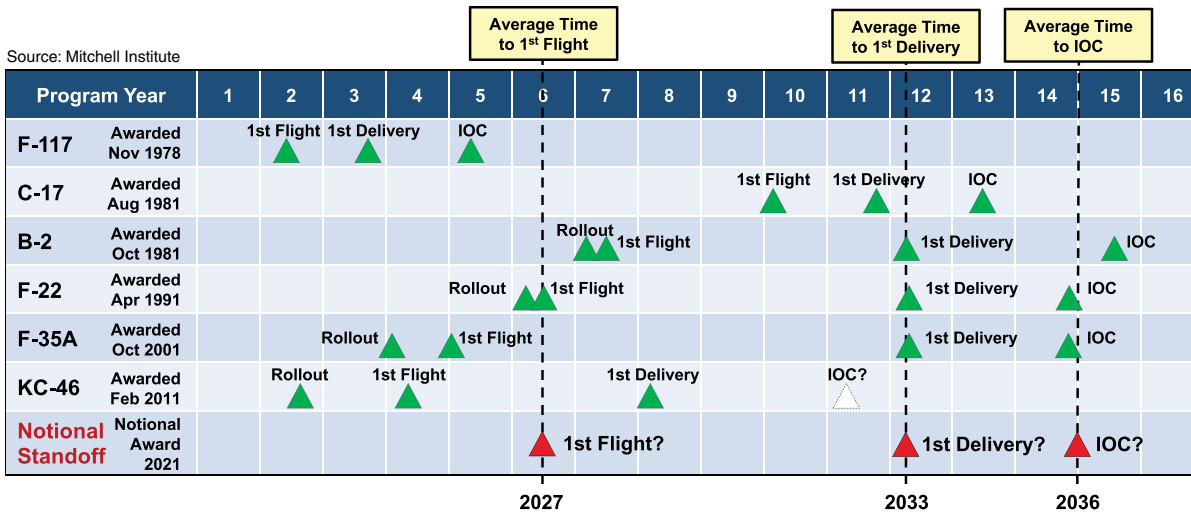


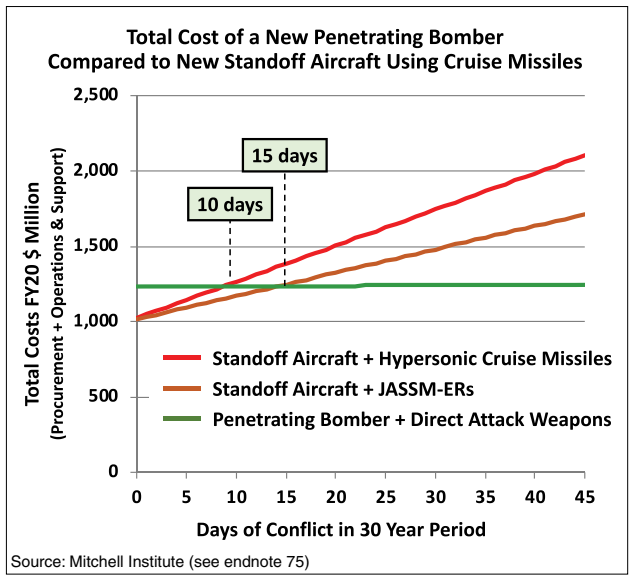
Table 4: Milestones in USAF new-start major aircraft development programs

On the question of schedule, a look at other USAF clean-sheet aircraft development programs can be instructive. The most notable of these is the F-117 stealth fighter program, which reached IOC in 1983, only five years after contract award. The F-117 program was a unique, streamlined acquisition venture that produced a single-seat fighter that carried two weapons internally. Later generation stealth aircraft—the B-2, F-22, and F-35—averaged about 14 years between contract to IOC. The time to IOC for a clean sheet arsenal plane may be closer to the C-17 program—about 13 years—and more optimistically, the KC-46 commercial derivative program's estimated 10 or 11 years. Even with this optimistic timeline, a clean-sheet stand-off bomber would

not be available until sometime after 2032. This would not help address the USAF's long-range strike shortfall before the B-21 reaches full-rate production. More worrisome, competition for resources to begin another new program could be at the expense of the B-21's acquisition rate, much as other competing priorities have reduced the Air Force's F-35A procurement to 48 per year instead of its originally planned 80 per year.

A New Stand-off Arsenal Plane Would Be Less Cost-Effective than a Penetrating Bomber

With this background, it is possible to compare the cost effectiveness of a stand-off arsenal plane that launches advanced cruise missiles with a penetrating bomber that delivers JDAMs. This comparison favors the penetrating bomber, assuming an optimistic average price of about $400 million for a new arsenal plane.[75] Using a penetrating bomber with JDAM payloads for more than 15 days over a 30-year period would cost less than the notional stand-off arsenal plane that launches an equivalent number of JASSM-ERs. The break-point would be even more in favor of the penetrating bomber—10 days—if the arsenal plane launches hypersonic weapons that cost $2 million or more each. Again, a 10 to 15-day air campaign would be far shorter than campaigns conducted during Operation Desert Storm (43 days), Operation Allied Force (78 days), and Operation Iraqi Freedom (42 days).



Source: Mitchell Institute (see endnote 75)

Figure 19: Comparing notional stand-off arsenal plane and penetrating bomber costs

Similar to the RAND study, the cost of additional ISR support needed to support stand-off cruise missile strikes is not included, which creates bias in favor of the stand-off arsenal plane alternative. Furthermore, this example assumes both the stand-off and penetrating bomber carry a like number of weapons per sortie. Not giving credit to the penetrating bomber's ability to carry a larger number of direct attack weapons also favors the stand-off option.

In summary, multiple DOD and non-government independent studies have assessed the cost effectiveness of different mixes of stand-off and penetrating long-range strike capabilities. The consensus is a stand-off-dominant force of long-range strike aircraft and weapons is *not* the most cost-effective force design approach *when assessed from an operational perspective*. Studies that focus primarily on comparing acquisition unit costs, an approach that all-too-often is taken by DOD to support its major program decisions, would conclude otherwise. Past analyses that were more concerned with the balance sheet rather than the best mix of forces to prevail in conflict have helped to create a 2020 force that now lacks the degree of survivability, lethality, and capacity called for by the national defense strategy. "Quick and cheap" from a budget standpoint may actually be the more costly option from a warfighting perspective.

Recommendations

Based on assessments in this report and a mature body of evidence from related studies, the Mitchell Institute offers the following recommendations:

The USAF should significantly increase its long-range strike capacity. A total force of *at least 316 bombers* is needed to support the U.S. national defense strategy, the vast majority of which should be B-21 aircraft. DOD's 1997 decision to stop buying stealth B-2s helped create a bomber force that is now too small, too old, and over-weighted toward stand-off aircraft. While this force may have been adequate for past operations against lesser regional militaries, multiple analyses have concluded the Air Force should increase its capacity to conduct stand-in strikes in contested environments against peer adversaries. Doing so would require the USAF to buy at least 240 B-21 stealth bombers.

The Air Force should prioritize penetrating strike platforms. Success in warfare comes down to inflicting rapid, overwhelming attacks against key targets, and sustaining such operations demands affordable means to conduct strikes. Today, B-1Bs and B-52Hs cannot penetrate Chinese or Russian IADS with an acceptable degree of risk, and the same is true for any non-stealth aircraft—old or new. The inability to penetrate limits bombers to using stand-off weapons to strike targets inside contested areas. The time needed for these weapons to fly hundreds of miles after launch reduces their effectiveness against relocatable targets such as missile TELs, a weapons system favored by adversaries to launch attacks against U.S. forces. Past this, long-range weapons lack warheads capable of destroying very hard or deeply buried targets. The need to attack these challenging targets in contested environments was a primary reason that DOD chose to procure the B-21. Long-range weapons are also more expensive and can be carried in fewer numbers per sortie compared to smaller direct attack weapons. Finally, if facing a choice, the Air Force should prioritize penetrating systems because it is the sole owner of these systems—other stand-off options and capacity exist. All of the other services seek to acquire new stand-off strike capabilities. To avoid redundancy the Air Force must ensure it can provide commanders with options to penetrate deep into contested areas and strike a large number of targets per sortie.

Hypersonic weapons are needed but will not be a panacea. Enemy IADs are increasingly effective against legacy weapons such as subsonic Tomahawk Land Attack Missiles as well as non-stealth aircraft. Due to their speed, maneuverability, and other characteristics, hypersonic (Mach 5 or greater) weapons will be better able to survive in these threat environments. Using more survivable

AGM-183 hypersonic stand-off munitions carried by the venerable B-52H will be one component of the long-range strike balance.

Source: Artist's rendering courtesy of Lockheed Martin

hypersonic weapons would help limit the total number of stand-off weapons needed to attack defended targets. However, hypersonic weapons launched from long stand-off distances will still be less effective against targets that can quickly relocate compared to direct attack PGMs that can reach targets in just a few minutes. Plus, hypersonic weapons will not be cheap. Air-breathing hypersonic cruise missiles require powerplants, fuel, and other design features to fly long ranges which increases their size (decreases weapons per sortie) and cost. Similar to other stand-off munitions, investments in hypersonic weapons should be informed by tradeoffs between their survivability, size, weapons per sortie, effectiveness against challenging targets, and affordability.

Allocating modified airlift aircraft to conduct strike missions does not make operational sense. There are already indications of a growing shortfall in the Air Force's capacity to provide heavy airlift to rapidly deploy and sustain forces. Schemas that would allocate some number of modified airlifters to strikes instead of their primary mobility missions could have a major impact on the U.S. military's ability to prevent China or Russia from achieving a quick victory.

Developing a new stand-off bomber is not a quicker and cheaper alternative to the B-21. There is a persistent myth that a new stand-off arsenal aircraft with large payload capacity could be developed quickly and for less cost than buying the B-21. Neither are true. Restarting a production line for a military airlifter like the C-17 would require years and billions of up-front program dollars. On top of this, modifying a C-17 or existing commercial cargo aircraft to carry stand-off weapons would require even more funding and time. Those who question this should consider the effort needed to develop the Navy's P-8 maritime patrol-strike aircraft from a commercial design and continued struggles surrounding the Air Force's KC-46A tanker. The resulting cost of a weapons-carrying widebody aircraft could equal or exceed the B-21's cost while providing a less operationally flexible, single-mission capability. It is likely that a clean-sheet design stand-off bomber would be even more expensive than a program that modifies a mature airlifter to launch weapons.

Conclusion

America is faced with a set of challenges to its security that are radically different than the regional threats it confronted over the last thirty years. The return of great power competition with a focus on the rise of a revisionist China, a growing Russian threat to our allies along NATO's eastern frontier, and the need to maintain a significant presence in the Middle East drive the need to rebalance the U.S. military. These threats are very real, and as history has shown the consequences of failing to invest in the right mix of military capabilities for plausible conflicts can be devastating.

In conclusion, the USAF bomber force offers unique options to U.S. commanders. Bombers can operate over intercontinental ranges to deliver weapons on targets on night-one of a conflict with China or Russia, without the need to first deploy to a theater of operations. The Air Force's stealth B-2s deliver large payloads

of guided weapons on targets in contested areas and non-stealth bombers can launch stand-off weapons to knock down A2/AD threats and counter enemy forces well before additional land- and sea-based strike forces can deploy to the fight. Without question, America's future bomber force should have a mix of stand-off and penetrating aircraft. What some continue to debate is the *optimal* mix of stand-off and penetrating capabilities.

Changing the balance in favor of long-range stand-off systems does not make sense for the Air Force from operational or cost-per-effect perspectives. It also does not make sense from a whole of DOD standpoint, since it could lead to over-investments in stand-off strike capacity.

The USAF should significantly increase its penetrating long-range strike capacity.

The USAF should significantly increase its penetrating long-range strike capacity. DOD's 1997 decision to stop buying stealth B-2s helped create a bomber force that is now too small, too old, and too focused on stand-off aircraft. While this force may have been adequate for past operations against lesser regional militaries, multiple analyses have concluded the Air Force should increase its capacity to conduct stand-in strikes in contested environments against peer adversaries. A total inventory of *at least 316 bombers* is needed to support the U.S. national defense strategy; the future bomber force should consist of 76 B-52s and at least 240 B-21s.

The choices that are made in coming years will fundamentally shape how our military will operate against great power aggressors. Penetrating strike bombers expand policy options available to America's leadership. Without a robust force of penetrating bombers, the United States will be at a severe disadvantage against peer competitors. ✪

Endnotes

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8 Ibid.

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52 It is important to note the comparison in Figure 13 is not the product of extensive campaign modeling and other analyses that would be needed to define actual USAF force requirements. Figure 13 also assumes each bomber flies a single sortie per day, and no U.S. aircraft or weapons are attrited by enemy defenses.

53 Weapon costs in Figure 14 are from multiple open source U.S. Government documents.

54 *Gulf War Airpower Survey Volume 5* (Washington, DC: U.S. Government Printing Office, 1993), pages 232, 233, https://media.defense.gov/2010/Sep/27/2001329816/-1/-1/0/AFD-100927-065.pdf; and Lt Gen David A. Deptula, USAF (Ret.), *Level of Effort Air Campaigns since Desert Storm*, unpublished paper, May 10, 2016.

55 Office of the Under Secretary of Defense (OUSD) (Comptroller)*, Air Force Missile Procurement for Fiscal Year 2021* (Washington, DC: DOD, February 2020); and Office of the Under Secretary of Defense (OUSD) (Comptroller)*, Air Force Ammunition Procurement for Fiscal Year 2021* (Washington, DC: DOD, February 2020).

56 Thomas Hamilton, "Comparing the Cost of Penetrating Bombers to Expendable Missiles over Thirty Years," RAND Project Air Force paper WR-778-AF, August 2010, https://www.rand.org/pubs/working_papers/WR778.html. Figure 14 assumes the penetrating bomber flies one sortie per day, and the advanced cruise missiles (red line) are launched from a stand-off platform at a rate of 12 per day.

57 For example, see Oriana Pawlyk, "Plans for Pentagon's Future Flying Bomb Begin to Take Shape," *Military.com,* November 12, 2019, https://www.military.com/daily-news/2019/11/12/plans-pentagons-future-flying-bomb-truck-begin-take-shape.html.

58 Theresa Hitchens, "Ray Asks Roper To Explore 'Bomb Truck' For Cheap Stand-off Capability," *Breaking Defense,* December 7, 2019, https://breakingdefense.com/2019/12/ray-asks-roper-to-explore-bomb-truck-for-cheap-stand-off-capability/.

59 U.S. Air Force, "C-17 Globemaster III," May 14, 2018, https://www.af.mil/About-Us/Fact Sheets/Display/Article/1529726/c-17-globemaster-iii/.

60 C-17s also have air-dropped modified medium-range ballistic missile targets for missile defense tests. For an interesting description of one such drop, see Rebecca Amber, "AMC C-17 facilitates airdrop for Missile Defense Agency test," U.S. Air Force, December 9, 2015, https://www.af.mil/News/Article-Display/Article/633494/amc-c-17-facilitates-airdrop-for-missile-defense-agency-test/. "The extended ballistic missile was extracted from the AFTC C-17 using an experimental carriage extraction system to pull it out of the aircraft."

61 The USAF's Air Mobility Command has said that more strategic airlift capacity may be needed to support National Defense Strategy requirements. Valerie Insinna, "Could the Air Force restart the C-17 production line?" *Defense News,* October 26, 2018, https://www.defensenews.com/digital-show-dailies/airlift-tanker-annual/2018/10/26/could-the-air-force-restart-the-c-17-production-line/.

62 Courtney Albon, "USAF global strike commander says Arsenal Plane may be a clean-sheet platform," *Inside Defense,* April 10, 2020, https://insidedefense.com/daily-news/usaf-global-strike-commander-says-arsenal-plane-may-be-clean-sheet-platform.

63 These cost estimates include funding to replace non-retained tooling. John C. Graser, Edward G. Keating, Guy Weichenberg, Michael Boito, Soumen Saha, Robert G. DeFeo, and Steven Strain, *Options for and Costs of Retaining C-17 Aircraft Production-Only Tooling* (Santa Monica, CA: RAND Corporation, 2012), page xii, https://www.rand.org/content/dam/rand/pubs/technical_reports/2012/RAND_TR1143.sum.pdf.

64 U.S. Government Accountability Office (GAO), *Timely and Accurate Estimates of Costs and Requirements Are Needed to Define Optimal Future Strategic Airlift Mix* (Washington, DC: GAO, November 2008), page 12, https://www.gao.gov/new.items/d0950.pdf; and Christopher Bolkcom, "Hearing on Cost Effective Airlift," statement before the Senate Homeland Security and Government Affairs Committee Subcommittee on Federal Financial Management, Government Information, Federal Services, and International Security, September 27, 2007, page 5, https://www.hsgac.senate.gov/imo/media/doc/Bolkcomtestimony.pdf.

65 "The C-17 is currently certified to conduct airdrops at a maximum height of 25,000 feet." Kenji Thuloweit, "418 FLTS testers record highest cargo airdrop," Air Force Material Command, July 20, 2011, https://www.afmc.af.mil/News/Article-Display/Article/153867/418-flts-testers-record-highest-cargo-airdrop/.

66 The C-17 crew that released a target MRBM in 2015 for missile defense testing purposes had to un-pressurize their aircraft and breathe 100 percent oxygen during weapons preparation and release: "The high-altitude drop was done from just below 25,000 feet, requiring the crew to breathe 100 percent oxygen for the duration of the inflight build-up to the drop itself. Amber, "AMC C-17 facilitates airdrop for Missile Defense Agency test."

67 In 1979, Secretary of Defense Harold Brown testified to congress: "I consider the cruise missile carrier aircraft to offer a prudent option for rapid growth in our strategic capability should it be needed. On this basis, the Air Force is completing concept/system definition studies based on the consideration of both military and civilian aircraft. These aircraft include existing wide-bodied transport aircraft as well as the B-1 design, Advanced Medium STOL Transport (AMST), C-141, C-5A and other candidates." "Cruise Missile Carrier Aircraft (CMCA)," *GlobalSecurity.Org,* https://www.globalsecurity.org/wmd/systems/cmca.htm.

68 Figure 17 is from Tyler Rogoway, "Why Boeing's Design For A 747 Full Of Cruise Missiles Makes Total Sense," July 19, 2014, https://foxtrotalpha.jalopnik.com/why-boeings-design-for-a-747-full-of-cruise-missiles-ma-1605150371.

69 Bryan J. Benson, Major, USAF, *Transport Bombers: A Conceptual Shift in Precision-Guided Munitions Delivery* (Maxwell AFB, AL: Air University Press, June 1996), page 22, https://media.defense.gov/2017/Dec/27/2001861442/-1/-1/0/T_0004_benson_transport_bombers.pdf. The 72 cruise missiles could have included AGM-86C Conventional ALCMs that have since been retired by the Air Force. Figure 17 is from https://foxtrotalpha.jalopnik.com/why-boeings-design-for-a-747-full-of-cruise-missiles-ma-1605150371.

70 According to a 1981 assessment: "The extensive structural modifications necessary to ensure that airframes can tolerate intense cavity oscillation warrants a significant development activity on suppression." H.W. Bartel and J.M. McAvoy, *Cavity Oscillation in Cruise Missile Carrier Aircraft* (Wright-Patterson AFB, OH: Air Force Wright Aeronautical Laboratories, June 1981), pages 57-58, https://apps.dtic.mil/dtic/tr/fulltext/u2/a108610.pdf.

71 P-8s now carry AGM-84D Harpoon anti-ship missiles and Mk 54 air-launched lightweight torpedoes. Future modifications could allow it to carry Long Range Anti-Ship Missiles (LRASM), a derivative of the JASSM-ER, and other munitions.

72 The United Kingdom has announced it will also procure Wedgetail airborne early warning and control aircraft.

73 Prices in the following sources have been adjusted for currency conversion and inflation to estimate conversion costs for the E-7A Wedgetail and the P-8A Poseidon. Australian National Audit Office, *2011–12 Major Projects Report* (Canberra, Australia: Defence Material Organization, 2012) page 205, https://www.anao.gov.au/sites/default/files/201213%20Audit%20Report%20No%2015.pdf?acsf_files_redirect; Defense Acquisition Management Information Retrieval, *P-8A Poseidon Multi-Mission Maritime Aircraft (P-8A) Selected Acquisition Report* (Washington, DC: DOD, 2018), page 30, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/19-F-1098_DOC_73_P-8A_SAR_Dec_2018.pdf; and "Average Prices for Boeing Aircraft as of January 2019, by Type," Statista, January 2019, https://www.statista.com/statistics/273941/prices-of-boeing-aircraft-by-type/.

74 The B-767F list price is from Richard Aboulafia, "Boeing 767/KC-46," Teal Group, August 2019, page 4. The A330-200F list price is from Richard Aboulafia, "Airbus Industrie A330," Teal group, June 2019, page 4. The B-777F list price is from Richard Aboulafia, "Boeing 777," Teal Group, June 2019, page 5. The B-747F list price from Richard Aboulafia, "Boeing 774," Teal Group, January 2020, page 4. With discounts from Boeing, the cost of a 767F could be about $85 million, a 777F could cost about $185 million, and a 747F could cost be between $190-225 million.

75 The cost to operate and support both aircraft over a 30-year period is assumed to be $600 million, both aircraft fly a single sortie per day, and carry an equivalent number of weapons per sortie holding effects created on targets constant. The $600 million estimate assumes 100 aircraft fleets are procured. For estimates of O&S costs based on aircraft fleet size, see Todd Harrison, *The Air Force of the Future: A Comparison of Alternative Force Structures* (Washington, DC: Center for Strategic and International Studies, 2019), page 10, https://csis-prod.s3.amazonaws.com/s3fs-public/publication/191029_Harrison_AirForceoftheFuture_WEB_v4.pdf.

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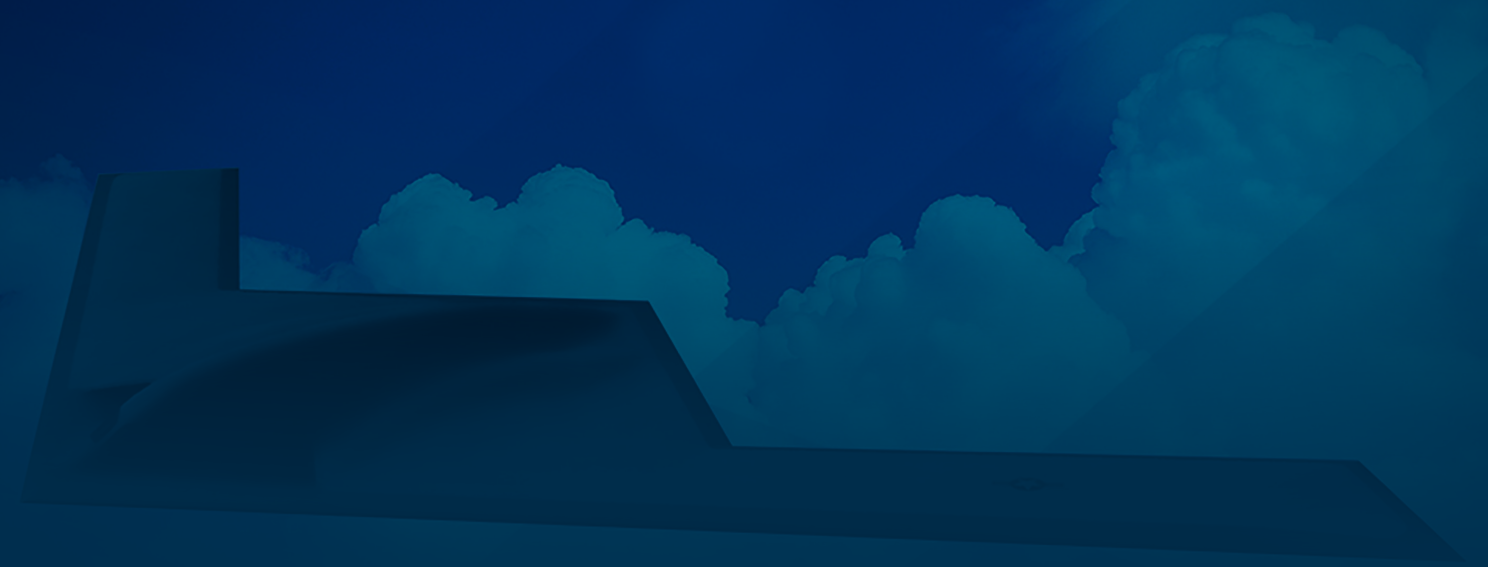

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