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HIGHER, HEAVIER, FARTHER, AND NOW UNDETECTABLE?

BOMBERS: LONG-RANGE FORCE PROJECTION IN THE 21ST CENTURY

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About the Defense Strategies and Assessments Program

The Defense Strategies and Assessments program focuses on the strategic choices and opportunities available to preserve and extend U.S. military advantage in the face of evolving security challenges. From assessing the past, present, and future security environments to exploring alternative operating concepts, force structures, and basing options to testing alternatives through innovative scenarios and war games, the program aims to be a hub of innovation and action.

TABLE OF CONTENTS

PREFACE

On Christmas Day in 1914, three former cross-channel packet ships, the *Engadine, Empress*, and *Riviera*, stood off the island of Heligoland in the North Sea. Under the watchful eye of the Royal Navy cruisers *Arethusa* and *Undaunted*, the three ships pulled back the tarps erected on their sterns and forecastles to reveal nine seaplanes. The aircraft – three Short Folders (Short was the company name; Folder was the model and denoted the aircraft's ability to fold its wings for storage), four Short 74s, and two Short 135s – were assembled and carefully lowered into the water. The Folders had a 67-foot wingspan, were powered by a 160-horsepower engine, and weighed 3,040 pounds fully loaded. The other two models were derivatives of the original Folder and had similar, if not exact, characteristics. Seven of the nine aircraft were able to get airborne (the other two were unable to break the dynamic tension of the water) and headed eastward carrying three 20-pound Hale bombs apiece, each of which contained 4.5 pounds of explosives within 13 pounds of steel guided by aluminum tail fins. Combined, the 21 bombs had less destructive power than one 13-inch shell fired from a British battleship, but these weapons could be taken directly to their targets and dropped precisely on top of them.

The seven aircraft flew on, searching for their target, the 600-foot-long zeppelin hangar at Nordholz. However, a thick fog shielded the building from view, forcing the aircraft to drop their bombs on the hangar's estimated position, with no effect. The aircraft then returned to their ships, landing nearly four hours after takeoff. The raid and several others that followed, ranging up and down the Belgian and German coastlines, were the products of the planning and thinking of Squadron Commander Charles R. Samson.

Samson sought targets that mattered: zeppelin sheds, railway stations, bridges, and submarine piers. Experience, however, began to reveal shortcomings in the British method of attack. Samson realized he could not go far enough to reach the really important targets nor was he carrying enough bombs that were large enough to have the desired effect.

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Nearly nine decades later, on October 8, 2001, two large black objects looking much more like spacecraft than strategic bombers took off from Whiteman Air Force Base, Missouri, near Kansas City, close to the geographic center of the continental United States. These huge tailless flying wings, known as B-2 Spirits or "stealth bombers," were to follow two other B-2s that had taken off the previous night to attack targets in Afghanistan. In total, six B-2 bombers would strike an enemy that thought itself safe in its sanctuary halfway around the world. The six B-2 missions were spread out across the first three nights of the operation, from October 7–9.[1] Afghanistan's Taliban government had not surrendered the terrorists located within its borders to face justice after the cowardly attacks of September 11, so the United States brought justice to Afghanistan. The primary mission of these stealth bombers, manned by two pilots each, was to sneak into enemy territory and attack airfields and air defenses to secure air superiority for the non-stealthy aircraft that would be carrying out subsequent attacks in the coming weeks.

The six bombers all headed west, for operational security reasons, on course to traverse the Pacific Ocean, past India, and then head north over the Indian Ocean toward their targets. The flight over the Pacific took 24 hours alone. Four refuelings from airborne tankers later, the aircraft crossed "feet dry" over Pakistan just as the sun set. On October 9, the second wave of two aircraft split up and conducted individual bomb runs on multiple targets throughout Afghanistan. During some bomb runs, the B-2 pilots used their onboard synthetic aperture radar to put eyes on targets to refine target coordinates before releasing their satellite-guided precision bombs or Joint Direct Attack Munitions (JDAMs). A combination of the B-2's stealth characteristics, endurance, and modern onboard sensors allowed the pilots to take their time while deep in enemy territory and methodically provide their own last-minute intelligence, surveillance, and reconnaissance (ISR) update to find, fix, and target any threats that had popped up or changed position since the bombers had taken off from the continental United States dozens of hours earlier. After spending about two hours over enemy territory prosecuting targets, the two crews exited the country and headed for the tankers waiting to provide the fuel for the last leg of the trip. A radio call came over secure communications from the Air Operations Center asking the crew of the B-2 aptly named *Spirit of America* to return to Afghanistan since it had four JDAMs remaining. The crew accepted the mission.

Low on fuel, the *Spirit of America* orbited over the Arabian Sea waiting for a tanker that would provide it the fuel needed for another trip into enemy territory. As the pilot flew behind the tanker while receiving fuel, the mission commander (the second pilot) programmed the new mission into the aircraft's computers. After another 90 minutes over Afghanistan, the crew exited the combat zone a second time to find a waiting tanker ready to provide the required fuel to reach the B-2's destination, the island of Diego Garcia in the Indian Ocean. Four hours later the *Spirit of America* touched down on the small island after being airborne for more than 44.3 hours, logging the longest combat mission in aviation history. For that crew the mission was over, but not for the *Spirit of America*. While the engines continued to run, the exhausted crew switched out with a pair of rested pilots. Maintenance personnel put oil into the running engines. Then, after the 45-minute pit stop, the new crews lifted the two bat-winged aircraft back into the sky for the 30-hour flight home to Missouri. In total, the *Spirit of America* and five other B-2s operated for more than 70 hours each over a three-night period, traversing the globe on those missions without stopping engines. Bombers had come a long way in 87 years, proving no enemy, no matter where it resided, was safe.[2]

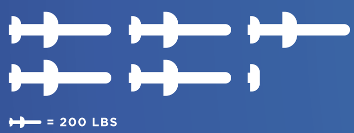
A combination of the B-2's stealth characteristics, endurance, and modern onboard sensors allowed the pilots to take their time while deep in enemy territory and methodically provide their own last-minute intelligence, surveillance, and reconnaissance.

As proved by this B-2 mission and many others, today's bombers can successfully strike targets anywhere in the world and hold a nation's enemies at risk in their own territory. Over time, bombers have developed and maintained this ability to operate deep in the enemy's heartland where other weapon systems could not reach. This unique capability derives from a combination of three critical traits all bombers must possess in some dynamic combination, which may alter within a single mission: range, payload, and the ability to penetrate enemy defenses. This paper will trace the origins of bombers, primarily U.S. heavy bombers, from the before the First World War to today. The authors will introduce the theory, doctrine, and technology behind their development, as well as the performance characteristics and trends that combined to provide ever-increasing range, payload (or volume of fires), and most importantly the ability to penetrate constantly improving defenses. To accomplish the mission, bombers would initially depend on self defense and then progress to a reliance on other defenses such as fighter escorts, increasing altitudes, supersonic speeds, low-altitude penetration to fly below enemy radar, and, eventually, stealth technology to avoid or minimize radar detection. Following the historical analysis, the paper will focus on what this means for the next-generation American bomber, the B-21, and why the United States should continue to invest in the bomber as a concept and a platform.

CHAPTER 01

THE HEAVY BOMBER AT ITS INCEPTION

PAYLOAD - 1,040 LBS



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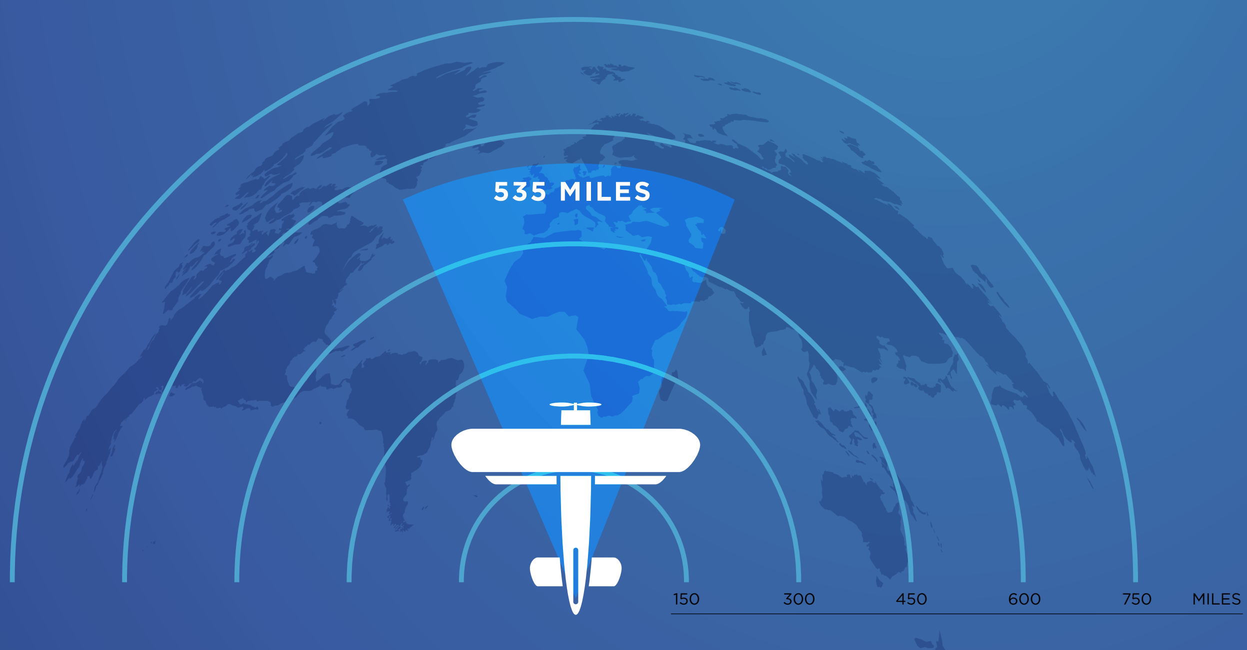

STRATEGIC RANGE

In the beginning, the challenge of flight was simply getting into the air and then landing safely again. The Wright brothers' 1903 achievement at Kitty Hawk was not just the first manned flight, but also doing it repeatedly, and living. In the years that followed, early aircraft, often no more than wooden frames with canvas-covered wings and far-from-reliable engines, claimed more than their fair share of early flyers, such as Army Lieutenant Thomas Selfridge, who crashed along with Orville Wright (who lived) during a demonstration flight at Fort Myer in September 1908. After initial issues with safety and reliability were addressed, the next challenge was carrying more weight, often in the form of passengers, and then attempting to go farther. During the 1908 tests, Wright had set records by flying first 62 minutes and then 74 minutes, all at speeds just in excess of 40 mph.[3] Only a few years later, another pilot, Cal Rogers, who had been trained to fly by Orville Wright, attempted to fly his Wright Flyer B model across the United States in less than 30 days. It took him 49 days, and shortly after arriving on the West Coast, while flying near Long Beach, he struck a flock of seagulls, crashed, broke his neck, and died. Range, speed, carrying capacity: All remained largely elusive in the first decades of the 20th century.[4]

The Others: Russian and German Initiatives

Commander Samson's home country of Great Britain was not the first nation to build a heavy bomber, nor even the second. Igor Sikorsky, whose name is now closely linked with the modern helicopter, had worked at the Russo-Baltic Railroad Factory as a design engineer. There, he conceived the world's first four-engine aircraft, the Russky Vitaz, in 1913. Built to be a heated passenger plane capable of carrying up to 16 people in relative comfort, the new aircraft, called the Ilya Mourometz (IM), first flew in December 1913, with one of its initial test flights flying 14.5 hours from St. Petersburg to Kiev. The aircraft had a large, 98-foot biplane wing configuration reinforced with heavy cables and struts, as well as three vertical tails for stability.

After the war commenced, Sikorsky worked with the Russian Ministry of War to convert the large aircraft into the world's first heavy bomber. Ten aircraft were ordered. They were built with defensive machine guns, and the passenger compartment was converted into a bomb bay capable of carrying 1,100 pounds of bombs. These first 10 aircraft became operational in December 1914. The aircraft's 300-mile range allowed it to strike key railroad yards and other transportation nodes. Used in groups, IMs were reportedly capable of "rendering enemy positions destroyed for weeks." The aircraft was known for its ability to absorb damage and keep fighting, and its configuration of defensive machine guns left German fighter pilots hesitant to tangle with it. Ultimately 85 of the aircraft were produced, and such was their worth that their ground crews had standing orders to burn the aircraft rather than have them fall into the hands of approaching German forces.[5]

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Germany was the font of much of the early thinking regarding strategic bombing. At the outset of hostilities, the German deputy chief of the naval staff argued that the navy's force of zeppelins, each armed with 2,200 pounds of bombs, should attack strategic British "cities, factory complexes, dockyards, harbor works with war and merchant ships lying therein, railroads, etc."[6] Germany had entered the war with two operating rigid-frame, lighter-than-air dirigible manufacturers, the Schutte-Lanz Co. and the Zeppelin Co. Both the German army and its navy had dirigibles in their inventories and they set out to use them. The army bombed the cities of Liege and Antwerp but suffered setbacks as anti-aircraft guns brought down three of their airships in the war's opening months. The German navy, suffering from a lack of cruisers in its inventory, co-opted its dirigibles to provide reconnaissance in the North Sea. Finally, in January 1915, nearly four months into the conflict, the kaiser granted permission to turn the naval airships against England. Attacks were conducted at an average rate of two per month, including strikes against London in May 1915. Britain attempted to mount a defense by launching aircraft to intercept the dirigibles, largely referred to as zeppelins due to their manufacturer, but these airships flew too high for the early aircraft to reach them. In

1916, the tide turned against the zeppelins, as British planes began carrying a mixture of explosive bullets to pierce the skin of the zeppelins and to set the gas inside afire. By the end of 1916 the Germans shifted to new Gotha aircraft to conduct strategic bombing raids. In total 115 dirigibles were manufactured and used during the war.[7]

Germany had been experimenting with aircraft throughout the opening decade of the 20th century. Just prior to the beginning of World War I (WWI), Oskar Ursinus, the editor of *Flugsport*, a magazine focused on flying, sketched out a large biplane with the unusual placement of the cockpit in line with the upper wing and the large twin engines placed close to each other near the centerline of the lower wing. This aircraft, the Gotha G.I, carried only machine guns, but its larger frame and longer range provided key options for designers. The Gotha models G.III and G.IV followed in 1915 and 1916. Their twin, 260-horsepower engines provided a three-man crew with a 370-mile range while carrying 2,200 pounds of ordnance on external racks in various combinations. With wings spanning 77 feet, the aircraft could climb to an altitude of nearly 15,000 feet and had a cruising speed of 75 mph.[8]

The Gothas took over from the zeppelins as the major strategic bombing asset for Germany in 1917, conducting 27 attacks against dockyards and the houses that surrounded them. While these attacks did cause damage and created a sense of panic in the populations directly affected, they did not seriously damage the morale of the British people writ large, as had been hoped.[9] However, the June 13, 1917, attack on London did create a stir. Fourteen Gothas, carrying 72 bombs, attacked the Liverpool Street Station in downtown London, killing 162 people in broad daylight. The British high command reacted by diverting two squadrons of pursuit fighters from their duties in France to protect the homeland while also taking the initial steps to create a bombing force under the command of Major General Hugh Trenchard to place the German homeland at risk.[10]

The British as First Movers

Trenchard came to aviation at the fairly advanced age of 40 after a career in the infantry. His previous professional experience provided him with a number of principles that both guided him and by extension the Royal Air Force (RAF), which he would lead for most of the next decade. First of all Trenchard believed that air power, like land power, should remain on the offensive and should act in mass, which is to say in large formations of aircraft performing simultaneously. While mass formations proved disastrous in the vast no-man's territories between the trenches, dominated as they were by the machine gun and the artillery pieces, in the fairly unconstrained environment of the air over the battlefield, Trenchard's ideas had merit.[12] Trenchard sought the opportunity to fly mass formations of aircraft carrying bombs against the enemy's vital centers in order to crush the opponent's will to fight, but to do this he first needed an aircraft capable of carrying the bomb loads he desired across long distances, and secondly, he ultimately needed the authority to dispatch a portion of the aircraft to fly independently against targets far behind the front lines where trench warfare raged.[13]

The beginning of what would become RAF's bomber force can be found in its original complement of bombers, the de Havilland DH-4 and the Handley Page 0/100. The DH-4 became the ubiquitous day bomber for the Allied forces. Powered by a strong 12-cylinder engine, each DH-4 could fly 230 miles carrying 460 pounds of bombs on under-wing racks at altitudes above 20,000 feet. Its powerful Rolls-Royce engine could generate top speeds of 140 mph, allowing the DH-4 to outrun most pursuit fighters.[14] Targeting was initially accomplished by the pilot by looking through a bombsight set into the floorboards that was calibrated for different altitudes and airspeeds. Pilots soon found that the bombsight was often obscured by leaking engine oil running along the bottom of the aircraft and that releasing the bombs at 15,000 feet just when the target disappeared under the leading edge of the lower wing worked just as well, especially when several planes dropped their loads together in formation in a manner that soon became known as "flock bombing."[15]

Such formations, the precursors for later mass bombing runs, became standard for DH-4 squadrons. Based upon the experience of the observer/gunners, the aircraft were arranged in flight to enable the observers, acting together as a group, to scan the skies around them in a disciplined manner, looking for approaching enemy aircraft. Consideration was also given to assigning sectors of fire for the gunners so as to avoid shooting a friendly aircraft in the formation. Lastly, the formation design also maximized the chance of hitting the intended bombing target as the aircraft all released their bombs together. With these considerations in mind, the six aircraft took off together with the flight leader taking a center-front position. The second and third aircraft held positions to the left and right of their leader, and just slightly above and behind him. Planes four, five, and six formed a "V" below and still farther behind the leader. This positioning provided a balance between the desire of the observer/gunners to have a clear view of the sky to detect and attack approaching enemy fighters and presenting a compact formation to allow for effective combat bombing once over the target. However, pilots and observers reported that maintaining tight formation positions during five-hour missions was both mentally and physically exhausting.[16]

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The Handley Page 0/100 had no real need to fly in formation; it was a flying battleship on its own. Crewed by a pilot and an observer/gunner, the bombers were called the "bloody paralyzer" by the director of the Admiralty's Air Department. The 0/100 bomber was conceived after a requirements document was issued at the very end of 1914 calling for manufacturers to build a land-based, twin-engine plane that could climb to 3,000 feet, cruise at 72 mph, have a tactical range of just over 300 miles, and carry six 112-pound bombs. Handley Page responded with a design that had a 114-foot wingspan and was powered by two 250-horsepower engines. Hence, the 0/100 was designed from the ground up as the first true bomber. It carried its ordnance inside an enclosed cell, mounted on top of movable crossbeams. To drop its bombs, the observer would look down on the ground through a primitive bombsight that was little more than a crosshair with some horizontal range lines to account for altitude and airspeed variations. When over the target, the observer would pull a wooden lever to release the aircraft's bombs either singularly or all at once.[17]

After the 1915 and early 1916 London bombing raids by German airships, Britain began to formulate the first truly strategic bombing plan utilizing the "bloody paralyzer." Targeting "root industries" as well as the morale of the German population by attacking population centers, British air-power leaders began to plan even as they fought.[18] Two 0/100s attacked a railway junction at Arnaville. A few days later they attacked industrial furnaces and an enemy airfield. In their first four operational flights between March and April the two new bombers dropped as many bombs by weight as 21 single-engine bombers had during the previous two months. What's more, the British flyers armed with the new 0/100s continued to see the effectiveness of flock bombing.

Often, significant targets had to be struck more than once. In January 1917, 10 bombers accompanied by six escort aircraft struck the Saarbrucken ironworks. A month later 13 bombers revisited the factory. A few weeks after that, in early March, 10 bombers returned, and they were in turn followed by 6 bombers at the end of the month. In total, bombers dropped 10,140 pounds of ordnance on the blast furnaces at Saarbrucken, largely with no effect as most of the bombs fell outside the boundaries of the factory's complex.[19] Industrial facilities were not the only targets. On March 16, a military attack upon the town of Freiburg was conducted in retaliation for a German submarine attack on two Allied hospital ships. This last attack leveraged the theory that strikes against German civilian targets would force the German high command to withdraw fighter aircraft from the front lines to defend the cities against the new attacks, something that never actually happened.[20] In fact, the high losses of French and British aircraft to ground fire and attacks from enemy aircraft during the "Bloody April" of 1917 led to the withdrawal of Allied bombing aircraft for service elsewhere – not the withdrawal of German fighters, as the Allies hoped.

After the devastating German Gotha bomber attacks on London in June and July of 1917, British Prime Minister David Lloyd George directed Field Marshal Jan Christiaan Smuts, a soldier and statesman of great repute from South Africa, to form a committee to look into the question of home defense.[21] The Smuts committee report has come to be known as "The Magna Carta of British Air Power." The Smuts report recommended improving the air defenses around London but then went on to suggest combining the army's Royal Flying Corps and the Royal Navy Air Service into one independent military unit. In addition, the committee recommended that an Air Ministry be established in line with the War Ministry and the Admiralty.[22] The Smuts report included a visionary statement:

> … an air fleet can conduct extensive operations far from, and independently of, both Army and Navy … the day may not be far off when aerial operations, with their devastation of enemy lands and destruction industrial and populous centres [sic] on a vast scale, may become the principal operations of war, to which the older forms of military and naval operations may become secondary and subordinate.[23]

In September 1917, Major Hardinge Giffard, Lord Tiverton, of the Royal Naval Air Service, presented an overarching strategic bombing plan to the Air Board that advocated hitting chemical factories, machine shops and steelworks. Lord Tiverton believed that such attacks would not only undermine Germany's military capabilities by interdicting the supply of weapons, but would also exert a tremendous negative psychological blow against the German population.[24] In October 1917 Britain's War Cabinet decided to begin attacking German towns, with a focus on targeting "root industries" that supplied the components for explosives, propellants, and poison gas.[25] The Royal Flying Corps No. 41 Wing was assigned this mission, and soon was expanded to become the Royal Flying Corps' No. VIII Brigade, and ultimately evolved to become the Independent Bombing Force of the newly created Royal Air Force in June 1918.[26] Under the command of Trenchard, the Independent Bombing Force, stationed in Nancy, France, had the objective of carrying out a strategic bombing campaign deep inside of Germany's lines.[27]

The No. 41 Wing in October 1917 had but three squadrons: Nos. 55, 16, and 100. The 55 Squadron was equipped with DH-4 (soon to be DH-9) aircraft and flew high-altitude, formation, daytime bombing missions, while the 16 (soon renumbered as the 216) Squadron and 100 Squadron ultimately flew the Handley Page 0/400 (an updated version of the 0/100) on low-altitude, single-aircraft, night-mission profiles. By the spring, when the force was renamed the Royal Air Force, the Independent Bombing Force boasted four day- and five night-bombing squadrons. The day bombers, by now equipped with DH-9s, lacked both range and altitude capabilities to be effective against Germany, but the night bombing elements, equipped with the 0/400, were up to the task.[28]

The 0/400, powered by a more powerful 360-horsepower Rolls-Royce engine, was an evolutionary advancement over the 0/100. Additional fuel capacity allowed it to fly a longer mission at an altitude of 8,500 feet. Its chief tactical advantage was its ability to carry 2,000 pounds of ordnance, including the new 1,650-pound bomb, dropped using the new Drift Sight Mk 1A bombsight, which corrected for the effect of wind upon a bomb's falling trajectory.[29] Flown at night in relative safety and in formations of up to 40 aircraft, these new bombers produced a degree of devastation on their targets that had not been seen before.[30]

Low-level, night bombing missions took on a character all their own. Possessing no more than a rudimentary compass for instrumentation, the crews largely guided themselves by landmarks: roads, railroads, and towns. The crews studied their maps and knew their routes well – so well, in fact, that one crewman remarked, "I got so used to it that I could almost go to sleep and wake up and tell you where I was in a few seconds, provided the visibility was right." In the fall of 1917 the 0/400s took part in an ongoing campaign against the Burbach Works at Saarbrucken. While the works themselves suffered only minimal damage, the surrounding areas experienced the torment of nightly bombing for weeks.[31]

A great account of the bombing techniques developed by the community of 0/400 pilots and perhaps the first appearance of "stealth" as a desired characteristic of the bomber force centers on the attack against the Badische Works near Mannheim in the late summer of 1918. The Hanley Page 0/400 bombers made most of their attacks at night in an attempt to avoid detection and targeting by enemy pursuit fighters or ground artillery. Germany took the additional step of setting up pickets around the high-value industrial site that listened for the sound of the large engines of the approaching heavy bombers and then swung bright searchlights to illuminate the targets for gun crews.

On the night of August 25, 1918, two 0/400s took off, with the first flying near Mannheim at 5,000 feet to draw the attention of searchlight and gun crews. Meanwhile, the pilot of the second 0/400 diverted from the target by a distance of four miles, then turned, and, in an attempt to avoid detection and approach its target stealthily, cut his engines in order to arrive silently over the target in a glide at a safe altitude of 1,000 feet before dropping the plane's bombs. The planes approached Mannheim as planned, but the second aircraft, piloted by Lieutenant MC Purvis Lawson, cut its engines too soon, bringing the large bomber silently over its target at 200 feet. A German searchlight crew, tardily swinging in a panic to catch the silent aircraft in its beam, fortunately illuminated a church steeple just ahead of the Handley Page bomber. Lawson gunned his engine, maneuvered, and remained over the area for the next seven minutes dropping bombs and strafing the area, expending 1,100 rounds. The works were degraded for the next three weeks.

For a time, night bombing runs such as these were safer and more effective than the day bombing operations of the DH-4s and DH-9s, but the bombing community continuously sought to innovate, to be more effective even as it focused on becoming safer. A serious debate occurred between those who wanted to strike specific industrial targets and those who wanted to indiscriminately bomb as a tool of psychological warfare against enemy civilian populations. As it was, the war for the Independent Bombing Force wound down throughout the fall of 1918 as the weather worsened, obscuring targets and grounding aircraft, while armistice negotiation reached its ends in November. As WWI ended, the characteristics of longer range, larger bomb loads, formation flying, and the pursuit of stealthy ways to approach the target were already embedded in the concept of the heavy bomber.[32]

Toward the end of the war, Britain's leadership evidenced a desire to strike Berlin, the capital of Germany, in much the same manner as Germany had hit London. The ability to take the fight directly to the enemy capital and to its leadership appealed to both sides. Handley Page was tasked to create yet another bomber as a natural evolution of its 0/100 and 0/400 aircraft. The 0/1500 flew its first test flight in May 1918. With a 126-foot wingspan and four Rolls-Royce 375 Eagle VIII engines, it was capable of carrying 30 250-pound bombs or even a single 3,300-pound bomb designed uniquely for the 0/1500 aircraft. The 0/1500 reached 99 mph and an altitude of 11,000 feet and had a combat range of 1,300 miles, enough to reach Berlin. The aircraft did not reach the Royal Air Force in time to participate in "the Great War," but a 0/1500 operating from a base in India did strike the royal palace of Amanullah Khan in Kabul, Afghanistan, in May 1919, bringing a swift end to an insurrection there, validating the British theory.[33]

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The Americans, Second Movement, and the Interwar Era

The United States had been late to join "the Great War," not entering until April 6, 1917. Still, from an aviation standpoint, Americans had been flying alongside European Allies as volunteers for years, most notably within the Lafayette Escadrille and the Lafayette Flying Corps. These flyers helped to form the backbone of newly commissioned American squadrons in 1917. Forty-five such squadrons were activated under the command of Brigadier General (temporary) William "Billy" Mitchell, and all made use of European aircraft, such was the sorry state of the American aviation industry at the time. Seven of the squadrons were designated as bombing squadrons and were equipped with either DH-4s or the French Breguet Br14B2, otherwise known as the "B2." Mitchell and his squadrons were assigned roles in support of ground forces, including the bombers, although there were plans to detach an element of the American aviation forces to the Independent Bombing Force in late 1918. The signing of the armistice brought a halt to this initiative.[34] While Trenchard and Lord Tiverton may have laid the initial foundations of air-power theory, massed formations of aircraft carrying large loads of bombs against vital industrial and psychological centers of power, it would be Mitchell and the Italian theorist General Giulio Douhet who provided depth, clarity, and coherence to air-power theory during the interwar period of the 1920s and 1930s.

Douhet's *The Command of the Air*, first published in 1921, observed that the space above the battleground was so vast as to be uncontrollable. While fighter aircraft

The DH-4 was the first aircraft the United States used for the purpose of bombing. (U.S. Air Force/Flickr)

Brigadier General Billy Mitchell was an outspoken advocate for the creation of an independent Air Force. (NDU/Flickr)

could provide some measure of local defensive control (fighters were only defensive platforms in Douhet and Mitchell's strategic constructs), reconnaissance aircraft would be able to penetrate and overfly enemy positions, and bombers, especially massed formations of bombers, would always be able to reach their targets. Douhet took pains to point out that the initial targets of any bombing campaign should always be the enemy's airfields, with priority assigned to those fields that supported pursuit fighters who could pose a threat to the bombers. Once those were eliminated, the battle, and even the war, was essentially won.[35] Mitchell evangelized along a similar line of strategy, but his interwar-era story began with more "practical" demonstrations of air power.

Mitchell had returned from Europe in early 1919 to take up a frustrating position as the deputy of the Army Air Service behind the leadership of an artilleryman, Major General Charles Menoher. Mitchell immediately began to advocate on behalf of aviation, arguing that aircraft would assume the leading role in warfare, rendering both the Army and the Navy obsolete. He proposed the creation of an independent Air Force within the U.S. military. Mitchell's immediate aim in the early 1920s was to demonstrate the vulnerability of Navy ships, specifically the battleship, to aerial attack. He sought and received permission to participate in a joint Navy-Army Air Service test in which a captured German battleship, the *Ostfriesland*, along with some other ships of smaller size, were bombed in July 1921. Flying British Handley Page 0/400 bombers as well as American Martin NBS-1 bombers, the Navy and Army Air Service crews made numerous approaches on the ships while dropping bombs of varying size that sunk the smaller destroyer and cruiser vessels while leaving the *Ostfriesland* lower in the water due to small ruptures in the hull. However, on July 21, 1921, with Mitchell observing from his own DH-4 orbiting overhead, Captain Walter R. Lawson led a flight of bombers that dropped four 2,000-pound bombs. While none hit the ship directly, landing instead close aboard, they nevertheless raised the ship up out of the water and then capsized it when the underwater hydrostatic forces of the large explosions ruptured its hull.

Mitchell was convinced that these tests demonstrated and definitively validated his argument that the heavy bomber should be accorded its place as the principal capital weapon of war, supplanting land formations and naval battleships. He began to publish a series of articles as well as publicly speak about the supremacy of air power, to the increasing consternation of his superiors. In 1925 he published his compiled essays in a book, *Winged Defense*, which described an independent Air Force composed of bombers, pursuit aircraft, and observation aircraft, with the long-range heavy bomber being the primary weapon.[36]

Even as Mitchell was carrying on his crusade for military aviation, aircraft manufacturing became a radically innovative sector of the American economy during the interwar period. Nearly every aviation company had a bomber design and the Army and the Navy were interested customers, to a certain extent. It was an era of many prototypes but few large production runs. The Huff-Daland Aero Co. (eventually renamed the Keystone Aircraft Co.) produced a series of prototypes that featured a common open cockpit airframe while differing in the engines used in each iteration as well as some modifications to the wings and tail construction. LB-1 had a single Packard engine, tapered wings spanning 66 feet and a single tail assembly. The LB-1 had a ceiling of 11,000 feet, cruised

The success of Billy Mitchell's Army-Navy tests validated his argument that the heavy bomber should be accorded its place as the principal capital weapon of war. Flying British Handley Page 0/400 bombers as well as American Martin NBS-1 bombers, the Navy and Army Air Service crews made numerous approaches on the target ships while dropping bombs of varying size. (Air Force/Flickr) at 105 mph, and could carry 2,750 pounds of bombs 215 miles. The LB-3 progressed to two Liberty engines mounted upon the lower biplane wings. LB-5s incorporated twin tails to improve stability and maneuverability in flight, and LB-6 came with straight corded wing and two Wright Cyclone engines suspended between the bi-wings rather than resting upon the lower one. The evolution of the airframe meant that the range of the LB-6 design improved modestly to 315 miles while carrying its bomb load. The LB series was manned by a crew of five: a pilot, co-pilot, bombardier, and front and rear gunners. Between 1927 and 1934 Huff-Daland/Keystone built over 140 bombers of various types for the Army Air Corps before being superseded by the Martin B-10.[37]

Martin Aircraft, founded by aviation pioneer Glenn Martin in 1912, had been successful in selling bomber aircraft to a number of customers both inside and outside of the United States during WWI and the years that followed. However, by the late 1920s the company was struggling to land a large-scale production contract. With its own resources, the company designed and built a prototype, Martin 123, with the hope of luring an Army contract. The aircraft began its trials at Wright Field in July 1932.

The Martin 123 was a breakthrough design featuring three enclosed crew positions. Its low-drag, twin-cowled Cyclone engines, mounted within the two shoulder-mounted wings, allowed for an unencumbered internal bomb bay capable of carrying 2,200 pounds of bombs 300 miles. The prototype could reach an unheard-of 197 mph at 6,000 feet and had a top service ceiling of 21,000 feet. The prototype was modified shortly after its initial flights to carry a gun turret in the nose canopy area, its engines were upgraded from two 675-horsepower R-1820-19s to two 775-horsepower R-1820-33s, raising both the maximum speed and the combat radius to 213 mph and 620 miles respectively. The aircraft, designated the B-10, carried a crew of four: a nose gunner/bombardier, a pilot, a rear gunner, and a crew member who worked inside the fuselage. With its all-metal construction, enclosed crew stations and bomb bay, cowled engines, and, lastly, the new Mk15 Norden bombsight, the aircraft rendered all previous American bombers obsolete.[38]

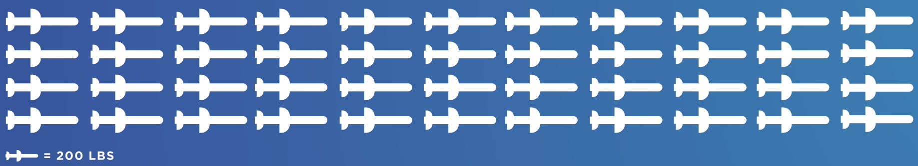
> **Mitchell's 1925 book *Winged Defense* described an independent Air Force composed of bombers, pursuit aircraft, and observation aircraft, with the long-range heavy bomber being the primary weapon.**

Yet, the pace of aviation advancement during the 1930s soon outpaced even the B-10. Aircraft, engine, and weapons designs all made dramatic leaps in that decade. In 1934, the Army issued a request for aircraft designs that could meet three criteria that were representative of the important characteristics that emerged during WWI. The Army wanted an aircraft that could carry 2,000 pounds of bombs to a range no less than 1,020 miles at speeds of at least 200 mph (250 mph if possible).[39] Several companies began designing an aircraft to meet these requirements of payload, range, and speed that would both signal and define the next age of heavy-bomber development.

CHAPTER 02

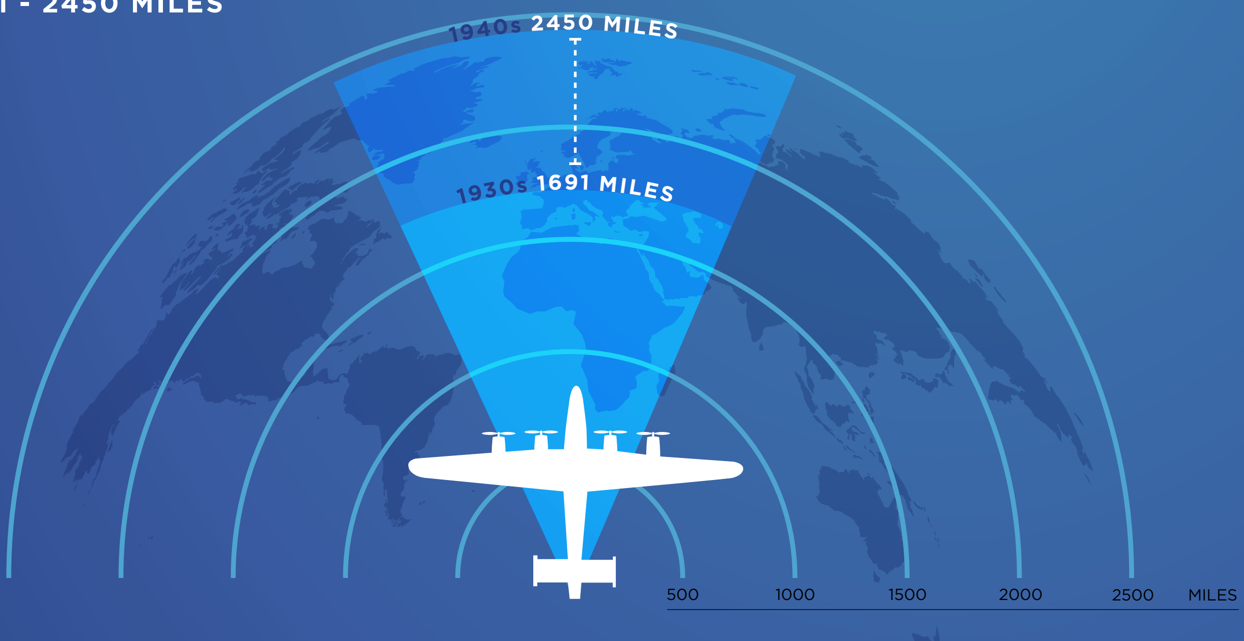
THE BOMBER TAKES CENTER STAGE

PAYLOAD - 8,800 LBS



1930
-1940

1691 - 2450 MILES



STRATEGIC RANGE

The all-metal, monoplane Martin B-10 gave credence to the long-held held belief of many early air-power theorists that the bomber would always get through enemy air defenses. (Air Force/Flickr)

The advancements in aircraft design during the late 1920s and 1930s progressed in parallel with innovation in the corresponding theory for how to employ bombers. The U.S. Army Air Corps opened a school, Air Corps Tactical School (ACTS), in 1920, originally designed to train air-power leaders in the use of aircraft based on WWI experience. But with the evolution of "bomber theory" toward offensive operations, the school increasingly focused on developing an air doctrine for future wars. As the doctrine began to gain traction, the school's cadre even had a say in setting the aircraft specifications for future acquisitions.[40] By 1931, ACTS had already started to draft its influential strategic bombing theory. The theory focused efforts on directly bombing the enemy's "vital centers" rather than destroying the opposing ground army, circumventing the traditional front lines to attack the enemy's morale and ability to wage war by destroying the fragile web of interconnected services, industries, and lines of communication necessary to sustain a country's war effort. The targets would consist of transportation networks, factories, oil and electric supplies, communications installations, and raw material stocks and stores, all critical for both a war effort and daily civilian life. Of course, the only military platforms that could execute such strikes into the enemy's heartland were heavy bombers with large payloads, ranging extremely long distances, penetrating enemy defenses, and operating largely independent from the Army or Navy.[41] Thus began the emergence of the unique skill set provided by heavy bombers. Their use could effectively move the fight beyond the front lines to decision makers residing in national capitals. While at this point it was not overtly stated, the planners did make it known they wanted to take the war directly to a nation's industrial complex and civilian population to affect the enemy's warfighting capability and civilian morale with a goal to eventually affect the enemy's leadership and its decisions.

The Theoretical Framework

Air power theory produced defense contracts in the 1930s that centered on a modern heavy bomber like the previously mentioned B-10. Advances in low-wing monoplane designs led to huge advances in speed, range, and payload. These technical advances also gave credence to the long-held belief of many early air-power theorists that the bomber would always get through enemy air defenses. The all-metal, monoplane Martin

B-10 became the standard Air Corps bomber of the mid-1930s, with a speed more than 200 mph. In 1934, then-Lieutenant Colonel Henry H. "Hap" Arnold led a squadron of B-10s from Washington, D.C., to Alaska and back, demonstrating the incredible range and potential of the new generation of bombers. The focus on high-flying, long-range heavy bombers in the early 1930s led to some very dangerous assumptions about the next generation of bombers. For instance, B-10s consistently outflew the best Air Corps fighter of the time, the Boeing P-26, also an all-metal monoplane. These fighters could not match the speed or stay aloft long enough to challenge or even find the B-10s. The disparity was so extreme that after viewing maneuvers in 1933, Brigadier General Oscar Westover, then assistant chief of the Air Corps, wanted to eliminate fighter aircraft entirely from the Army inventory because they could not intercept bombers.[42] The bombers continued to prove themselves unstoppable. The perceived gap would only widen with the next bomber development, the iconic Boeing B-17, Flying Fortress.

> **The planners wanted to take the war directly to a nation's industrial complex and civilian population to affect the enemy's warfighting capability and civilian morale with a goal to eventually affect the enemy's leadership and its decisions.**

Europe, the B-17, and the B-24: Range and Self Defense

The four-engine B-17 competed against the B-18 for the next heavy-bomber contract in August 1935. The Douglas B-18 was derived from the boxy DC-2 commercial transport, with similar wings and engines. While size (89-foot wingspan and 57-foot length) and performance provided improvements over the B-10, its two engines only provided a cruising speed of 167 mph and a service ceiling of 23,900 feet. The B-17 was clearly superior to the twin engine B-18 as it could fly faster and 7,000 feet higher than its competitor.[43] Both aircraft had twice the range of their B-10 predecessor. Unfortunately, pilot error led to the loss of the sole B-17 prototype before it had been fully tested, and the B-18 won the contract by default. The Army leadership clearly realized the B-17's potential and purchased a handful of aircraft for test and evaluation, and eventually the B-17 became the Army's front-line bomber by the late 1930s.[44] As a result, the B-18 served primarily as an anti-submarine and trainer aircraft during World War II (WWII). The B-17's sleek aerodynamic design, four engines, and 103-foot wingspan helped provide it with superior performance that made it the premier American heavy bomber. Westover, by this time the chief of the Air Corps, considered the B-17 "the most outstanding airplane development of modern times."[45] The Air Corps finally had the bomber with the speed, altitude, range, and payload necessary to carry out strategic bombing on a large scale, and WWII would provide the opportunity to test proponents' theories.

By the winter of 1938 the Air Corps possessed only a handful of B-17s, but the Munich crisis of September

The B-17's sleek aerodynamic design, four engines, and 103-foot wingspan helped provide it with superior performance that made it America's front-line bomber. (Air Force/Flickr)

1938, wherein the European powers acquiesced to Adolf Hitler's demands over the Sudetenland border region of Czechoslovakia, transformed the international environment and stimulated President Franklin D. Roosevelt to dramatically expand and accelerate American rearmament. He appointed an Air Board in March 1939 to investigate procurement. The board ruled strongly in favor of heavy bombers, and in particular the B-17. The B-17 was so impressive that it almost single-handedly made converts to the theory of air power and the importance of the heavy bomber in future wars. In the space of one year, 1939, the nation embraced the theory, made massive investments, and even decided on a future bomber. Production of B-17s was immediately accelerated, and specifications for a new B-29 "super bomber" with a range of over 4,000 miles were simultaneously issued.[46]

As America prepared for the possibility of war, plans were drawn up that emphasized the value of the heavy bomber, emphasizing the criticality of attacking the enemy's air force to neutralize it as a vital condition to enable successful follow-on attacks upon the adversary's critical infrastructure – fuel, oil, electrical power, and transportation. To effectively hold these critical target sets in the enemy heartland at risk, the plan selected a high-altitude daylight precision bombing profile, a mission that only high-flying heavy bombers could do. The initial plans called for the production of tens of thousands of combat aircraft to include over 11,800 heavy bombers.[47] The United States would eventually produce 30,865 B-17s and B-24s and 3,700 of the larger B-29 heavy bomber by the end of the war.[48]

Although today, from a historical perspective, the B-17 attracts most analytical scrutiny when it comes to American heavy bombers in the European theater, the B-24 outperformed it in many ways. The Consolidated B-24 Liberator was established as a kind of "running

Eaker believed that the top-secret Norden bombsight combined with tight formations would provide American B-17s and B-24s with unprecedented accuracy, not yet experienced by either side.

By 1944, the United States had produced 18,188 B-24s, making the B-24 the most-produced aircraft in American history. (Air Force/Flickr) mate" for the B-17, not its replacement, although it fulfilled most of the same missions, since the United States needed every bomber it could produce. In January 1939, Arnold, by then a general, asked Consolidated to build a heavy bomber with a speed more than 300 mph, a ceiling of at least 35,000 feet, and a range of 3,000 miles. Consolidated used many innovative design features to create the Liberator. First, it adopted the new "Davis airfoil" wing design with a very efficient high-aspect ratio and new retractable "Fowler Fowler flaps" that combined to allow for a very thin and narrow wing that was light and aerodynamically efficient.[49] The new wing design gave the B-24 the same payload capacity as the B-17, but with a much greater speed of 300 mph and a range that was as much as 600 miles farther than that of the B-17. It also employed four engines, tricycle landing gear, and a steerable nose wheel instead of the B-17's tail wheel for ease of ground handling and shorter takeoff distances. Although much maligned by some historians when compared with the B-17 in durability, the B-24 proved itself in all theaters of operations, and the 8th Air Force statistics in the European theater show that the Liberator was more resilient than the B-17 (B-17 operational losses being 15.2 percent compared with the B-24 at 13.3 percent).[50] By 1944, the United States had produced 12,677 B-17s and 18,188 B-24s.[51] This made the B-24 the most-produced aircraft in American history.[52]

As the American formations grew and ventured farther afield from their short-range fighter escorts, the vulnerability of the American bombers and their tactics became painfully clear. Fighter technology had indeed caught up with that of the B-17s and B-24s.

Although heavy bombers and the same basic U.S. bombardment theory were used in both the European and Pacific theaters during the war, each theater ended the war with a unique way of using its bombers. The lack of Allied military options during 1942 made strategic bombing the primary method for keeping pressure on the Germans. The Royal Air Force had been bombing continental Europe since the early days of the war. The RAF possessed a respectable fleet of heavy bombers and had initially tried bombing industrial and transportation targets during the day but quickly discovered that the heavy losses were unsustainable. The RAF also found that it was not able to carry out the attacks with the precision necessary. The Germans developed radar stations of their own and were very effective at intercepting the lightly armed RAF bombers. The RAF transitioned to night area bombing simply because the force did not have the technology or the ability to do anything else.

When the first commander of the American 8th Air Force, Brigadier General Ira C. Eaker, arrived in England, the RAF immediately tried to persuade him to join its night campaign. Eaker and the other American airmen were not swayed by the RAF's combat experience and stuck to their plan for daylight precision bombing. They were convinced that they could succeed where the British had failed because their B-17s and B-24s, with higher-caliber guns and more of them serving as defensive armament, would fly in tight, mutually supportive formations that would keep enemy fighters at bay. Eaker also believed that the top-secret Norden bombsight combined with tight formations would provide them with unprecedented accuracy, not yet experienced by either side.

The American bombing campaign was slow to start. It would take months to build sufficient heavy-bomber airframes and train the crews to carry out the massed bombing missions. The initial small number of bombers available did not allow for the large formations the American bombers needed for self defense. As a result, the first missions against continental Europe were against closer targets in France where the bombers could be escorted by scores of short-range British Spitfires for protection. Most importantly, the Americans were not able to attack Germany and concentrate on their first priority, the Luftwaffe, until January 1943.[53]

Eaker accompanied the B-17s on their first significant raid in Europe on August 17, 1942, when he dispatched 23 B-17s against the locomotive repair shops in Rouen, France (in part to quell the public reservations about America's daylight bombing by its ally the RAF and the British press). Colonel Frank Armstrong led the mission with his co-pilot, Major Paul W. Tibbets, who would earn enduring fame three years later for dropping the first atomic bomb on Japan, in his B-29 the *Enola Gay*. The departure was watched by many dignitaries as well as members of the press. Flying at 23,000 feet over the English Channel, a diversionary flight of 12 B-17s turned back before crossing into France, keeping the German fighters busy. The other two flights of B-17s, six and five aircraft respectively, took a separate route, rendezvoused with their Spitfire escorts and proceeded to Rouen, 87 miles northwest of Paris. The weather was good, the anti-aircraft artillery (AAA) was light, and they easily found the target. The B-17s unloaded 36,900 pounds of bombs, as Eaker peered down from the bomb bay of his aircraft. As he watched the explosions, he considered the bombing encouraging for a first try, "with about half of the bombs in the target area." He was excited for the prospect of huge formations doing the same thing.[54]

As the American formations grew and ventured farther afield from their short-range fighter escorts, the vulnerability of the American bombers and their tactics became painfully clear. Fighter technology had indeed caught up with that of the B-17s and B-24s. The high-flying and faster fighters were guided to the large bomber formations by radar operators, and while the large formations could provide some protection, they were by no means impregnable. The Luftwaffe quickly identified weaknesses in the protective armament of the B-17s and B-24s and their formations. The Germans would attack the formations head-on and would concentrate AAA around their high-value targets to break up the tight formations. The Americans would counter by putting more guns in the nose of the bombers and by changing the formation sizes and shapes continually throughout the war, but it eventually became apparent that the small tactical changes would not provide the self-protection the American strategy required. The unescorted bombers were finding it difficult to penetrate enemy defenses day after day without sustaining unacceptable loses.

American bomber legend Curtis LeMay, a colonel commanding a bombardment group in 1943, arranged his bombers into aerial combat boxes of 18 to 21 heavy bombers each, with two or three combat boxes forming groups stacked in flight creating overlapping fields of defensive fire.[55] These huge formations of up to 60 aircraft would fly in streams of hundreds of bombers, which would simultaneously drop their payloads on one target. Despite the large bomber numbers, the tactic proposed by LeMay lacked the results desired. The Norden bombsight did not provide the promised accuracy and despite the large formations, targets would have to be struck several times to get the job done. Although it seemed that the bomber formation was always able to get through to the target and back home, more and more of the individual aircraft and crews were not. The attrition among the self-defending American bombers became unsustainable.

The attrition among the self-defending American bombers became unsustainable.

The Blitz Week attacks carried out July 24–30, 1943, highlighted the vulnerability of the B-17s and B-24s without proper fighter escort. Orchestrated by Eaker, the Blitz Week attacks were the largest yet, with more than 1,000 bomber sorties flown against 15 industrial and military targets in Germany. Although the new longer-range P-47 fighters now had drop tanks that provided greater fuel range, they still could not escort the bombers all the way to their targets. Without sufficient fighter protection the heavy bomber continued to be difficult to defend. In all, during the summer of '43, the United States lost five bombers for every 100 it launched.[56] Something had to change.

The Americans did stick to high-altitude daylight precision bombing, thus making large contributions in Europe, but only after changes were made. The Air Corps leadership realized early in 1943 that the concept of self-defending bombers was not sustainable. Soon, great numbers of capable long-range fighters with increased fuel and range, due to drop tanks, were arriving in Europe. The three fighters that helped turn the tide were the twin-engine P-38 Lightning, the rugged P-47 Thunderbolt, and the real game changer, the P-51 Mustang. All three were capable of longer ranges than the previously used Spitfires and could carry drop tanks to lengthen their ranges. The P-38 contributed in Europe but is perhaps best known for wreaking havoc on the Japanese in the Pacific, where it was flown by America's all-time ace, Richard I. Bong, who downed 40 enemy aircraft. The P-47 was an excellent fighter-bomber that flew over 423,000 sorties, nearly double the number of the P-51, while destroying 6,284 enemy aircraft, 3,202 on the ground. The Thunderbolt's rugged frame withstood enormous battle damage; its loss rate was as low as 0.7 percent, while the Mustang's stood at 1.2 percent. Despite its apparent vulnerability, the P-51 was the difference maker. The Mustang was an American design with a near-miraculous Rolls-Royce Merlin 61, 12-cylinder engine. Unlike the P-38 and P-47 that could escort the bombers on some missions, the P-51 could go anywhere with the B-17s and B-24s. It had an amazing service ceiling of 42,000 feet and attained an unmatched 441 mph at 30,000 feet. The piston-engine fighters of the Luftwaffe could not match it above 20,000 feet, and the P-51 was "credited with destroying over 9,000 enemy aircraft, 4,950 in aerial combat." Several of those aircraft were models of the world's first jet fighter, the vaunted Messerschmitt Me 262, encountered after mid-1944.[57]

Arnold, now the overall Air Corps commander, made a leadership change that would allow him to take advantage of those fighters. Before the change, Eaker kept the fighters tied to the bombers in an escort role; this limited the fighters' ability to take the initiative against German fighters. When Arnold replaced Eaker with Lieutenant General "Jimmy" Doolittle, he found a commander who would take the fight directly to the Luftwaffe. He "freed" the fighters by reversing the practice of keeping them within 100 feet of bombers until the formations were attacked. He ordered the fighters to not only protect the bombers, but go after the German fighters. With this newfound freedom, the P-51s, P-38s, and P-47s broke up the German fighter formations before they could attack, fought them wherever they found them, and even followed them home to attack them on the ground.[58] The changes implemented by Doolittle proved impactful. By D-Day, June 6, 1944, it could truly be said that the Allies had won air superiority through a combination of bombing attacks by heavy bombers and the addition of long-range fighter aircraft.

The large payloads and massed fires provided by the B-17s and B-24s that made the bombers so powerful were also coveted by ground commanders. The same attributes that made the bombers great strategic weapons could also be used for more tactical missions in support of ground troops and their movements. Several times during the Combined Bomber Offensive, bomber sorties were diverted to smash enemy ground forces (such as in the Falaise pocket in Normandy), destroy bridges and rail lines (in preparation for D-Day), or most visibly to open up large holes in the front lines that allowed Allied forces to break through enemy lines (Operations Cobra and Goodwood in Normandy). These attacks helped the Allied cause but frustrated Air Corps leadership as they diverted bomber sorties from their strategic bombing campaigns. The utility of bombers to serve both strategic and tactical purposes made them even more valuable assets.

By the end of the European campaign it was clear that the B-17s and B-24s were effective in large numbers and formations. They possessed the range required for the European theater, but they still lacked the accuracy, bomb load capacity, and self-protection that was needed to get the job done quickly and efficiently. In the end they accomplished their mission by making multiple attacks, often at great cost and sacrifice, on the same targets while being escorted by P-51s or P-47s. There was another American bomber developed during this period that would start to break this mold and proved to be a leap forward in heavy-bomber technology – the B-29.

> **B-17s and B-24s possessed the range required for the European theater, but they still lacked the accuracy, bomb load capacity, and self-protection that was needed to get the job done quickly and efficiently.**

The Pacific and the B-29

From its inception, the B-29 Superfortress proved novel and groundbreaking. In 1940, The Boeing Co. began work on this amazing long-range heavy bomber, and from the start it would be unique. It started with a three-story-tall tail fin, four 2,200-horsepower turbocharged engines, pressurized crew cells, remote-controlled automatic gun turrets, and its own radar navigation and targeting system. The wingspan alone was almost 40 feet longer and the weight was almost double that of the B-17.[59] This was a huge leap forward on several levels. The concepts were so new that it became known as the "$3 billion gamble" when it went straight from the drawing board to production.[60] The B-29 was evolutionary in both technology and capability. Its cruising speed of 230 mph was 50 mph faster than the B-17 and 15 mph faster than the B-24. Although the maximum altitudes of the three aircraft were similar, the strategic range of

The B-29 was a leap forward in technology and capability. Its cruising speed of 230 mph was 50 mph faster than the B-17 and 15 mph faster than the B-24. (Air Force/Flickr)

3,250 miles with a 20,000-pound bomb load for the B-29 doubled that of its predecessors.[61] These performance characteristics made it the natural choice to carry out a bombing campaign against the Japanese mainland across the vastness of the Pacific Ocean. The Superfortress had the range, payload, and the ability to take the fight to the heartland of Japan.

When the B-29 entered combat in 1944, its increased range was so revolutionary that it caused a command and control dilemma. The aircraft could strike almost any enemy target in the Pacific and thus crossed the regions of command controlled by several unified commanders, from General Joseph Stilwell to General of the Army Douglas MacArthur to Fleet Admiral Chester Nimitz. To avoid confusion and retain unity of command, it was determined that Arnold would command all B-29s from his office in the newly built Pentagon, where he desired to wear dual hats as chief of the Army Air Forces and commander of the XX and XXI Bomber Commands (composing all the B-29 units). Thus the B-29's awesome firepower was focused exclusively on Japan throughout the entire war no matter where the aircraft took off from. Under Arnold's command, the B-29s could concentrate their efforts on the "dislocation of the Japanese military, industrial and economic systems and … undermine the morale of the Japanese people to a point where their capacity and will to wage war was decisively weakened."[62] Despite this amicable arrangement for strategic bombing advocates, continually focused on showing that air power could win the war by itself, the B-29's amazing range and large volume of fires resulted in its being diverted at times to support more tactical mission sets, such as softening up ground positions for the invasions of Iwo Jima and Okinawa later in the war.

Despite its 1,600-mile combat radius that outranged the other bombers of the time, one of the greatest limitations for the B-29 in 1944 was still the limited number of Allied bases within this extended range to reach Japan. Before Allied ground efforts seized key islands in the Pacific, China was the only possible staging point from which the B-29 could reach Japan, but during this time in the war Allied-held territory in China was so far removed from Japanese targets as to make logistical support for bombers based there difficult. Consequently all the bombs, fuel, parts, people, and planes necessary for the war effort in the Pacific had to be flown in over the desolate "Hump" route through the Himalayas. This severely limited the effectiveness of the B-29 mission until subsequent amphibious campaigns provided airfields in Guam, Tinian, and Saipan.[63]

Early B-29 missions also suffered maintenance, training, and tactical problems. The new technology on the huge supercharged engines still had some deficiencies. The mechanical problems with the engines at high altitudes caused around 1 in 5 bombers to return to base without making it to their target. During the early B-29 missions, crews had difficulty navigating the long distances over water and, once over target they still had to use the imperfect Norden bombsight. More challenging still were the strong high-altitude jet stream winds over Japan that wreaked havoc on bombing accuracy. The jet stream winds caused unsolvable problems from high altitude, affecting not only the speed of the aircraft over target but also the dispersal of bombs, which would often pass from one swiftly moving air current to a slower layer moving in a completely different direction.[64] The bombs rarely hit their intended target. Fortunately, one of the most innovative bomber leaders of the European campaign arrived on the scene just in time to make a difference.

Bomber legend Gen Curtis LeMay first employed incendiary bombs using radar-aimed bombing from medium altitudes over Tokyo on February. 25, 1945. His B-29s attacked in seven echelons, producing huge firestorms and destroying 10 percent of Tokyo's houses (190,000 structures). (U.S. Air Force/ Flickr)

Newly promoted Brigadier General LeMay arrived in Asia on August 29, 1944, to take over the day-to-day operations of XX Bomber Command's B-29s based in mainland China (although Arnold would always retain overall responsibility for the B-29s from Washington, he had operational commanders in the field who reported directly to him). Just as LeMay had in Europe, he determined to fly at least one combat mission before making any changes, stating: "I won't know what's going on until I do." After being unimpressed by the Japanese air defenses and losing four B-29s to noncombat-related issues, his force still only moderately damaged the targeted industrial facility.[65] In the following months LeMay and other innovative airmen would concentrate on fixing the problems with the engines, improving sortie rates, and increasing crew training and would begin to modify their bombing tactics in an effort to improve bombing results. On January18, 1945, LeMay left the XX Bomber Command to assume command of the newly formed XXI Bomber Command in the Marianas Island chain. These recently liberated islands would prove crucial to the B-29 campaign. The islands had several advantages over Western China. They had more direct access to friendly maritime and air supply, insulation from enemy ground attack, relative immunity from hostile air attack, better weather, and most importantly, a radius of action that exposed the heart of metropolitan Japan to the full bomb load of the B-29s.[66] In short, the long-range B-29s still required these islands in order to be within the range of all their targets.

Arnold had removed one of his favorite officers, Brigadier General Haywood Hansell (one of the original ACTS planners, a member of Arnold's prewar staff, and a veteran of the air campaign in Europe), to put LeMay in this position, but even the legendary LeMay was not able to turn the campaign around overnight.[67] Due to poor bombing results and heavy losses, he eventually shifted his B-29s from high-altitude daylight precision bombing to medium- to low-altitude night raids against area targets. Japan was especially susceptible to this type of attack. Much of the industrial production was carried out by cottage industries located in homes and shops throughout the cities, and those homes and buildings were primarily constructed of wood and paper. As soon as B-29s dropped to lower altitudes in combination with high-explosive incendiary bombs, the entire situation changed. LeMay first employed incendiary bombs using radar-aimed bombing from medium altitudes over Tokyo on February 25, 1945. His B-29s attacked in seven echelons, producing huge firestorms and destroying 10 percent of Tokyo's houses (190,000 structures). The Japanese firefighters could not keep up. The raid was so successful that LeMay decided to take it a step further. He ordered his B-29s to even lower altitudes to avoid heavy AAA, but high enough to avoid the light AAA. He eventually took his bombers down from 30,000 feet in the daytime to 5,000 to 8,000 feet at night, with impressive results. At that altitude one B-29 with incendiary bombs could take out approximately 16 acres of ground construction. This also alleviated the strain on the B-29's engines that resulted from high-altitude flight.[68]

A team of National Defense Research Committee scientists had developed the primary ordnance chosen for these B-29 incendiary missions back in 1942. The 6.2-pound M-69 firebomb was three inches in diameter and 20 inches long and was unlike any previous incendiary. After the device crashed through the roof of a home or factory and came to rest, a delay fuse actuated a TNT ejection charge that spewed magnesium particles into gasoline gel contained in a sock. The resulting "explosion blew burning gel out of the tail of the casing and – like a miniature cannon – shot it as far as 100 feet. If the gel struck a combustible surface and was not extinguished, it started an intense and persistent fire." The load of clusters of M-69 incendiaries, mixed with conventional high-explosive bombs (totaling up to 20,000 pounds for each B-29), was devastating in an area attack on the wood and paper buildings in Japan, and the conventional high-explosive bombs drove the defenders under cover with large explosions.[69]

On the evening of March 9, 1945, LeMay's forces returned to Tokyo. Two hundred seventy-nine B-29s surprised the Japanese defenders by attacking the city's most important industrial zone. They flew in streams of aircraft, leaving behind their traditional formations and spreading out across the target area. The bombers dropped 1,665 tons of incendiaries, completely leveling 16 square miles in the heart of the capital. They destroyed 63 percent of the commercial district, 18 percent of the industrial area, and the entire core of the residential zone. The destruction was immense: 276,791 dwellings burned, 83,793 people were killed, and around 40,000 were injured. More than one million residents lost their homes. The terror was not confined to Tokyo; the fires could be seen over 150 miles away. All this was done without the loss of a single bomber to Japanese fighters, and only 14 were lost to AAA.[70]

Both Arnold and LeMay were convinced that the B-29 campaign in the Pacific could force the surrender of Japan, which was already short on food and oil.

The new tactics immediately produced results and forced the Japanese leadership to think about the material and human cost of the war. The situation also forced Japan's leaders to consider how long the people could or would continue to resist. The awesome destruction of the B-29 incendiary raids promised to be the kind of decisive aerial bombardment that would vindicate the proponents of strategic bombing theory by destroying Japan's cities, and with them, the nation's capacity to resist. This most certainly showed that heavy bombers could take the fight directly to the enemy population and leadership. Although strategic bombing had neither taken the place of an invasion nor prevented the Germans from fighting on as the Allies closed in on Germany, both Arnold and LeMay were convinced that the B-29 campaign in the Pacific could force the surrender of Japan, which was already short on food and oil. The assumption they shared was that an all-out incendiary campaign could lead to a Japanese surrender without the need for an invasion.[71] In 1945 Secretary of War Henry L. Stimson received a report that estimated an invasion of the Japanese home islands would result in 1.7 million to 4 million casualties with between 400,000 and 800,000 Americans killed.[72]

LeMay quickly expanded the use of his new tactics throughout Japan, causing major destruction to industry and the will of the population. This debate represented an interesting preview of the counter value (targeting civilian population centers as an act of deterrence) versus counterforce (targeting military targets to degrade or destroy an opponent's ability to wage war) debate that dominated the forthcoming nuclear era.[73] Concurrently, he embraced an important mission that bombers carry out to this day when he supported the use of B-29s to sow heavy sea mines. His bombers joined U.S. submarines and surface ships in cutting off the last remaining imports of food and raw materials into Japan. B-29s flew only 34 percent of the mine-laying sorties, but due to their large bomb bays they laid 63 percent of all the mines during the operation. Although an average of only 40 B-29s ever participated in mine-laying activities, mines dropped by B-29s destroyed 1.25 million tons of the total 2 million tons of Japanese shipping lost to this campaign.[74] The next B-29 contribution would shape the development of bombers and strategic bombing theory to this day.

In August 1945, the United States possessed some 3,700 B-29s, all dedicated to ending the war with Japan. Two of those bombers carried a payload that eventually did just that without the dreaded land invasion when they dropped top-secret atomic bombs on two Japanese cities. At 8:15 a.m. on August 6, 1945, a B-29 named *Enola Gay* and piloted by Tibbets (by now a Colonel) dropped the world's first atomic bomb, code-named "Little Boy," on Hiroshima. Although that single bomb did not inflict the same scale of devastation that 279 B-29s delivered on March 9 over Tokyo, the devastation delivered by one aircraft had never reached such a scale. That one bomber mission razed 4.4 square miles in the center of the city. The blast and flames began a firestorm that destroyed 68,000 of the city's 90,000 buildings. Initially, 60,000 to 80,000 people were killed and many more were injured. It is estimated that as a result of the radiation produced, over 200,000 people eventually died as a result of that attack.[75] Three days later, on August 9, 1945, a second B-29, named *Bockscar*, dropped another atomic bomb, code-named "Fat Man," on Nagasaki. "Fat Man" eventually killed 100,000 people. Japan surrendered five days later. Atomic weapons inflicted unprecedented mortality and casualty rates, exceeding those seen during the firebombing of Tokyo by 300 to 400 percent even though the population densities at the two cities hit by the atomic bombs were a fourth to half those of the capital.[76] To match the physical damage wrought by the nuclear weapons, some 2,100 tons of conventional munitions would have had to be dropped by at least 210 B-29s at Hiroshima, and 1,200 tons by 120 B-29s on Nagasaki.[77]

For the foreseeable future, American heavy bombers would be the only weapon system capable of delivering the new atomic bomb. If it was not already the most lethal weapon in air combat after the firebombing raids on Tokyo, the heavy bomber certainly moved to the top spot in the dawn of atomic warfare with its unmatched payload and the range to deliver it almost anywhere on the planet. In Japan, the superior range, speed, and firepower of the B-29s had proved effective in destroying both the enemy's industrial capability and its morale. Although the ability to sneak through enemy defenses undetected was still years away, American bombers had smashed their way through the enemy defenses, and bombing theory remained largely intact, with some minor modifications, throughout WWII. Although it could be argued that the bombing campaigns failed to accomplish all their goals, Allied air power, as the *United States Strategic Bombing Surveys* found, "was decisive in the war in Western Europe."[78] In the Pacific, the area bombing of Japan's large cities combined with the use of the atomic bomb appeared to have brought about the unconditional surrender. Taken as a whole, evidence strongly suggested that air power, led by strategic bombing, had contributed significantly to the defeat of the Axis powers.[79]

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The recognized success of air power, especially the strategic bombing campaigns led by U.S. heavy bombers, directly resulted in the formation of an independent Air Force in 1947. The new Air Force maintained the doctrine, theory, and important airframes that helped it gain its independence. At the Air Force's core was the heavy bomber with its unmatched payloads, range, and ability to penetrate enemy defenses. The torch was effectively passed to the Cold War generation of bombers with the use of the atomic bomb. Warfare would never be the same, but the basic bombardment theory remained unchanged; what

The B-36 was designed to carry a huge bomb load from the eastern shores of the United States to Europe and return to its original point of departure. Everything about this bomber was big. It was nearly twice the size in both wingspan and aircraft weight as a B-29. (U.S. Air Force/Flickr)

did change were more powerful weapons intended to destroy the enemy well beyond the front lines.

Air Force leaders entered the postwar period expecting future wars would be fought by bombers employing atomic weapons, giving the United States a "net advantage" for the foreseeable future.[80] Despite the postwar drawdown, the Air Force and newly formed Department of Defense were determined to stay ahead of potential adversaries by maintaining that advantage. The race was on to develop the next generation of bombers and to increase the range of the bombers already in its inventory.

Bombers in the Early Cold War

The Air Force designated the command that embodied the doctrine of strategic bombardment the Strategic Air Command (SAC) in March 1946, and it quickly began working on extending the range, altitude, payload, and speed of its heavy bombers. First, it continued to acquire additional B-50s, an extended-range version of the B-29. B-50s looked like traditional B-29s but could fly 50 mph faster and almost 2,000 feet higher than their older without the early engine problems.[81] In late 1948, and under the leadership of its new commander, LeMay, SAC took delivery of its first truly intercontinental bomber, the Convair B-36 Peacemaker.

A requirements document issued in 1940, when the loss of the British Isles seemed likely, directed that the B-36 be designed to carry a huge bomb load from the eastern shores of the United States to Europe and return to its original point of departure. Everything about this bomber was big. It was nearly twice the size in both wingspan and aircraft weight as a B-29. In sheer size it was – and remains today – the biggest bomber to ever serve in the U.S. Air Force. While the B-29 had a bomb load of up to 20,000 pounds, the normal bomb load on a B-36 was 72,000 pounds with an option to carry up to 86,000 pounds with a reduced range. That roughly equates to the bomb-carrying capacity of five B-17s.[82] The B-36's size required six enormous 3,500-horsepower propeller "pusher"-type engines to thrust it through the sky.[83] The aircraft was not actually built until 1946, and with the addition of two jet engines mounted under each wing, its range reached 6,800 miles at a speed of 391 mph, easily outpacing the B-50 by 2,000 miles and over 100 mph.[84] Finally, around the same time, SAC began to field its first squadrons of air refueling tankers (modified B-29s), making it possible for other legacy bombers such as B-29s and B-50s to fly even greater distances.[85]

With the exception of the B-36, all of the strategic bombers still needed to be forward-deployed in order for enemy territory to be within range. Thus, the advances in bomber technology in the 1950s and beyond would have had limited utility without the mostly unsung development of aerial refueling. As early as 1926 air-power visionaries such as General Carl Spaatz saw a need for a refueling capability to stretch aircraft range. Forward air bases were the only alternative in WWII despite some Air Corps experiments. Early Air Force tankers such as the KB-29 and the KB-50 used a probe and drogue system, consisting of a hose equipped with a funnel-like female connector into which the receiver inserted a probe. Unfortunately, when refueling massive bombers this method took too long to transfer the large amounts of fuel needed (although it worked well for the small offloads required for fighters). Boeing proposed a new method called the flying boom, which revolutionized in-flight refueling and is still in use today. This method consists of a long telescoping transfer tube with two V-shaped control surfaces, called "ruddervators." The receiver aircraft flies in close formation behind the tanker, and the boom operator on the tanker flies the boom into the receiver's receptacle. This innovative system allowed fuel to be transferred under high pressure, reducing refueling times.[86]

The advances in bomber technology in the 1950s and beyond would have had limited utility without the mostly unsung development of aerial refueling. As early as 1926 air-power visionaries such as General Carl Spaatz saw a need for a refueling capability to stretch aircraft range.

In the post-WWII world of force reductions and nuclear weapons, the economy of force provided by heavy bombers armed with atomic bombs became the clear economic and strategic choice for most politicians and defense leaders. The Air Force quickly combined its strategic bombing theory with the more abundant and powerful nuclear bombs being produced in the late 1940s and made sure its strategic doctrine focused primarily on waging nuclear war. The Truman administration's decision to focus scarce resources on enhancing the Air Force's strategic bombing capabilities, relative to the capabilities of the other services, was vindicated by

The B-36 was not actually built until 1946, and with the addition of two more jet engines mounted under each wing, its range reached 6,800 miles at a speed of 391 mph, easily outpacing the B-50 by 2,000 miles and over 100 mph. (U.S. Air Force/Flickr) the discovery in fall 1949 that the Soviet Union (USSR) had successfully detonated its first nuclear device, years ahead of most predictions.[87] In an attempt to reassure the public, the new chairman of the Joint Chiefs of Staff, General Omar N. Bradley, said, "As long as America retains (as it can) a tremendous advantage in [atomic] bomb quantity, quality, and deliverability the deterrent effect of the bomb will continue."[88] In 1949 bombers were still the only way to deliver the larger and more powerful atomic bombs, and the budget reflected that.

Even with the growing threat from the Soviet Union, the Truman administration kept defense spending at relatively low levels until the start of the Korean conflict in June 1950 forced the president to greatly expand the budget. During the ensuing buildup, a formidable strategic deterrent centered on heavy bombers. SAC's plan in the event of a communist attack in Europe was to strike directly at the Soviet industrial heartland. Thus, by 1951, SAC had expanded considerably to a force of some 85,000 personnel and 1,000 aircraft. By the end of 1951 SAC had grown to nearly 145,000 personnel and 1,200 aircraft, including 96 B-36s, 340 B-29s, and 219 B-50s. The expansion was only the beginning and this was only the tip of the iceberg in eventual bomber strength.[89] At the same time, some of the B-29s would be diverted to fly conventional missions in Korea.

The Air Force always considered Korea to be a secondary theater to Europe. There was a long-standing belief that Korea was a diversion and that the Soviets would attack Western Europe. Consequently, only the older B-29s, at reduced numbers, were released to fly combat missions in Korea. North Korea possessed very few industrial targets, so bombers were asked to attack airfields and lines of communication in addition to their preferred targets. Incendiary attacks were avoided to prevent negative propaganda and possible escalation to an all-out war with the Soviet Union and China. Despite the limited numbers employed, the B-29s were very effective in attacking diverse targets such as hydroelectric plants, railroad lines, warehouses, and docks. Due to improved training, accuracy, and the small target sets, B-29 tactics differed from those of WWII. During the Korean conflict, B-29s would usually attack in V formations consisting of only three aircraft. When the target was obscured by weather, a stream of bombers would cross the target at one-minute intervals, bombing individually by radar. They became so effective that B-29 operations were temporarily suspended on October 24, 1950, "because no targets were available on the Korean side of the Yalu."[90]

A limited number of B-29s were effectively employed for the duration of the war, but one significant change came with the introduction of high-performance jet aircraft, primarily the MiG-15s flown by the Chinese. The faster enemy jets were a serious threat to the piston-engine bombers for the remainder of the war and forced the B-29s to fly night missions against the targets closer to the Chinese border. The shift from daylight proved very effective in protecting the bombers.

The Heavy Bomber Enters the Jet Age

The rapid advancements in jet technology, especially among fighters, were closely watched by U.S. strategists. The Air Force in particular knew that the power and effectiveness of its nuclear forces still relied on its formidable fleet of bombers in the 1950s. The bombers had to be able to penetrate enemy air defenses. The rapid development of jet fighters would soon make SAC's piston-engine bombers obsolete. SAC's entry into the jet age was indeed revolutionary in the evolution of heavy-bomber aircraft and would completely change the course of U.S. heavy-bomber development for decades to come.

The Boeing B-47 Stratojet, with its six turbojet engines, sweptback wings, and tail surfaces that allowed it to handle like a fighter, became operational in 1951, and within four years SAC phased out all its B-29s and B-50s.[91] The B-47 is often overlooked because it was quickly overshadowed by its replacement, the venerable B-52, but over 2,000 B-47s served as SAC's backbone for several years and introduced the technology and many of the design features that have made the B-52 a legend.[92] With the B-47's jet engines and swept wings, it could fly more than 150 mph faster and 1,000 feet higher than any of its predecessors, but the range fell back to 4,000 miles (almost 3,000 and 1,000 miles less than the B-36 and B-50, respectively). The jet engine technology was not yet perfected for fuel efficiency, but the prevalence of tanker aircraft in the SAC inventory made up for this shortcoming in range. While the B-47 took bomber design to the next level, the bomb loads were the same size as those of the B-29 and B-50. The B-47's 20,000-pound load was dwarfed by the 86,000-pound load of the B-36, and the Stratojet's reduced range required a fleet of supporting tankers in order to get it to the target and back.[93] The B-47 was more or less a technology demonstrator for jet engines on a long-range bomber, and as a result the size and bomb load were lower than the Air Force desired, but it was crucial in getting bombers to the next level. Importantly, the Stratojet was designed primarily as a nuclear bomber and thus did not need to carry huge loads to carry out its primary mission. The B-47's powerful nuclear payload, speed, and ability to refuel aerially allowed it to penetrate enemy airspace and hold the enemy at risk.

The bombers had to be able to penetrate enemy air defenses.

Despite the fact that the B-47 was the Air Force's first mass-produced jet bomber, it served as a transition platform between two larger airframes: the B-36 and B-52. Thus, the Stratojet failed to win the recognition it deserved and is now largely forgotten, but it would not be an exaggeration to claim that it was a revolutionary aircraft design and took Boeing and the Air Force to the next level in aircraft production. The groundbreaking Boeing 707, 747, and B-52 clearly have their roots in the design philosophy that defined the B-47. Besides serving as the nation's front-line bomber for a decade, it set Boeing on a path toward pre-eminence. Flying more like a fighter than a lumbering bomber, the Stratojet was lighter on the touch than its predecessors, more responsive, but less stable and far more difficult to operate in the landing pattern. "Experience with the B-47 was invaluable in helping shape the B-52 program."[94]

The B-52 built upon the B-47's strengths and made up for some of its shortcomings. Originally conceived to replace the B-36, the B-52 would take much more time to develop and would eventually follow the B-47, not the B-36. The requirement for a replacement heavy bomber for the B-36 was initiated as early as 1945, but as technology continued to evolve and the international situation changed, the individual requirements were modified. As Boeing moved forward with its B-52 design it was also developing the B-47. The original designs for what would become the B-52 included piston engines and straight wings and did not provide much improve-

The B-47 is often overlooked because it was quickly overshadowed by its replacement, the venerable B-52, but over 2,000 B-47s served as Strategic Air Command's backbone for several years and introduced the technology and many of the design features that have made the B-52 a legend. (U.S. Air Force/Flickr) ment over the B-36. Then, after meeting with Air Force representatives at Wright-Patterson Air Force Base in Dayton, Ohio, on October 21, 1948, the Boeing design team spent the weekend in a Dayton hotel and redesigned the B-52 on a hotel table. The designers took the swept wing and jet engine technology of the B-47 and designed both into their proposal for the B-52.[95]

The new, jet-powered bomber would eventually be known as the B-52 Stratofortress, or as it was affectionately known by its flight crews, "Big Ugly Fat F#@&ˆ* (BUFF)." Unlike its B-47 cousin that could carry only two nuclear bombs, the B-52 could carry substantially larger payloads over much longer distances. Early B-52 models (series A-D) had an unrefueled range of more than 6,000 miles while carrying four nuclear bombs. Later models, such as the G and H series, would have an unrefueled range of over 10,000 miles and could carry as many as eight nuclear bombs. The B-52 also had enough payload capacity and thrust to carry and incorporate such self-defense measures as Quail decoy missiles and nuclear-tipped Hound Dog air-to-surface missiles for clearing a path through the Soviet Union's increasingly sophisticated air defenses. Around the same time period, SAC's acquisition of 300 KC-135 jet-powered tankers (based on the Boeing 707 airliner design and B-47 innovation), capable of refueling the bombers at 500 mph and above 35,000 feet, gave the B-52 a truly global reach.[96] Before the introduction of the KC-135, jet-powered bombers would have to descend to a lower, less fuel-efficient altitude and slow down almost to a stall speed to refuel behind piston-engine aircraft that were in a continual dive just to fly fast enough for the jets. Then the jet aircraft would waste fuel flying back up to its best range altitudes and airspeeds.[97] The advent of jet tankers changed the calculus for bomber designers. They could now sacrifice range for payload and speed, knowing they had a tanker force that could help the bomber get to the target.

For all their technological advances, the B-47 and B-52 were still designed based on the same strategic bombing theory of WWII. They would fly higher and faster with large bomb loads of nuclear weapons to attack industrial targets deep in enemy territory. The Soviets were not content to sit back and let that happen. They continued to focus their defenses on jet fighters and advanced radars and soon developed very sophisticated surface-to-air missiles (SAMs) capable of shooting down these high-flying jet bombers. Eventually SAC's bombers were forced to plan their penetration of Soviet airspace at low altitudes, below the radars of the defenders, while relying heavily on their own self-protecting jamming and electronic warfare (EW) capabilities. Perhaps an even greater threat to this generation of heavy bombers appeared with the development of intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs). These could remain on constant alert and did not need the prior notice required to generate and fly nuclear bombers to their targets. Soviet air defenses and the development of ICBMs combined to force the phase-out of the B-47 fleet after only 10 years and curtailed work on the high-altitude supersonic B-70, the planned replacement of the B-52.[98]

During the late 1950s and the 1960s the heavy bombers faced considerable challenges in the form of fiscal and strategic competition from ICBMs and SLBMs and physical obstacles from the very active air defenses being developed by the Soviets. Even by the end of WWII it was clear that small fighters would have a difficult time trying to escort the new long-range bombers due to the tremendous ranges involved. There were no fighters that could fly anything resembling the extended ranges of the B-50s and B-36s in the early 1950s. To provide escorts during this period the Air Force ran tests to see if the B-36 could carry its own fighter protection for long-range missions attached to a hook on the bottom of the aircraft. This innovative approach quickly proved impractical. Despite the addition of aerial refueling capabilities on fighter aircraft during the late '50s and '60s it was obvious that the fighters could not go all the way to targets deep in enemy territory with the new longer-range bombers. Air Force planners began to develop innovative ways for the bombers, and in particular the B-52, to protect themselves.

Early B-52 models (series A-D) had an unrefueled range of more than 6,000 miles while carrying four nuclear bombs. Later models, such as the G and H series, would have an unrefueled range of over 10,000 miles and could carry as many as eight nuclear bombs.

First, the B-52 had its own electronic warfare suite for detecting and jamming enemy radar systems, as well as chaff and flare dispensers that would hinder the seekers of radar- and heat-seeking missiles as they closed in on their prey. The B-52 even held on to the old standby defensive countermeasure and had a tail gun to ward off fighters that got too close. B-52 tail gunners even claimed five kills on enemy fighters in Vietnam, although only two were officially confirmed.[99] During the 1950s the B-52 was provided with the GAM-72 Quail decoy missile. The Quail measured approximately 13 feet long, had a wingspan slightly over 3 feet, and in its stowed form, with wings and tail folded, was surprisingly compact. Despite its small size, its ingenious design of radar reflectors, electronic repeaters, chaff and infrared simulators resulted in it producing an infrared and radar image that closely resembled the B-52's. The decoy could also change airspeeds and make two turns to further confuse the enemy. The B-52 could carry four missiles without giving up much of its destructive payload. The decoys could deploy from a single B-52 as it approached enemy air defenses and now the Soviets would think they were seeing five B-52s instead of one.[100]

In an effort to more completely protect the B-52s as they penetrated enemy airspace, the Air Force provided missiles that were to be used to clear a path all the way to the target area. Four types of nuclear-tipped missiles have been service on Stratofortress at different times. The first was by far the largest: the 10,150-pound Hound Dog cruise missile, measuring over 42 feet long and with a wingspan of more than 12 feet. Powered by a 7,500-pound thrust jet engine, the Hound Dog could reach Mach 2.1 with a maximum range of over 700 nautical miles. The B-52 could carry two of these missiles, one under each wing, and use them to clear out concentrated SAMs and AAA sites along its flight path, allowing the B-52 to deliver gravity weapons on its primary targets. Later the Air Force would develop the smaller Skybolt (the B-52 could carry four) and the much more compact short-range attack missile (SRAM), of which the B-52 could carry 20. These missiles were originally designed to clear a path for the B-52, but the SRAM actually became the primary payload on some bombers, introducing the idea of purpose-built cruise missiles that would become the primary payload.[101] This idea of aircraft as "trucks" carrying long-range missiles continues to resonate to this day. Despite these advances the B-52 was still at risk.

The Soviets continued to focus their defenses on jet fighters and advanced radars and soon developed very sophisticated surface-to-air missiles capable of shooting down these high-flying jet bombers.

In the 1960s, the Johnson administration decided to keep 600 B-52s as part of the nuclear triad, but the decision to downplay strategic bombers meant that for several decades no new planes with intercontinental range would be added to the force after the delivery of the last B-52H in 1962.[102] However, the conflict in Vietnam would give SAC's bombers another venue to show their effectiveness. Not unlike North Korea, North Vietnam did not have a lot of industry or transportation systems to attack. The Vietnam War was yet another "small" conflict in the great struggle against global communism, and LeMay, now the Air Force chief of staff, was unsure the conflict would stay limited. Consequently, LeMay was hesitant to release too many strategic bombers for use in the Vietnam conflict. In the early 1960s, the Air Force was so focused on nuclear war and deterrence that the B-52s were not even capable of dropping conventional bombs. In January 1965, LeMay finally authorized the modification of SAC's D and F model B-52s so that they could carry approximately 70,000 pounds of 500- and 750-pound conventional bombs.

B-52s began to fly conventional bombing missions in South Vietnam in June 1965.[103] These missions, referred to as Arc Light sorties, were usually interdiction missions against supply routes, attacks against suspected Viet Cong logistic bases or assembly areas, and close air support (CAS) for troops on the ground. The major difference between the air defenses in North Korea during the 1950s and those of North Vietnam in the '60s and '70s was the introduction of SAMs. The new SA-2 SAMs were specifically designed to knock down heavy bombers like the B-52, so the Air Force usually kept the huge bombers away from the heavily defended areas in North Vietnam. The B-52s were by far the biggest bomb carriers in theater and were effective bombing platforms. The huge bombers flew hundreds

The B-52 could carry two Hound Dog missiles, one under each wing, and use them to clear out concentrated SAMs and AAA sites along its flight path, allowing the B-52 to deliver gravity weapons on its primary targets. (U.S. Air Force/Flickr)

of sorties each month and were considered critical to saving the Marines under siege at Khe Sanh in 1967-68, among thousands of other heavy-bomber operations. Echoing the near-unanimous praise ground commanders bestowed on B-52s, General William Westmoreland, U.S. Army and overall commander in Vietnam, called the B-52 “the most lethal weapon employed in South Vietnam.”[104]

thing less will only make the enemy contemptuous.”[105] So B-52s went back to strategic bombing in Operations Linebacker and Linebacker II. The area around Hanoi was one of the most heavily defended regions in the world. The North Vietnamese possessed front-line Soviet fighters, advanced radars, AAA, and a highly advanced web of SAMs. Getting the bombers in and out would require hundreds of support aircraft on each mission.

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Toward the end of the war in 1972, President Richard Nixon wanted to force the North Vietnamese to accept a cease-fire. He knew he had to bring the full strategic weight of the B-52s to bear to achieve this outcome. As Nixon recalled in his memoirs, he told Henry Kissinger, “We’ll take the same heat for big blows as for little blows ... and that means we will have to make the big decision to hit Hanoi and Haiphong with B-52s. Any-

The bombers generally attacked at night in waves of 40 to 50 B-52s flying in three-plane cells. Each wave had the support of about 40 jammers, fighter escorts, Wild Weasels (SAM hunters), and chaff spreaders in addition to the B-52’s own jammers and protective guns. Smaller groups of fighter-bombers would continue to attack during the day to soften up the defenses. During the around-the-clock Linebacker II operation, which lasted for more than 11 days, B-52s flew 724 sorties against 59 strategic targets. Support sorties numbered 2,066, and more than 42,000 bombs, more than 15,000 tons, were dropped on targets. In all, the North Vietnamese fired 1,242 SAMs, 844 directed at B-52s; 15 B-52s were destroyed, a loss rate of about 2 percent.[106] Linebacker II did bring the North Vietnamese back to the negotiating table, effectively ending U.S. involvement in the war. As planned, the bombers got through the world's best defenses, but it took the help of hundreds of support aircraft in the strike packages to make it happen.

As missile defenses became even more advanced after the Vietnam War, the Americans developed two sets of purpose-built cruise missiles that would allow its heavy bombers to launch very destructive nuclear payloads precisely from standoff ranges of around 1,500 miles. In 1979 the Boeing air-to-ground missile AGM-86B beat out the General Dynamics AGM-109H Tomahawk to win the Air Force air-launched cruise missile (ALCM) contract. For storage on the aircraft, the wings, elevons, and vertical tail folded. Once released, the weapon would free-fall approximately 450 feet while the engine spooled up and the control surfaces deployed. Once configured for flight the ALCM measured over 20 feet long, with a body diameter of 24.5 feet and a wingspan of 12 feet. ALCM deliveries ended in 1986 after a total of 1,815 missiles were accepted. The B-52G could carry six missiles under each wing for a total of 12. The B-52H (the only version in service today) had that same capacity but could carry an additional eight missiles on an internal rotary launcher in its weapons bay for a total of 20 weapons. In the late 1980s several ALCMs were reconfigured with conventional 1,000-pound warheads and were designated as conventional air-launched cruise missiles (CALCMs).

The ALCM concept was so successful that the Air Force developed an even more survivable stealth version in the late 1980s, the AGM-129A ACM (advanced cruise missile). It possessed even greater range and survivability as well as enhanced accuracy, and around 650 ACMs were delivered by 1991. ALCMs, CALCMs, and ACMs are still maintained as part of the B-52 weapons inventory today and have given the BUFF a viable strike capability from outside enemy air defenses despite heavy Integrated Air Defense Systems (IADs) that have proliferated around the world.[107]

Most importantly, the addition of survivable cruise missiles allowed the aging bomber force to maintain its credibility as a vital part of the nuclear triad and as a uniquely important nuclear deterrent during periods in which the survivability of the B-52 in a heavily contested environment seemed questionable. The bomber force has survived to this day as a member of that triad because the United States was always able to make the

During the around-the-clock Linebacker II operation, which lasted for more than 11 days, B-52s flew 724 sorties against 59 strategic targets. Support sorties numbered 2,066, and more than 42,000 bombs (more than 15,000 tons) were dropped on targets. In all, the North Vietnamese fired 1,242 SAMs, 844 directed at B-52s; 15 B-52s were destroyed, a loss rate of about 2 percent. (U.S. Air Force/Flickr) argument that its heavy bombers provided critical strategic versatility as a recallable, reusable, visible, and flexible force. Cruise missiles became the weapon of choice to keep bombers viable but out of danger in politically sensitive or densely defended target areas.

B-52s would go on to serve with distinction in every major American conflict since then. Despite the fact that it was no longer a young bomber in 1991 during the first Persian Gulf War, it was called upon to fulfill a major role in that war. It had been almost 20 years since the last time the BUFF had dropped bombs in combat. The B-52 was the only aircraft deployed to the Gulf conflict that could carry 51 individual bombs. At the time the BUFF was not yet configured to drop laser-guided weapons, but it could carry a host of other weapons, including 750- and 1,000-pound "dumb bombs," CBU-89/Bs (cluster bomb units) with anti-personnel and anti-armor mines, and one of the most secretive and precise weapons of the war, the conventional air-launched cruise missile. The CALCM had been converted from a select few air-launched cruise missiles just for this type of mission. It used Global Positioning System (GPS) technology for guidance and accuracy and was the preferred way to carry out surgical strikes without sending pilots into heavily defended areas.

The CALCMs gave the B-52 the distinction of being among the first groups of aircraft to strike Iraq during the initial hours of the war. At first light on Feb. 16, 1991, seven B-52s armed with 39 CALCMs took off from Barksdale Air Force Base, La., flying nonstop to the Middle East. They launched 35 CALCMs at eight targets, including a telephone exchange facility, power stations, and other electrical generating facilities. Postwar analysis showed the mission far surpassed expectations in terms of results, with only two missiles missing their targets (it is presumed that one was shot down; the other was unaccounted for). All seven B-52s returned to Louisiana 35 hours later. The award-winning flight was the longest combat mission up to that time.[108]

Approximately 90 B-52s contributed to the war effort; instead of delivering standoff weapons from halfway around the world, most were stationed at four bases in Europe, the Middle East, and Diego Garcia. They would take the fight into Iraq with conventional gravity weapons. B-52s flew low-level missions in three-ship streams in the opening days against runways, air bases, hardened aircraft shelters, radar facilities near Baghdad, and ammunition factories. Later in the war the BUFFs focused on destroying enemy fighting forces, including tanks, artillery, fortifications, vehicles, storage facilities, and troops. They, along with other air assets, rendered the Iraqi army virtually ineffective as a fighting force. In all, the B-52 completed 1,620 sorties, released just over 72,012 weapons, and delivered about 25,700 tons of ordnance. That equated to almost one-third of the tonnage of bombs dropped by U.S. aircraft while comprising less than 10 percent of the American aircraft used.[109]

The B-52 was later used to carry out postwar CALCM strikes from Guam, in the western Pacific Ocean, against Iraq during the Clinton administration in the 1990s and employed both CALCM and gravity weapons against Serbian forces during Operation Allied Force in 1999. With the advent of a variety of GPS-guided precision weapons, especially the JDAM in the late '90s, the B-52 was called upon to fly close air support and interdiction missions in Afghanistan and Iraq in the most recent American conflicts. In Afghanistan, the long loiter time allowed B-52s to orbit over the country for several hours with tanker support, providing support to ground forces throughout the entire country around the clock. They were heavily involved in the first few years of the conflict as a continuous presence. In 2003, B-52s again launched scores of CALCMs against Iraqi air defenses and communications nodes during the opening hours of Operation Iraqi Freedom and flew precision JDAM strikes during the opening months of the war. Today they are employing precision weapons while flying missions against Islamic extremists in both Iraq and Syria. During its entire lifespan the B-52 has proved to be a very versatile bomber. It has continued to

In all, the B-52 completed 1,620 sorties, released just over 72,012 weapons, and delivered about 25,700 tons of ordnance. That equated to almost one-third of the tonnage of bombs dropped by U.S. aircraft while comprising less than 10 percent of the American aircraft used.

show its worth in both the high-end fight by maintaining a viable nuclear deterrent through its ability to deliver ALCMS and ACMs anywhere in the world, and in the low-end fight by continuing to train to deliver a range of conventional weapons. In addition to employing scores of unguided and guided bombs and CBUs, the B-52 contributes to the nation's maritime strategy by retaining

> **The range, payload, endurance, and mix of standoff and precision weapons have kept the B-52 on the front lines of air warfare.**

its ability deploy anti-ship mines and by retaining the ability to employ AGM-84 Harpoon anti-ship missiles.[110] The range, payload, endurance, and mix of standoff and precision weapons have kept the B-52 on the front lines of air warfare. The venerable and versatile B-52, designed to win the Cold War, is scheduled to continue service for at least another 30 years and maybe even longer. It continues to prove itself a legend.

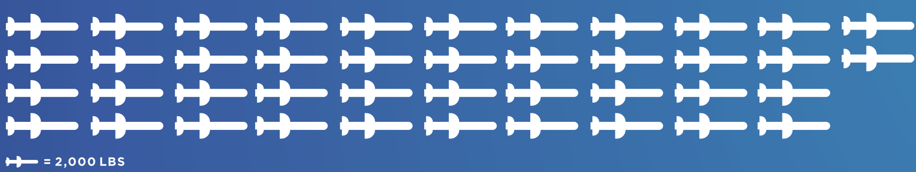

MARTIN MB-1
1918
MARTIN MB-2
1920
CURTISS B-2 CONDOR
KEYSTONE B-6
1931
MARTIN B-10BM
1932
DOUGLAS B-18 BOLO
1935
XB-35
1946
B-47
1947
B-50
B-52
1952
CONVAIR B-58 HUSTLE
1956
XB-70
1964


19
29
KEYSTONE B-4
19
30
KEYSTONE B-5
19
30
B-17 FLYING FORTRESS
19
35
B-24 LIBERATOR
19
39
B-29
19
42
19
47
YB-49
19
47
B-36 PEACEMAKER
19
49
B-1B
19
74
B-2 SPIRIT
19
89
B-21 USAF
20
21

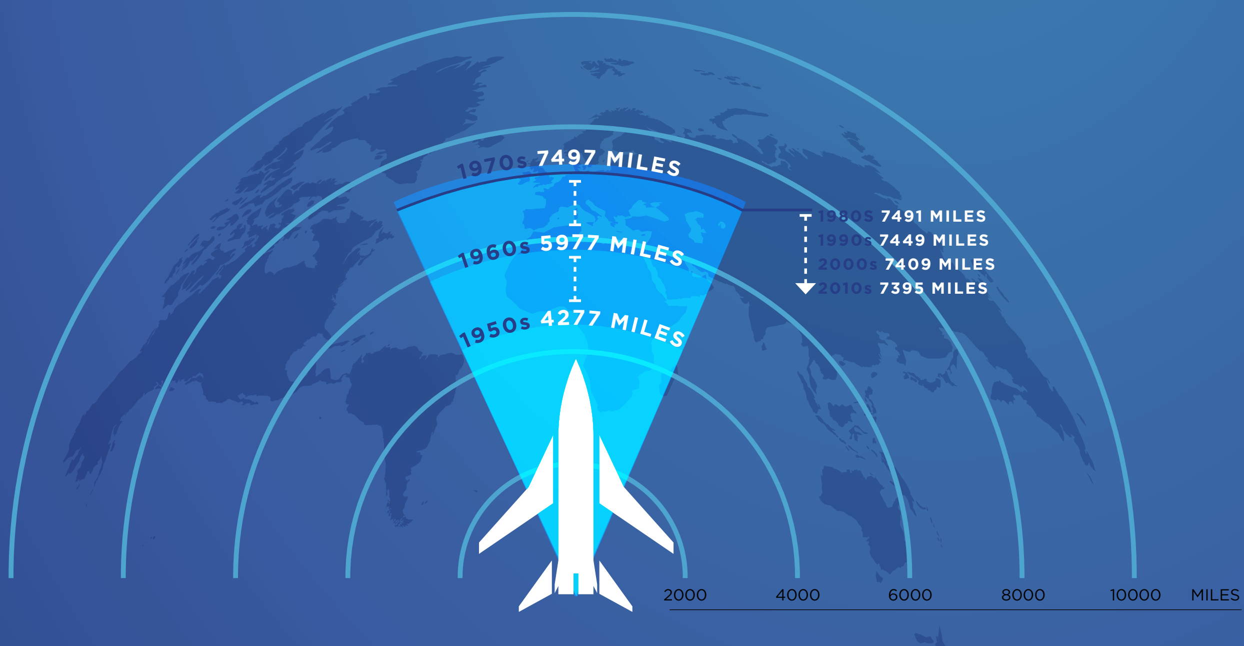
CHAPTER 03

EXPERIMENTATION, HIGH SPEEDS, HIGH ALTITUDES, AND THE RISE OF STEALTH

PAYLOAD - 84,000 LBS



1950
-2010



STRATEGIC RANGE

The B-52 represented the culmination of an evolutionary line of heavy-bomber development stretching back to the Handley Page 0/100 aircraft first flown during World War I. The Stratofortress was a big-winged, multiengine aircraft capable of carrying a large load of bombs very long distances. It was the last bomber to be produced in large numbers. The reasons for this are explored as we examine certain divergences from the evolutionary path, offshoots that took new approaches to aircraft design or that pressed the limits in design, on speed, or on altitude in an effort to gain an advantage with regard to a perceived weakness on the part of a competitor, who was, in more cases than not, the Soviet Union. In most cases these approaches failed, resulting in at least a handful of prototypes or at most a rather limited production run. However, in the end, these experiments illuminated a path to a new series of heavy bombers that have a role in the current force and promise to have an even greater impact upon the future force.

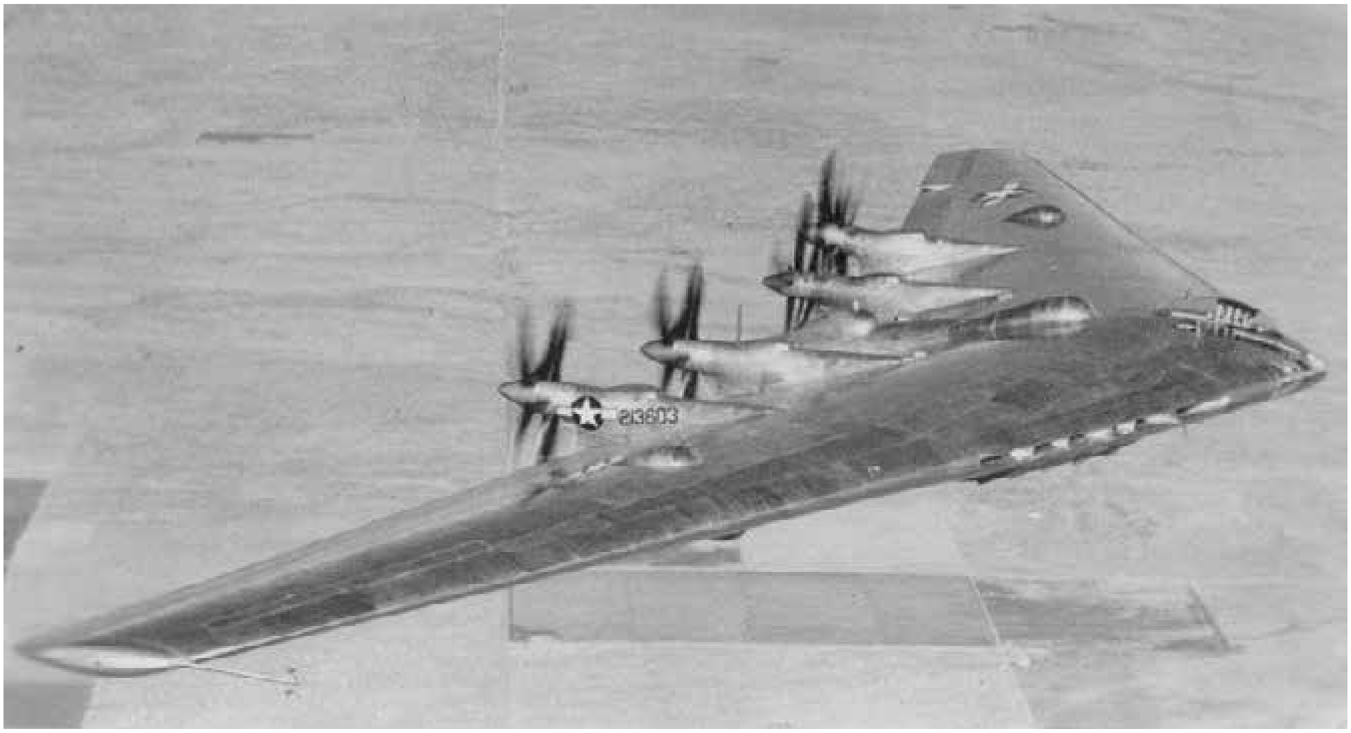
The Flying Wing – The XB-35

One of the most disruptive and innovative designs to enter the broader aviation conversation was that of John K. "Jack" Northrop's flying wing. Northrop's formal education ended when he graduated from high school, after which he worked as a mechanic on automobiles in and around Santa Barbara, California.[111] In 1916 he was offered a position as an architectural draftsman for Alco Hydro-Aeroplane Co., which had been founded just four years earlier by Allan and Malcolm Loughead (later Lockheed). While with Alco, Northrop cut his teeth helping to design the F-1 multiseat flying boat and the S-1 two-seat sport biplane. When these new aircraft did not sell, the brothers closed up shop in 1921 and Northrop was forced to find work with his father.[112] In 1923 he found a position with Douglas Aircraft Co. and contributed to the M-1 design that was later made famous by Charles Lindbergh. In 1927 Northrop returned to the newly named Lockheed Aircraft Co. to design the company's Vega aircraft, a sleek monoplane design that was used to break world aviation records by the likes of Amelia Earhart and Wiley Post.[113] Northrop's inclination toward innovation continued with his use of designs that leveraged the strength of stressed skin, wherein the metal skin of an aircraft is applied in such a way as to add to the aircraft's strength and rigidity.

Northrop first made use of this technique with the Alpha monoplane, built under his own name when he took over the Avion Corp. in 1928 and renamed it the Northrop Aircraft Corp.[114] He went on to sell and buy a number of other aircraft companies while designing innovative aircraft until he ultimately founded Northrop Aircraft Inc. in August 1939. Northrop envisioned the company being primarily a research and development entity, but World War II intruded and soon the business was producing subcomponents for other aircraft manufacturers while he himself continued to experiment with various designs and most particularly the flying wing.[115]

Northrop, the self-educated aeronautical engineer, had become focused on aircraft designs that limited drag while increasing lift, not a radical combination but difficult to achieve during the early years of aviation. It was his insight that a flying wing, an aircraft without

Jack Northrop's vision of a flying wing, an aircraft without a fuselage or even a vertical tail assembly, resulted in the greatest aerodynamic efficiency. A flying wing also had more internal space, which translated into more room for fuel, leading to longer ranges, as well as more room for internally stored ordnance. (Northrop Grumman Corporation)



A benefit of Northrop's design wing was the unanticipated introduction of stealth characteristics, discovered when the ground radar crews tasked with tracking the aircraft during flight had difficulty finding it and then holding track on it, leading to initial understandings of stealth. (U.S. Air Force/Flickr)

a fuselage or even a vertical tail assembly, resulted in the greatest aerodynamic efficiency. It also had more internal space, which translated into more room for fuel, leading to longer ranges, as well as more room for internally stored ordnance. The bottom line was that the airframe promised range and more bombs. Of course the design also came with a drawback, namely lateral instability. Entering into a flat spin without a vertical tail, the aircraft had little ability to recover.[116]

Northrop's first flying wing, the X216H, was an amalgam, a flying wing with a boom-attached vertical tail for lateral stability. A decade later he rolled out the N-1M, a true tailless flying wing driven by two aft-mounted "pusher" propeller engines. In 1940 Northrop began experimenting with this aircraft to explore the strengths and weaknesses of the flying-wing design. In early 1941, before Japan's attack upon Pearl Harbor, he wrote to officials in the Army Air Corps, "We have made very successful and encouraging flights of the flying mockup (N-1M) and I believe the time is here when we can seriously consider building bomber aircraft to this design."[117]

A few days later the Army took him up on his proposal, requesting that Northrop submit a design for a bomber based upon his flying-wing concept. The Army Air Corps wanted the new bomber to be able to fly 6,000 miles at a minimum cruising speed of 250 knots while carrying 10,000 pounds of bombs. The aircraft also needed to be able to reach a service ceiling of 40,000 feet. Northrop negotiated a contract with the Army to build XB-35 prototypes for testing at a cost of $2.9 million. The XB-35 was constructed with four Pratt & Whitney R-4360 radial piston pusher engines attached to a complex drive gear that originally drove two counterrotating propellers. This drive train was set into a 172-foot aluminum alloy cantilever wing constructed of one piece and swept back. The aircraft measured only 53 feet 1 inch in length while weighing 209,000 pounds.[118] The design also offered some characteristics never seen before. The crew compartment and the various mission bays were all fully pressurized. The aircraft was envisioned to carry a crew of 15 in comfort, with a galley and bunks for six. It also had eight separate bomb bays to carry the 10,000 pounds of bombs of the various sizes used in World War II.[119]

Problems with the program arose immediately. Because Northrop's facility at Hawthorne, California, was not large enough, production of the 200 B-35s desired by the Army was subcontracted out to the Glenn L. Martin Co. in Baltimore. Martin, however, placed the aircraft low on its priority list and, besides, had already began to lose employees to the draft. Additionally, prototype testing began to reveal problems. By the end of 1943 flight test results suggested that the flying wing would not reach its range goals nor could it attain the top speed of 400 knots desired. What's more, the complex gearbox to drive the aircraft's counterrotating propellers began to fail with alarming frequency. By 1944 production of the aircraft was effectively canceled, but flight testing continued on the small population of prototypes as the Army Air Force remained interested in the potential of the flying wing going forward.

By 1947 the cost of the tests ballooned from the original $2.9 million to nearly $14 million. The newly created U.S. Air Force requested that two of the by now eight prototypes be converted to jet engines. It was clear that propeller-driven bombers were on the way out of use in the future Air Force, and what's more, the flying-wing design, in either its propeller-driven XB-35 or the jet-powered YB-49 versions, was not performing well as a bomber. The aircraft's design led to instability about the yaw axis, as the absence of a tail left the pilots unable to make fine corrections to the aircraft's direction, making it difficult to accurately drop bombs or to serve as a photo reconnaissance platform. In addition, the aircraft's bomb bays were not large enough to carry the huge new atomic bombs under development.[120]

However, one aspect of the aircraft was noted but not appreciated during the initial tests in the late 1940s. Ground radar crews tasked to track the aircraft during its flights had difficulty finding it and then holding track on it.[121] Even airborne "chase" pilots tasked to observe the flying wing during its test flights from other aircraft had to be instructed exactly where to rendezvous with the flying wing at a specific geographic point and altitude, often 2,000 feet above the bomber. "This is necessary," one pilot said, "if you are to see us. The wing, after all, is nothing more than a knife's edge coming towards you."[122]

One final stab at taking advantage of the immense internal volume of the flying wing to serve as an aerial tanker was launched with a study in 1948 but came to nothing. By the late 1940s, the original prototypes began to fail structurally due to metal fatigue caused by high heat and excessive vibrations. In the end, 15 aircraft with various modifications were built for a cost of $66 million. In December 1949 the scrapping of the aircraft commenced.[123]

Jack Northrop's vision turned out to be years ahead of his time. While the advantages of the wing design were evident in terms of volume, range, lift, and carrying capacity, both propulsion and controllability emerged as problematic issues during these initial tests. The age of the propeller passed while the aircraft was in development, and the inefficiency of the initial jet engines did not allow the flying wing to perform to its full potential with regard to range. Add to these issues, in pre-fly-by-wire days, the inability of the aircraft's pilot to provide fine control and accuracy over a target using analog flight control systems. The use of opening and closing flaps to orientate the aircraft about the yaw axis, as opposed to a vertical tail fin, was inexact and often resulted in overcompensation or undercompensation. It would be decades before the computers and advanced control surfaces would be developed to allow the flying wing to reach its full potential. At this point, Northrop, in ill health and financial decline, would find redemption, but not before a series of other aircraft tested the limits of bomber development.

The Failed 'Champion of Champions'

The Thompson, Bleriot, Bendix, Collier, Mackay, and Harmon trophies are all considered the most prestigious in aviation. Some are presented annually; others, such as the Bleriot, had waited on the shelf for decades to be awarded just once for a specific achievement and never issued again. To receive one of these would ensure enshrinement in an aviation Hall of Fame. One aircraft, the B-58 Hustler, the young Air Force's "Champion of Champions," received them all at one time or another – and yet the aircraft is viewed as a failed design.[124] That the B-58 should receive such attention and yet have such a short – 10-year – operational life is a lesson unto itself. It is a lesson of "zigging" when everyone else is "zagging," as well as a reminder that the enemy gets a vote.

In spring 1947, fresh off his World War II experiences with B-17s over Germany and B-29s over Japan, LeMay, acting as the head of the Air Force's research and development division, requested that work begin on a new jet bomber that would have a range of 2,500 miles at 50,000 feet altitude while cruising at 500 mph and carrying 10,000 pounds of ordnance. This initial request for a design soon morphed into a larger Air Force study,

In the late 1940s, interest in supersonic delta-wing configurations almost invariably led to the Convair design that would fly at high altitude and at speeds exceeding Mach 1.5. (U.S. Air Force/Flickr)

the Generalized Bomber Study (GEBO). In February 1952 the Air Force formally issued a requirement for a supersonic bomber capable of carrying 10,000 pounds of bombs 5,000 miles at an altitude of 50,000 feet or greater while traveling at supersonic speeds. The aircraft also had to be capable of refueling in flight. To save money, the Air Force authorized only one company to build a prototype, rather than have multiple companies present aircraft for a fly-off evaluation round. LeMay, now head of the Strategic Air Command, preferred big bombers with longer ranges. Such a preference would have favored Boeing's suggested design, but the Air Force's Development Center at Wright Air Force Base advocated for proceeding with a high-performance, higher-altitude, and higher-speed design submitted by the Convair Co. In November 1952, Air Force Chief of Staff Hoyt Vandenberg selected the Convair B-58 Hustler as the Air Force's next bomber.[125]

In the late 1940s, interest in supersonic delta-wing configurations almost invariably led to the Convair design. Convair had come into existence in 1943 through the merger of Consolidated Aircraft and Vultee Aircraft and had gone on to build the B-36 long-range heavy bomber. Convair began to explore a series of designs that would fly at high altitude and at speeds exceeding Mach 1.5. The initial challenge lay with the new aircraft's engines, the General Electric J79, the world's first production Mach 2-capable engine. The single-spool, 17-stage compressor design was so innovative that the engine design team was awarded the prestigious Collier Trophy for its efforts.

The B-58 design went through several stages. Models were created and wind tunnel tests were run with engines attached at various points on the wing and with multiple pylon designs to determine which configuration would yield the highest-performing and most stable flight characteristics. There were questions regarding the angle of the swept-back wing, and the control elevons and rudders had to be reinforced to prevent flutter at transonic and supersonic speeds. Split engine nacelles gave way to Siamese nacelles and then back to split nacelles. There were also basic questions such as whether the bombardier should sit next to the pilot, necessitating a wider cockpit, or behind him.

The B-58's design did not incorporate an internal bomb bay. Instead, its bomb load, a nuclear weapon, along with additional fuel, was carried in an external MB-1C "pod" slung under the centerline fuselage of the aircraft. The concept was that the aircraft would fly to its target at supersonic speeds, taking all the fuel from the pod en route, and then would drop the pod along with its nuclear bomb, which in most scenarios was the W39Y1-1 variable yield thermonuclear warhead, over the target and egress out of the target area.[126] The size, shape, location, and design of the pod underwent continuous revision during the aircraft's design and test phase. Once test flights began, alternative pod designs were dropped from the aircraft at speeds varying from .9

to 2.0 Mach. Test flights revealed other problems, ranging from fuel imbalances to "sloshing" in wing fuel tanks as the aircraft accelerated and decelerated.

The aircraft was also inherently unstable. Delta wings were superb at supersonic speeds but unforgiving in the subsonic range zone, especially at the low speeds associated with takeoffs and landings. There was also a problem of lateral instability if the aircraft experienced a loss of power in one of its engines while at supersonic speeds. The imbalance in thrust caused the aircraft to yaw uncontrollably and depart its flight envelope. Seven test aircraft were lost between December 1958 and June 1960, including an event wherein one test aircraft simply disintegrated in flight on December 7, 1959. Electrical problems, tire failures, and structural weaknesses were all identified. SAC under LeMay's leadership came down hard against the B-58 as it neared full-scale production. He continued to favor a larger bomber that could fly farther on its own internal fuel while carrying a heavy load, and the B-58's test issues, as well as its ravenous need for tanker support, left him nervous and unconfident.

The event that doomed the B-58 as a concept centered on the shoot-down of the U-2 spy plane in May 1950. The aircraft, operating at 65,000 feet over the Soviet Union, was knocked out of the sky by an SA-2 Guideline missile, capable of reaching 85,000 feet and speeds up to Mach 3.5. The advent of these new missiles caused American planners to reconsider methods of approaching Soviet targets. As previously mentioned, rather than go in high and fast, tactics shifted to flying in at low altitudes, below enemy radar horizons, to avoid detection and interception. Rather quickly the orders for new B-58 aircraft went from 300 to 200, and ultimately only 116 were built, which included nearly 30 test aircraft. With the high-altitude mission gone and its instability at lower speeds as well as its sensitivity to the buffeting associated with low-level flying, the B-58 no longer made sense. In December 1965, Secretary of Defense Robert McNamara made the decision to phase the B-58 out of the inventory by June 1970. Barely 10 years into its life, the B-58, the Air Force's "Champion of Champions," the holder of so many records and recipient of so many trophies, was consigned to the "boneyard" at Davis-Monthan Air Force Base in Arizona. So anxious was the Air Force's leadership to be done with the aircraft that phaseout of the failed experiment was accomplished six months ahead of schedule.[127] However, the Air Force was not finished with its hunger for speed.

The XB-70: A One of a Kind Going Nowhere Fast

The XB-70 supersonic bomber began with an examination of the potential of a nuclear-powered, large heavy bomber, but it quickly morphed into a design that sought to reclaim the initiative from the Soviet Union by designing a bomber that could go yet higher and faster, rendering it invulnerable to the Russians' new surface-to-air missiles. The XB-70, designed and built by North American, was an exceptionally large aircraft, weighing in at 521,000 pounds. It was 196 feet long and had a delta wing design that spanned 105 feet. The aircraft's wingtips were designed to cant downward at lower speeds to provide stability during takeoffs and landings. It was powered by six General Electric YJ93 engines, each of which could generate 30,000 pounds of thrust in afterburner. The aircraft had a range of over 4,000 miles and could cruise at altitudes in excess of 70,000 feet with a dash speed in excess of Mach 3.[128] The aircraft's range was found to be longer than originally expected due to a newly discovered phenomenon called "compression lift," which allowed the B-70 to ride its own supersonic compression wave.[129]

North American received its contract to build prototype aircraft in December 1957, but budget restrictions almost immediately imposed obstructions to its development. General Thomas White, then Air Force chief of staff, decreased funding for the program in the fall of 1958 and moved its initial test flight date to the right, from 1960 to 1962. While money continued to trickle in on ancillary projects and technologies associated with the new aircraft design, the big allotment of funds for full development never came. In November 1959, President Dwight Eisenhower, not an amateur when it came to military matters, informed White that the B-70 "left

The B-70's range was found to be longer than originally expected due to a newly discovered phenomenon called 'compression lift,' which allowed the aircraft to ride its own supersonic compression wave.

him cold in terms of making military sense." The problem was that the Soviets had not stood still in their SAM development, nor in their development of high-performance interceptor aircraft. The B-70 simply was never going to gain sufficient advantage in the high-speed/high-altitude domain to ensure its own survival and mission success, although its simple presence did cause the Soviet Union to spend billions on upgrading its SAM capabilities.[130] That capability was found alternatively in the ICBM projects being championed elsewhere in the Air Force. By 1960 the B-70 was reduced to an experimental program with only two aircraft being produced, one of which was destroyed during a photo-shoot exercise when an F-104 Starfighter jet collided with it, resulting in the loss of both the F-104 and the B-70.[131] However, key technologies associated with engine design, the brazen steel honeycombed composition of the aircraft's skin, and the B-70's innovative adjustable canard foreplane to achieve stability at lower speeds all contributed in some part to aircraft that came later.[132]

The B-1: A Little Something for Everyone

After the misadventure that was the B-70 program, White needed another bomber in the mix. The 1950s' B-52 would have to retire eventually (or so he thought) and he needed to produce a new bomber to replace it. While momentum was swinging in the direction of the missile force as the primary leg of the nuclear weapons delivery mission, it was generally understood that nuclear-tipped missiles could not be recalled. Manned bombers provided this advantage to decisionmakers: the ability to signal through overt moves, but also to de-escalate with ease. White's problem was that he needed a bomber that incorporated aspects of range and bomb load, while also possessing the high speed and maneuverability to penetrate enemy defenses via the low-level penetration preferred after the loss of the U-2. Previous aircraft such as the Hustler and the B-70 were bred for altitude and speed, but could not handle the G-loads associated with a low-level flight. White's solution was to solicit designs for a Subsonic Low-Altitude Bomber (SLAB) that could also serve offensive, defensive, recon-

The XB-70 simply was never going to gain sufficient advantage in the high-speed/high-altitude domain to ensure its own survival and mission success, although its simple presence did cause the Soviet Union to spend billions on upgrading its SAM capabilities. (U.S. Air Force/Flickr) naissance, and high-speed combat roles. It was a pretty big order.

A number of bomber studies commenced, some done by the Air Force, others by outside agencies. These resulted in a number of bomber designs that covered a range of performance from subsonic to Mach 3 and represented materials from aluminum to titanium. One key aspect of many of the designs was the emergence of variable swept wings. Research during the 1950s that was incorporated into the designs of the F-111 and the F-14 demonstrated how a movable outward tip of a wing could shift the aerodynamic center of the aircraft in flight, maintaining stability at all speeds. With newly emerging technologies and a firm undergirding in professional strategic deterrence literature as to the importance of the manned bomber in the nuclear triad, an interest once again emerged to embark on the procurement of another bomber, an interest that culminated in the Advanced Manned Strategic Aircraft Study (AMSA).

McNamara was convinced that the FB-111 variant of the joint service aircraft would provide the capabilities needed to take the bombing mission forward, but SAC continued to object to the aircraft's relatively short range (3,300 miles) and light bomb load (12,000 pounds). The Air Force and its allies in Congress fought a long battle to maintain funding for the development of a new bomber by investing in individual systems and independent aircraft design research. By 1968 the Air Force had decided that it wanted a variable swept-wing design that would fall somewhere between the FB-111 and the B-70 in size. After Nixon's victory in November 1968, the outgoing Johnson administration submitted a budget that increased funding for AMSA research. Nixon had made the need for a new bomber a part of his election campaign, so it came as no surprise that he arrived in the Oval Office looking for a design that he could shepherd into production. Three companies – Boeing, North American Rockwell, and General Dynamics – submitted designs. North American Rockwell's design with variable-geometry wings and aft-mounted engines was selected in June 1970.

North American Rockwell's design weighed in at 390,000 pounds and was 151 feet long with a wingspan of 140.2 feet. Powered by four General Electric F101 engines, each rated at 30,000 pounds of thrust that could propel the aircraft to a speed of Mach 2.3 at 50,000 feet and Mach 1.2 on the deck at sea level. The aircraft's normal cruise speed ranged from 560 to 650 mph depending upon its altitude, generating a combat range of 6,000 miles while carrying over 100,000 pounds of ordnance on internal and external stations. The aircraft was, of course, designed to be refueled while flying. B-1s were expected to last 1,280 missions or approximately 13,500 hours in the air.[133] The normal concept of operations was for the aircraft and its four-man crew to take off from a base in the United States or in an allied nation with the wings in a 15-degree position and proceed toward

To avoid radar and surface-to-air missile batteries while approaching enemy territory, the B-1 would descend to ground level, sweep the wings back to 65 to 67.5 degrees, and accelerate to ingress enemy territory below the radar horizon, speeding toward the target at supersonic speed. (U.S. Air Force/Flickr) the target at a high altitude with the B-1's wings now configured at 25 degrees but with the aircraft flying at a normal cruising speed to conserve fuel and extend its range. To avoid radar and surface-to-air missile batteries while approaching the enemy nation, the B-1 would descend to ground level, sweep the wings back to 65 to 67.5 degrees, and accelerate to ingress enemy territory below the radar horizon, speeding toward the target at supersonic speed.[134] Upon releasing its bomb load, the aircraft would egress similarly along a low-level route before climbing once again upon exiting the threat country and cruising home on a high-altitude, subsonic speed profile. Low-level supersonic flight was made possible by terrain-following radar, which aided the pilots in their maneuvers over land.[135]

The first of what was to be four prototypes (six were initially authorized) rolled off the line in October 1974 and flew two months later. However, in 1977, the B-1 suffered the same fate as the B-70 and was canceled by President Jimmy Carter and his secretary of defense, Harold Brown, who had been an understudy of McNamara a decade earlier. Carter and Brown cited the high costs of the program and their contention that the better investment was the air-launched cruise missile, which had a smaller radar cross section and could be produced at less cost than the new bomber and then launched from older B-52s as well as naval ships at sea.[136]

The real reason, however, could be tracked to the American development of the B-70 10 years earlier, which had triggered the Soviet Union to begin investing in a new family of tactical fighters that could achieve high altitudes and high speeds. The resulting MiG-25 Foxbat began rolling off Soviet production lines in 1969. It was capable of reaching altitudes of 90,000 feet and speeds of Mach 3.2, but only for a short time.[137] The Foxbat was in turn superseded by the MiG-31 Foxhound, which began testing in 1975 but did not enter service until 1981.[138] It was the defection of Soviet pilot Viktor Belenko with his MiG-25 in 1976 that provided the critical insight that restrained American investment in the B-1 and provided the impetus to go full speed in the development of the Advanced Technology, or "stealth," Bomber (ATB).[139]

Belenko, while delivering the Soviets' most feared fighter, described a new aircraft, the MiG-31 Foxhound, as having an advanced radar that possessed capabilities to "look down/shoot down" American cruise missiles even against the background clutter of forests and mountains. The radar, the N007 Zaslon, represented a breakthrough in aircraft air-to-air sensors. A phased array system, it provided the MiG-31 with the ability to instantaneously scan a wide geographic area while tracking multiple targets simultaneously. This "track-while-scan" capability, along with the radar's ability to discern small radar returns against a cluttered background, challenged all previous American investments in weapon systems.[140] If Americans were to penetrate Soviet air defenses, they were no longer going to be able to go either higher and faster or lower. They would need to disappear altogether. It was this information that persuaded Carter and Brown to terminate the B-1A program, a reasoning that Brown publicly announced in August 1980 to counter claims by the Republican candidate for president, Ronald Reagan, that Carter's decision on the B-1 was a sign of weakness.[141] Even Reagan, once in office and in command of the facts at hand, ultimately limited his order of the B-1 to 100 aircraft, viewing the B-1 as a stopgap measure to keep the bomber defense industrial base alive until the new Advanced Technology Bomber could be introduced.

Although the initial B-1 production program came to a halt in 1977, the four prototypes continued flight test and evaluations, accumulating nearly 1,900 hours of flight data, including electronic countermeasures system checks and penetrating maneuvers tests, on the new design prior to being grounded in 1981.[142] This data came in handy four years later when Reagan acceded to the presidency and decided to begin full-scale production of the B-1 as part of his overall arms buildup to confront the Soviet Union. The flight tests and the interregnum since Carter's termination order had allowed Rockwell and the Air Force to consider several modifications to the aircraft's basic design. The new airplane, designated the B-1B, that emerged was heavier (going from 395,000 pounds to 477,000) and slower (from Mach 2.3 top speed down to Mach 1.25) but could carry more ordnance (75,000 pounds), had a smaller radar cross section, and would be more effective as a low-level penetrating strike bomber. The new bomber carried every type of ordnance, from nuclear weapons to conventional bombs to the new Tomahawk cruise missiles.[143] The range of the aircraft also increased, from 6,000 to nearly 7,500 miles.[144] In the end, the changes persuaded the Reagan administration to order a production run of 100 aircraft, effectively replacing the previous supersonic bomber, the B-58, 15 years after it had left service.

The B-1B Lancer (affectionately named the B-One or "Bone" by its crews) rolled off the assembly line in 1984 and became operational in 1986.[145] It did not see combat until 1998 during Operation Desert Fox but has participated in every conflict since, from Yugoslavia in 1999 to Afghanistan, Iraq, and, most recently, Syria. During the first six months of Operation Enduring Freedom, eight B-1Bs dropped nearly 40 percent of the total ordnance expended, including nearly 3,900 precision-strike JDAMs, which was around 70 percent of that particular weapon.[146] Today 92 of the original 100 B-1Bs built remain in service. Eight have been lost to training accidents.

If Americans were to penetrate Soviet air defenses, they were no longer going to be able to go either higher and faster or lower. They would need to disappear altogether.

The B-2: Modern Long-Range Attack

In 1974 the U.S. government, through the Defense Advanced Research Projects Agency (DARPA), initiated a study as to whether a manned low observable or "stealth" aircraft could be built as a means of overcoming increasingly effective defensive air-search radar / surface-to-air missile combinations. Lockheed, which had gained significant radar cross section (RCS, the standard term of radar reflectivity measurement) reductions with its A-12/SR-71 spy plane, and Northrop, which presented an innovative design that became known as "the whale," participated in the study. The concepts that emerged drove stealth aircraft design as well as the development of radar absorbent materials (RAM) for the next generation. Lockheed's research led directly to the F-117 stealth attack aircraft, which depended on its jewel like multifacet design to direct radar energy away from the aircraft, preventing its return to its transmitter receiver.[147] The B-52 possesses an RCS of 100m2, which is somewhat analogous to the radar reflectivity of the side of a metal barn. The B-1B, a generation removed from the B-52 and already having an eye for RCS reduction, came in with an RCS of 1m2, about the size of a metal food cooler you might take on a long trip, but the F-117's design reduced its RCS to an incredible 0.01m2, about the size of a bird, a dramatic improvement.[148] Northrop's design and investments, however, went another direction.

The Advanced Technology Bomber program began in the waning years of the Carter administration. Both Lockheed (teamed with Rockwell) and Northrop (teamed with Boeing) submitted plans. Both submitted designs that resembled flying wings. Northrop's previous experience with its B-35 and B-49 designs decades earlier provided an advantage with the computerized (four of them) fly-by-wire system that managed the aircraft's control surfaces. Lockheed submitted a flying-wing design that also borrowed heavily from its partner's (Rockwell) experience in shifting from the B-1A to the B-1B as well as the lessons learned from the F-117 stealth attack aircraft project. The Advanced Technology Bomber had, as always, hefty goals: a 6,000-mile unrefueled range, a weapons load of nearly 20 tons, a low radar and infrared signature. Gone were the demands for supersonic speeds or ever-higher altitudes. All that mattered now was an aircraft that could disappear.

The competition between the two companies began on paper, progressed to wind tunnels, and finished with a "pole off" wherein both companies supplied scaled models to be measured for their radar cross section while mounted on a pole and having radars of various bands and frequencies fired at them. Northrop's design won going away, having achieved greater flight performance while also remaining "stealthier" across more transmission frequency bands than its competition. Northrop had also perfected ways to mask the aircraft's own source transmissions, hence reducing both the reflective and transmitting signatures in the final design.[149] The B-2 development program started in 1981 and full-scale production began six years later.

Initial mistakes added costs and time to the B-2's development. In 1980, the B-2 design team settled on a design that was optimized for stealth at high altitudes, and began to finish plans based on this design. At the same time a doubtful Pentagon began researching how adversaries might counter stealth aircraft. While these studies found that stealth aircraft were not completely invisible, more importantly they suggested that during the B-2's service life the Soviet Union might build large ground-based radars that could overpower stealth technology at a useful range. The Air Force then decided

The B-2's range, bomb load, and stealth allow two B-2 aircraft, unescorted by fighters, to equal the destructive capacity of 75 small attack aircraft. (U.S. Air Force/Flickr)

halfway through the program to do a complete redesign on the B-2 to enable the aircraft to bypass those radars at low altitude, thereby using terrain features to protect itself. By completely altering the airframe to strengthen it and optimize its aerodynamics for low-altitude flight, the Air Force made two mistakes. First, a complete redesign added significant cost to the already expensive program (designers basically had to completely design the aircraft twice). Second, the flight control systems and surfaces required for stable low-altitude flight were not as stealthy, as they added extra "V" or chevron-shaped surface and extra moving parts on the trailing edges of the aircraft. Making the aircraft more capable at lower altitudes made it much less stealthy.[150] The B-2's redesign caused a decrease in range and payload and most importantly increased its radar cross section.

Originally the Air Force was set to procure 132 of the new bombers to meet strategic deterrence mission goals, but the end of the Cold War scrambled initial assumptions and was the catalyst for changes to the aircraft's design late in the program development process to better allow it to contribute to conventional missions.[151] The aircraft also suffered from a growing public perception during the 1990s that the world was, and would be, quite friendly to the idea of forward-basing U.S. tactical aircraft at foreign bases. This perception rendered the importance of intercontinental range somewhat moot. This phenomenon had the ancillary effect of decreasing the importance of long-range strike and the bombing mission across the force. Between 1990 and today the bomber force has dropped from 17 wings consisting of 22 squadrons to five bomber wings made up of but nine squadrons. With regard to the B-2, sadly, in a strategic sense, only 21 of these modern bombers were ultimately produced before production was terminated.[152]

The ultimate aircraft produced, the B-2 Spirit, possesses a wingspan of 172 feet and measures just 69 feet in length. Crewed by two pilots, the aircraft can climb to 50,000 feet while reaching ranges in excess of 6,000 miles without refueling. The aircraft's massive

Making the aircraft more capable at lower altitudes made it much less stealthy. The B-2's redesign caused a decrease in range and payload and most importantly increased its radar cross section.

bomb bays carry more than 40,000 pounds of ordnance ranging from small-diameter bombs to nuclear weapons. B-2s can reach high subsonic speeds but are not designed to break the sound barrier.[153] The days of extreme altitudes and extreme speed are gone. Instead the aircraft depends upon its incredibly low radar cross section, 0.0001m2, which is about the size of an insect, to get it to its targets and back safely.[154] The B-2's range, bomb load, and stealth allow two B-2 aircraft, unescorted by fighters, to equal the destructive capacity of 75 small attack aircraft.

The B-2s have traditionally been used during the opening days of a campaign when the threat posed by enemy air defenses is the highest.

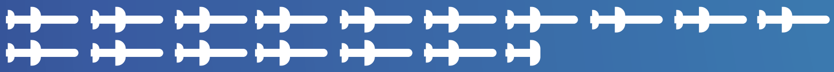
Although the B-2 entered initial service in 1993, it did not reach full operational capability until 2003.[155] Originally the B-2 was restricted to the strategic deterrence/nuclear delivery mission. The end of the Cold War and declining defense budgets resulted in a decision to truncate B-2 production at 20 aircraft (driving unit costs, with R&D expenses factored in, to nearly $2 billion per aircraft). This high unit cost was the result of the aircraft's low production run. Had the entire 132-aircraft run been completed, the unit cost would have averaged around $350 million.[156] The B-2 first proved its military might in Kosovo during Operation Allied Force, when it destroyed a third of all Serbian targets in the first weeks of the war. B-2s operated from their home base at Whiteman Air Force Base in Missouri, flying nonstop to their targets and then home again. The B-2 made its first forward deployment away from Whiteman in support of Operation Iraqi Freedom.[157] The B-2s have traditionally been used during the opening days of a campaign when the threat posed by enemy air defenses is the highest. They successfully strike the most heavily defended targets and help to dismantle leadership and air-defense-related targets in the opening hours, thus "knocking down the door" and making it safer for more conventional aircraft to operate during the later stages of the air campaigns. Most recently, on January 19, 2017, President Barack Obama's last full day in office, he ordered B-2s to attack an Islamic State training camp in Libya. The B-2s dropped over 100 precision weapons on the camps, killing more than 100 Islamic jihadists. The B-2s were reportedly chosen for the mission due to their ability to loiter over the area for a prolonged period.[158]

Jack Northrop, the visionary garage mechanic turned aeronautical engineer, retired abruptly from aviation in 1952, shortly after the final cancellation of his flying-wing bomber program by the Air Force. He was only 57. He sold his shares in the company that bore his name, made a number of bad real estate investments in the decades that followed, and saw his health decline. In 1981, just after the Air Force selected Northrop's highly classified flying-wing design for the B-2, the CEO of the company, Thomas Jones, approached the Air Force and asked permission to share the design with the company's founder. The Air Force granted its permission.[159] Confined to a wheelchair and unable to speak, Northrop stared at the design and then motioned for a pad of paper. He wrote, "Now I know why God has kept me alive for 25 years."[160] He died shortly thereafter. Bombers would never be the same again.

CHAPTER 04

THE LAUNCH OF THE B-21 ‘RAIDER’

PAYLOAD - ˜35,000 LBS



= 2,000 LBS

2020s

STRATEGIC RANGE

On February 26, 2016, then-Air Force Secretary Deborah Lee James revealed the first rendering of the B-21, the future of America's heavy-bomber force.[161] Later that year one of this report's authors had the honor of being present as she announced that the B-21 would be named Raider, harking back to a great moment in Air Force history when then-Lieutenant Colonel (later Lieutenant General) James H. "Jimmy" Doolittle led 16 B-25 medium bombers, Doolittle's Raiders, off the deck of the Navy's USS Hornet on a daring raid against mainland Japan.162 The heavily laden B-25s clawed into the sky from the rocking deck of the carrier to individually strike targets in the enemy's capital and two other cities on April 18, 1942. Although the raid inflicted very little damage and resulted in the loss of all 16 aircraft, it boosted American morale, shook Japanese confidence and demonstrated that America could hold the Japanese heartland at risk, a strategic psychological victory for the Americans. As a result, the Japanese drew precious military resources back to Japan early in the war to bolster homeland defense.[163]

The B-21: What Is Known

James announced the B-21's name at the annual Air Force Association's Air, Space, and Cyber Conference on September 19, 2016. As part of the secretary's message, she invited the sole remaining survivor of Doolittle's raid, retired Lieutenant Colonel Richard E. Cole, to join her onstage. The music blared as the national treasure well-deserving pilot slowly made his way to the stage. For at least one observer sitting in the crowded convention center surrounded by fellow airmen and air-power proponents, it was impossible not to ponder the real meaning of the symbolism of the name Raider. Were they honoring a courageous group of men who did the unthinkable in early 1942, or were they sending another message? Were they saying that although the mission was tactically insignificant, its strategic importance could not be questioned? Was the very notion of a new stealth bomber that could hold any enemy capital at risk, that could affect regime change, that could dramatically shorten the duration of future wars the real message, and would they produce enough of the bombers to make both a strategic and tactical impact on tomorrow's battlefield?

The B-21 next-generation stealth bomber is a critical part of America's air-power future and has been presented as a partial remedy for the area-denial and anti-access capabilities. (U.S. Air Force/Flickr)

Due to the classified nature of the B-21 program, the American public has few details about the aircraft and the contract to build it; as a result, there is rampant speculation. Here is what is known. By all accounts from Department of Defense and Air Force senior leaders, the B-21 next-generation stealth bomber is a critical part of America's air-power future and has been presented as a partial remedy for the area-denial and anti-access (A2/AD) capabilities of Russia, China, Iran, and North Korea, all of which began investing in A2/AD systems in the mid-1990s after the United States' overwhelming success during the 1990-91 Operation Desert Shield-Desert Storm campaign. These A2/AD systems have been designed to hold American air and sea power at risk and deny U.S. forces access to seas and airspace stretching out hundreds and or even thousands of miles from an enemy's territory. A2/AD advanced integrated air defense systems make it possible to target and shoot down conventional aircraft from hundreds of miles away; combined with increasingly lethal surface-to-surface cruise missiles and ballistic missiles, these systems put America's fixed instillations and carrier groups at risk. Capable A2/AD systems effectively form walls that push operating areas for conventional aircraft and ships out thousands of miles from territorial borders and present the United States with "tyranny of range" problems.[164] The rise of these systems triggered a reappraisal of the United States' strategic position in the world and the conclusion that a requirement for long-range penetrating bombers was once again present. Unfortunately, the United States as a nation was late to grasp this truth and now finds itself "late to need."

Some thought had been given during the early deliberations about the new bomber to shifting to a large aircraft derived from a commercial design, perhaps even a 747, and equipping it to carry a huge load of long-range cruise missiles within its fuselage.[165] The thought was that the large, and perhaps cheaper, big-wing aircraft would fly to the edge of the A2/AD border and then disgorge its load. However, cost analysis demonstrated that cruise missiles were neither cheap in mass nor guaranteed to penetrate enemy air defenses in sufficient numbers to bring about success.[166] The decision was made to go with a stealthy bomber with traditional range and ordnance-carrying capacity that could drop cheaper (at least in comparison to cruise missiles) precision-strike weapons.

It is worth noting here that the Air Force is still dedicated to using advanced cruise missiles as part of its nuclear deterrence. The Air Force has continued to press forward with development of the long-range standoff weapon (LRSO) that is to replace the AGM-86B ALCM.As mentioned previously, the ALCM emerged in the early 1980s and was only designed to have a 10-year life span. Unlike the ALCM and ACM, which can only be fired from the B-52, the LRSO is being designed to be fired from the B-2, B-21, and B-52. Thus, the LRSO will give the entire nuclear-capable bomber force a true long-range standoff capability. The LRSO is being designed to penetrate the most advanced A2/AD systems and provide even the stealthiest platforms an option to employ cruise missiles instead of penetrating ever-more-complex A2/AD environments. This will provide older bombers, such as the B-52, a viable nuclear threat while giving more survivable platforms greater options and flexibility. The LRSO is designed to keep the entire bomber force, stealthy or not, credible as a nuclear deterrent well into the future.[167]

> **Much like the American F-35, the B-21 will work as a forward-deployed sensor and communication node and as a surveillance and possible electronic warfare platform, as well as someday eventually controlling swarms of drone aircraft in mutually supporting attacks.**

By the very nature of its stealth origins, the B-21 is designed to penetrate the most advanced enemy air defense systems by possessing a reduced or barely existent radar cross section. The stealth design in effect shrinks the effective size of the enemy's radar detection and target track radar range rings. The B-21's stealthy traits will allow it to go where other aircraft cannot and to attack important targets deep within enemy territory to metaphorically "kick down the enemy's door," taking out A2/AD systems and allowing other aircraft to have access to the area. Its very pedigree as a bomber will provide it with the range to fly from distant airfields well beyond the enemy's A2/AD wall and still have the ability to reach important targets and possibly even remain in enemy territory for extended periods while searching for new targets. Much like the American F-35, the B-21 will work as a forward-deployed sensor and communication node and as a surveillance and possible electronic warfare platform, as well as someday eventually controlling swarms of drone aircraft in mutually supporting attacks. There was even talk that the B-21 itself may eventually be capable of being an unmanned platform.[168]

The Raider will be able to plug into a network of other Air Force fifth-generation aircraft, including the F-35 and F-22, to share information and to better compose a complete picture of the electronic and physical layout of the modern battlefield. While revealing the image of the B-21 to the public, Secretary James commented, "Our fifth-generation global precision attack platform will give our country a networked sensor shooter capability enabling us to hold targets at risk anywhere in the world in a way that our adversaries have never seen." While the Air Force initially intended the B-21 program to use many off-the-shelf technologies to hold costs down, there is much speculation that the B-21 will introduce new stealth technologies better suited against today's more modern air defenses.[169]

There have been many advances in stealth technology since the B-2 first took to the air on July 17, 1989.[170] Some of these advances have been used on subsequent stealth aircraft such as the F-22 or F-35, but since both these aircraft were actually flown as prototypes in 1990 and 2000 respectively, many more advances have been made.[171] Prior to awarding the contract to Northrop Grumman in 2016, the Air Force worked closely with a number of defense contractors as part of a classified research and technology phase to explore the possible technologies they could use on the B-21. Leading up to the formal announcement, the Air Force had already made a $1 billion technology investment in the new bomber. Then the Air Force made an assessment of the available technology, then set the requirements and locked them down. According to Lt Gen Arnold Bunch Jr., the military deputy, Office of the Assistant Secretary of the Air Force for Acquisition, "We set those requirements so that we could meet them to execute the mission with mature technologies." In other words, the B-21 will use proven technologies. To incorporate new or not yet developed technologies into the aircraft throughout its life cycle, the Air Force plans to use an "open systems architecture," a modular engineering method that designs the platform in a way that allows it to quickly integrate new technologies as they emerge. Bunch said: "We're building this with an open mission systems architecture. As the technology advances and the threat changes, we can build upon the structure. I can take one component out and put another component in that addresses the threat. I have the ability to grow the platform."[172]

What can be discerned from the concept art of the B-21 is that Northrop Grumman returned to its original design of the B-2 for inspiration. The B-21 looks surprisingly like the original Advanced Technology Bomber or the original B-2 concept from the 1980s. If the current concept art is accurate, the B-21 will take advantage of the smaller radar cross section demonstrated on the original B-2 design. This also means the aircraft is optimized for high- to medium-altitude flight. The return to the original design might also return some of the range and payload capabilities that the low-altitude redesign gave up.[173] Although the released drawing is just a rendering, many aviation writers are assuming the lack of chevron-shaped angles on the trailing edge of the aircraft will likely minimize the radar cross section against low-frequency radars. In addition, the longer outboard wing sections of the B-21 may also help increase endurance and operational altitude.[174]

The program is so secretive that the contractors and exact costs of the components are even being withheld from the public. The Air Force has said it plans to field the B-21 by the mid-2020s and hopes to acquire as many as 80 to 100 for a cost of approximately $550 million per aircraft in 2010 dollars.[175] The bomber is part of the Air Force's and Department of Defense's plan to modernize the nuclear triad, which means it will eventually be capable of delivering nuclear weapons, thus making it even more important that it remains a budget priority. The B-21 itself is being positioned for the budget battle to come. The bomber designation of B-21 is designed to remind Congress and the taxpayers that this aircraft is the bomber of the 21st century.[176]

The secrecy surrounding the project has led to much speculation about the B-21's performance. Many assume the aircraft will be smaller than the B-2 and might carry a smaller payload due to advancements in precision weapons. One weapon the B-21 has to be able to carry is a bomb that was designed to fit snugly in the bomb bay of the B-2, the GBU-57A/B Massive Ordnance Penetrator (MOP). This 30,000-pound "bunker-busting" bomb was designed to be carried by the B-2 and be employed against the most complex bunkers on the planet. Range and payload have always been a tradeoff.[177] You can increase range by reducing payload and the equation also works in reverse. The Air Force will not want to see this capability go away, so they could settle for the B-21 carrying just one bomb where the B-2 could carry two, one in each of its dual bomb bays. Others have supposed that the B-21 will have two engines instead of the four the B-2 uses, but for now that is all just that, speculation. No matter what the final specifications for the B-21 will be, one thing is clear. If it is as stealthy and survivable as advertised, it will impose a high cost on potential adversaries. They will be forced to develop, fund, and field more advanced radars, SAMs, and aircraft to keep the B-21 at bay. That in turn keeps them spending large amounts on defensive systems and eventually hurts their ability to fund offensive systems that hold the continental United States at risk.

Performance Characteristics

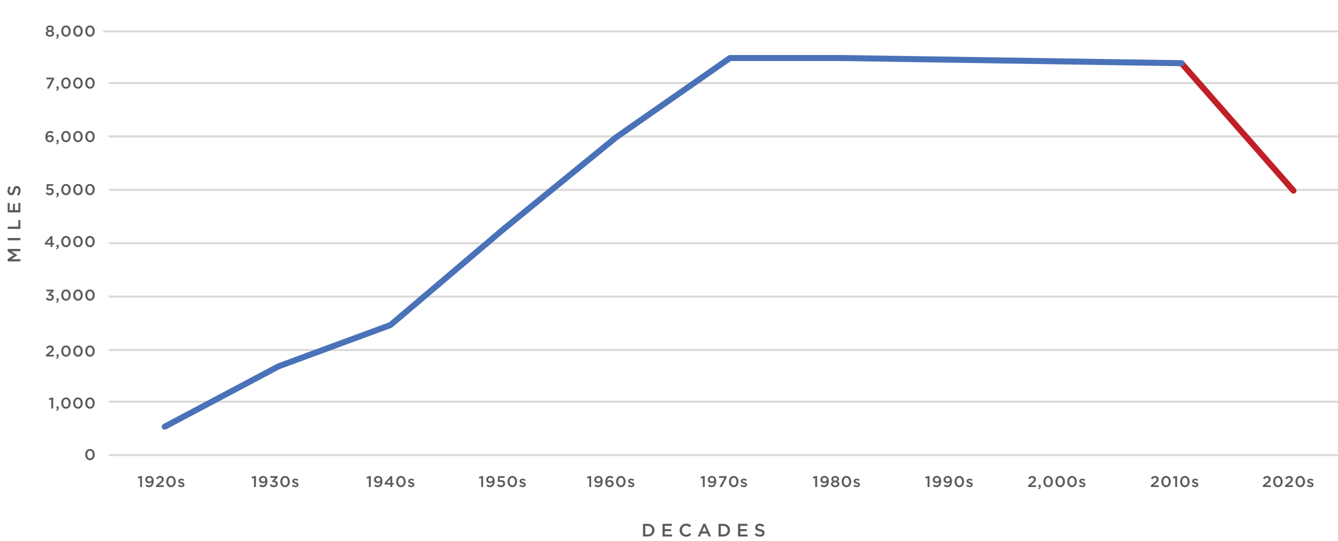
Based on our current trend analysis gained through following the historical development of American heavy bombers in this paper and based on open-source data, one can draw certain assumptions. First, the B-21's aerodynamic design properties and stealth characteristics mean that it will remain a subsonic aircraft with airspeed capabilities similar to that of a B-2. The design, featuring an extremely long wingspan, a very short body and no conventional tail, is not stable at supersonic speeds. Second, the service ceiling will be between 45,000 and 50,000 feet. At altitude it will also perform similarly to the B-2 and will find maximum fuel efficiencies at higher altitudes. Third, the range will be between 4,000 and 5,000 nautical miles. In an interview with *The National Interest*, former Air Combat Command Commander Gen. William Fraser III, a B-2 and B-52 pilot, stated what the B-21 would need to accomplish its mission in terms of range. Fraser said, "A combat radius of between 2,000 and 2,500 nautical miles is sufficient, which equals a 4,000–5,000 nautical mile range. All points on earth are within about 1,800 nautical miles from the closest body of water." Of course, he was assuming the Air Force would be able to aerially refuel its future bomber over international waters. Thus, one can assume that the B-21 will have at least that much range capability.[179] Fourth, the payload will at least be as high as 30,000 to 35,000 pounds as mentioned previously. It could actually be higher since the B-2 can carry twice that load.

System Integrator

While considering the B-21's ability to operate in contested airspace while carrying out a wide range of mission sets, we beg the reader's indulgence while presenting an analogy derived from an episode of the original

AVERAGE STRATEGIC RANGE[178]

Strategic Range (miles) including projected average through 2020s with the B-21



Strategic Range (miles) including projected average through 2020s with the B-21. With a projecting drop in the average strategic range of the heavy bomber force, leaders will have to consider critically how to employ successfully the B-21 in a less permissive A2AD environment.

Star Trek television series. In 1968, near the end of the original series' run, writers presented an episode, "Wink of an Eye," wherein the starship *Enterprise's* heroic captain, James T. Kirk, finds himself "hyper-accelerated" to the point that he disappears from the view of his crew, manifesting only as an annoying buzzing sound as he moves around the ship. Kirk's invisible actor condition provides us with an insight as to the real advantage of the B-21: its ability to sit in the middle of the battlespace, hearing all, seeing all, and yet remaining undetected, choosing its moment to have effect and then silently moving on without even an annoying buzz.

This ability derives from the aircraft's combination of stealth, swift onboard computers, and passive sensors. Presumably deriving much of its design and construction from the all-aspect, broadband stealth design of the progenitor B-2 Spirit, the B-21 should have a radar cross section somewhere between the size of metal bumblebee and a golf ball. This should ensure its ability to penetrate contested and heavily sensor-laden airspace, but should this advantage not be enough, the aircraft's passive sensor suite, which can leverage the technical lessons learned from the F-35 program, should provide it with enough information to maneuver away from sensors before the B-21 breaks through the signal to ambient noise barrier to become visible on enemy radar screens.

The F-35 aircraft uses its onboard computers to fuse the inputs from various sensors, active radars, passive electronic surveillance antennas, and optical and infrared receivers, to provide the pilot with a 360-degree understanding of the aircraft's near and distant operating environment.[180] The aircraft's radar, which detects targets by actively transmitting an electronic signal and then "listening" for its bounce-back return off of its target, can determine the target's location, course, and speed. However, it is also possible, much like submarines do with their sonars, to use the electronic surveillance receiver arrays to passively listen for the active signals being transmitted by targets without ever putting an active, identifying signal out into the local spectrum. By isolating and negating the background electronic self-noise of the aircraft, modern stealth aircraft can detect distant and faint radar transmissions before the targeting radar can begin to break fifth-generation aircraft out of the ambient electronic background noise.[181] Under these conditions, the aircraft's crew can gently maneuver to remain safely outside the detection range of the opposing sensor.

Should it be impossible to achieve this standoff, either due to the density of the sensor network or perhaps the proximity of the sensor to the bomber's intended target, then the aircraft could use self-jamming equipment to muddle or confuse sensors in critical frequency bands. Since this type of equipment is necessarily active and places electronic signals into the environment that could lead to detection of the bomber, the equipment would be used judiciously, with speed and finesse. These actions are possible due to the processing speed of the onboard computers, which can make millions of calculations and decisions per second to help mask the aircraft from opponents' operational view.[182] The combination of sensors and computing speed will allow the B-21 to hide in plain sight, always shifting its exposure just enough to remain out of view. This approach will enable it to remain within a contested environment for extended periods. Such duration will allow the B-21 to serve in a new role as a "sensor-shooter" against the newly emergent set of targets: widely dispersed weapons systems, deeply buried positions, and road mobile sensors/weapons.[183] These new target sets arose from the enemy's recognition that the United States' precision-strike complex had allowed it to find targets, fix their precise location, and then destroy them. By widely dispersing sensors and weapons, burying weapons or command and control nodes, or mating weapons with mobile vehicles, the enemy interrupted the find-fix-destroy chain by taking advantage of the time between finding a target and returning to destroy it. A long-duration B-21 could provide a long-stare intelligence, surveillance, and reconnaissance capability that, upon locating a moving or recently relocated target, could instantly destroy it. The B-21's large ordnance load-out will allow it to deliver a high volume of fire within a single mission against multiple targets. Its large fuel tanks

Presumably deriving much of its design and construction from the all-aspect, broadband stealth design of the progenitor B-2 Spirit, the B-21 should have a radar cross section somewhere between the size of metal bumblebee and a golf ball.

and resulting increased range or loiter time will allow for persistent fires over a longer period.

These characteristics firmly establish a new direction for the "bomber" in future operations. Bombers of the past operated in group formations both to ensure self-defense using overlapping defensive fields of fire and to guarantee the destruction of targets by having multiple aircraft drop their bomb loads at once, whereas the bomber of the future will carry large bomb loads but act as a lone participant on long-range missions, hitting multiple targets at various locations during a single sortie. The B-21, given its endurance, could even remain on station after it had expended its ordnance load to continue to identify targets as they emerge and then access long-range standoff weapons carried on nonstealth platforms, aircraft, or ships positioned outside the A2/AD "bubble." Communicating with these other ships and aircraft those platforms through advanced tactical communications links could dramatically expand the inflight weapons magazine of the bomber and increase its lethality. Stealth, communications, precision-strike, long-range, and full sensor integration capabilities not only enable this concept of operations, they often drive mission planning to this outcome as a consequence of these characteristics in a heavily contested environment.

The B-21's duration will allow it to serve in a new role as a 'sensor-shooter' against the newly emergent set of targets: widely dispersed weapons systems, deeply buried positions, and road mobile sensors/weapons.

Sizing of the Force

The original production plan for the B-21 stated that the Air Force hoped to acquire 80 to 100 new bombers. The FY2017 budget submission, created after the program was announced and had gained momentum, settled on the higher number as the program's goal.[184] These will replace retiring older B-52 and B-1B aircraft while supplementing newer but rapidly aging B-2 Spirit bombers. Another option would be to retire the B-1s and B-2s (a fleet of only 20 B-2s is very expensive to maintain), replacing them with 100 B-21s while providing new engines to the fleet of B-52s to maintain a contingent of cruise-missile-capable bombers. The "100" number was settled upon at the insistence of the Air Force's Global Strike Command's chief, General Robin Rand, who said that 100 aircraft represented his "best military advice" based upon his assessment of the demands of the regional combatant commanders.[185]

Military forces exist to serve two purposes, one largely understood and another often overlooked. Military forces exist to serve two purposes, one largely understood and another often overlooked. Winning the nation's wars is an obvious goal. The less obvious purpose is the requirement to supply aircraft to two major regional conflicts on the scale of the 1991 Iraq War or a defense of South Korean against an attack by North Korea. According to an Air Force Association Mitchell Institute study, a bombing campaign against North Korea would be expected to last 30 days. The peninsular nation has just under 74,000 targets, and planners believe that 60 combat bombers would be needed to successfully complete the campaign. A bombing campaign against Iran, on the other hand, could be expected to last 60 days. The Islamic Republic, with its widely varying geographic characteristics, has 82,000 target points. Commanders believe that such a campaign would require 103 bombers. A war against a rising great power such as Russia or China would pose an even greater challenge. Russia, for instance, has nearly 260,000 target points, three times the number associated with Iran. An air campaign against Russia is projected to last 180 days at a minimum and would require nearly 260 bombers.[186] Today the Air Force has fewer than 100 combat-coded bombers, well shy of the levels required to respond to two regional conflicts simultaneously.[187]

There is a second purpose for military forces beyond winning wars, and that is preventing them from occurring. Nations, especially competing nations, exist in a state of continuous collision, each straining against the other, or perhaps even multiple others, to uphold their interests or perhaps even shift conditions in their favor. Military forces, especially naval forces historically and air forces in the modern era, are deployed in "peace" to maintain "presence" in contested regions. These forces demonstrate national resolve, revealing what their nation stands for and, perhaps most importantly, what it will not stand

FORCE STRUCTURE REQUIREMENTS

Number of B-21s Nedded for a Minimum Force

Combat-Coded	120
Trainers	20
Backup and Attrition Planning Purposes	24
Total	**164**

for. Such forces, often face-to-face with peer military forces, provide daily opportunities to compete and, in do ing so, help to bleed off tensions between countries before they can flash into open warfare and destruction.

Such interactions allow for deterrence dynamics to gain traction, aiding in the maintenance of stability and peace. Nations with militaries that are too small to maintain persistent forward presence tend to invite competition and instability on a scale too large to be controlled. Under these circumstances, the reintroduction of forces back into a neglected region "shocks" the new equilibrium to a degree that can result in conflict.[188] Consistent presence is the key to avoiding such eventualities, and a bomber force of less than 100 combat-coded aircraft is simply too small to meet combatant commander requests for presence missions.

The Air Force tacitly acknowledges this within its own deployable force structure, which consists of 10 Air Expeditionary Forces (AEF) formed and trained to deploy on a rotational basis around the world. While each AEF comprises an assortment of tactical, strategic, and logistical aircraft, the current Air Force force structure is unable to meet the requirement to supply each AEF with one bomber squadron made up of a minimum of 10 and optimally 12 bombers. Should one deploying squadron rob another of its aircraft to meet requirements, the robbed aircraft will not be available for scheduled maintenance and training evolutions of the home-based AEF. Such conditions also create the accelerated demise of the force as the smaller numbers of aircraft are used at ever-increasing rates. Therefore, it is important to establish a base line of 12 combat-coded bombers per squadron, and 10 squadrons to fill out the 10 AEFs, resulting in a minimum requirement of 120 combat-coded bombers.

This is still shy of the 130 combat-coded bombers identified as optimal in a 1999 Air Force white paper, or even the 166 bombers suggested by the 1992 post-Cold War bottom-up review.

Combat-coded aircraft do not strictly define the total number of aircraft required. Generally, training aircraft, backup inventory, and an attrition reserve (for aircraft lost to accidents or in combat) also are considered in the upfront purchase.

Historically, a training squadron is larger numerically than an operational squadron in order to supply the force with trained pilots, technicians, and maintainers. In the past, a figure of 25 percent of the operational force has been used, which would equate to 30 aircraft, but modern simulators could likely help reduce this number to 20. Similarly, 10 percent figures for backup inventories and attrition reserve – which would equate to 12 aircraft each (or the equivalent of two full squadrons) – have been used, and serious consideration must be given before shifting away from these historic lessons learned, especially in light of the losses of B-52, B-1B, and B-2 aircraft to either training accidents or combat.[189] When considering theoretical requirements of up to 200-plus bombers to prosecute a penetrating strike mission against a great power such as Russia or China, it is better to err on the side of caution and maintain a healthy complement (24) of backup and attrition aircraft.

Taken together – 120 combat-coded bombers, 20 trainers, and 24 planes for backup and attrition planning purposes – the minimum buy would be 164 aircraft. Initial reporting suggests that aircraft production will begin in the early 2020s and reach initial operation capability (IOC) by 2025. The first 21 aircraft will be procured under a low-rate initial production schedule.[190] This is troubling from a strategic vantage point. Given that Russia, China, Iran, and North Korea have been investing in A2/AD capabilities since the mid-1990s and that the United States has but 20 B-2 bombers capable of conducting long-range strikes into contested areas, the nation is already 20 years late in its response. Another decade's passing prior to IOC will only compound the strategic problem.

CHAPTER 05

CONCLUSION

Why does the U.S. military have bombers and what do they offer? Through the history of military aviation bombers have provided range, payloads, and lethality unequaled by other aircraft and very few weapons systems. This analysis began with the dawn of combat aviation in WWI. In the beginning, airplanes dropped small bomb loads as a lone aircraft or in small groups. Very little was done in formation until later in the war, when the formation size began to grow in an effort to provide both mass and protection. Initial ranges of the aircraft did not allow them to reach strategic targets deep into enemy territory unless they took off from ships or started their journey close to their targets, such as when Germany bombed London from occupied Belgium. There was, however, the beginning of the thought that if one country could reach the other's strategic center, political or economic, the war could be shortened. After the war, technology continued to advance, materials became stronger, engines got bigger and more powerful, and aircraft size, speed, altitude, payload, and range all increased. Many nations, sparked by the writings of Douhet, Mitchell, and others, began to develop the tactics and forces that could deliver formations of bombers deep into an enemy's heartland. Purposely designed heavy bombers could now hold enemy leadership, capitals, industry, and populations at risk.

Initially, advances in technology favored the larger, faster, and higher-flying bombers. As WWII approached, fighter technology began to catch up, but not before the Americans and British had designed heavy long-range bombers designed to attack enemy targets far beyond the reach of their fighter escorts. After experiencing large combat losses during the daytime, the British switched to a night flying campaign that sacrificed precision and formation integrity. Unwilling to sacrifice precision, the Americans continued forward with the Norden bombsight, heavily armed bombers, huge formations of mutually protecting aircraft, and the belief that the bomber would always get through. The large formations provided support, but they were also the only way the bombers could really destroy a single target given the lack of precision of that time. Mass made the difference, not the individual weapon.

In Europe, thousands of bombers supported by almost an equal number of fighters finally gained air superiority, and eventually the loss rates were sustainable. Meanwhile, in the Pacific a long military campaign characterized by "island-hopping" slowly but surely brought bombers first within range of the next island, but ultimately within range of Japan. There, the large, fast, and adaptable B-29 moved back from the tactic of high-altitude daylight bombing in large formations, instead dropping to medium and low altitudes to lay waste to Japanese cities at night with very little fighter protection. The advent of the atomic bomb exponentially increased the value of a single bomber over a target. Despite the trend toward the end of the war to attack in streams of aircraft or in small groups for conventional strikes, bombers would continue to fly in groups of three or more through Korea and Vietnam. The nuclear mission was altogether different, as one bomber could do so much damage. Still, despite all the changes and advances, the advantages of the heavy bomber remained its range and ability to get through the enemy defenses and threaten regime change, capitals, industry, and populations deep in the heartland of a nation. Bombers could not make a huge difference in North Korea because the real leadership during the later years was in China, not Pyongyang. In Vietnam, when the bombers were used against Hanoi, the communists came to the negotiating table.

> **The bomber force has survived because the United States was always able to make the argument that its heavy bombers provided critical strategic versatility as a recallable, reusable, visible, and flexible nuclear force.**

Although bombers were always about range and lethality, the Cold War brought that to a higher level. The distances between enemy capitals necessitated ever-greater ranges that were aided by the advent of aerial refueling. The weapons of the Cold War also meant that one bomber could deliver unthinkable damage with multiple weapons. At first the bomber was the only weapons system that could deliver an atomic weapon deep into enemy territory. Even with the development of ICBMs and SLBMs that could deliver nuclear weapons more rapidly, the bomber force continues to serve as a critical leg of the United States' nuclear triad. It has survived to this day because the United States was always able to make the argument that its heavy bombers provided critical strategic versatility as a recallable, reusable, visible, and flexible nuclear force. Bomber development in the 1950s and '60s trended in the direction of extreme high-altitude, supersonic aircraft to fly over enemy threats or A2/AD. When radar and SAM technology continued to match aircraft technology that trend gave way to the reality of hundreds of support aircraft accompanying streams of B-52s into heavily defended A2/AD environments to screen them, protect them, and attack the A2/AD systems. Vietnam is a great example of the enormous resources required to get the bombers in and out safely. The trend in the 1970s and early '80s was back to supersonic, but now low-altitude bombers such as the FB-111 and the B-1 could take the fight to the enemy by flying below their radars. Even the B-52 did most of its training at low altitudes during this period. When one of this report's authors was first assigned to the B-52 training squadron in spring 1999, he flew on one of the last real B-52 low-level training missions. In the career that followed, only one additional low-level mission has been logged to simulate dropping mines or for special orientation training in both the B-2 and B-52. Besides drastically cutting range, this low-level tactic did not keep bombers much safer. Vietnam, and to a lesser extent the first Gulf War, proved low-flying aircraft are very susceptible to enemy fire.

The era of the late 1980s through the present day brought back a familiar trend with a twist: one of new long-range, high-altitude bombers that fly at subsonic speeds, at altitudes around 40,000 feet, and at ranges of 4,000 to 5,000 nautical miles. These bombers can get through highly defended A2/AD environments due to a new weapon: stealth. Their small radar cross section allows access to areas where conventional aircraft cannot go. A single stealth bomber can still take the fight directly to the enemy and hold the enemy's leadership and other important assets at risk. The cost of stealth has kept this force small in numbers, and thus the force is not very flexible and cannot provide mass except in the number of precision weapons that can be placed on one aircraft, and for the B-2 that is 80 500-pound JDAMs.

Bombers hold the enemy at risk anywhere in the world with nuclear weapons or high-volume precision-guided conventional fires.

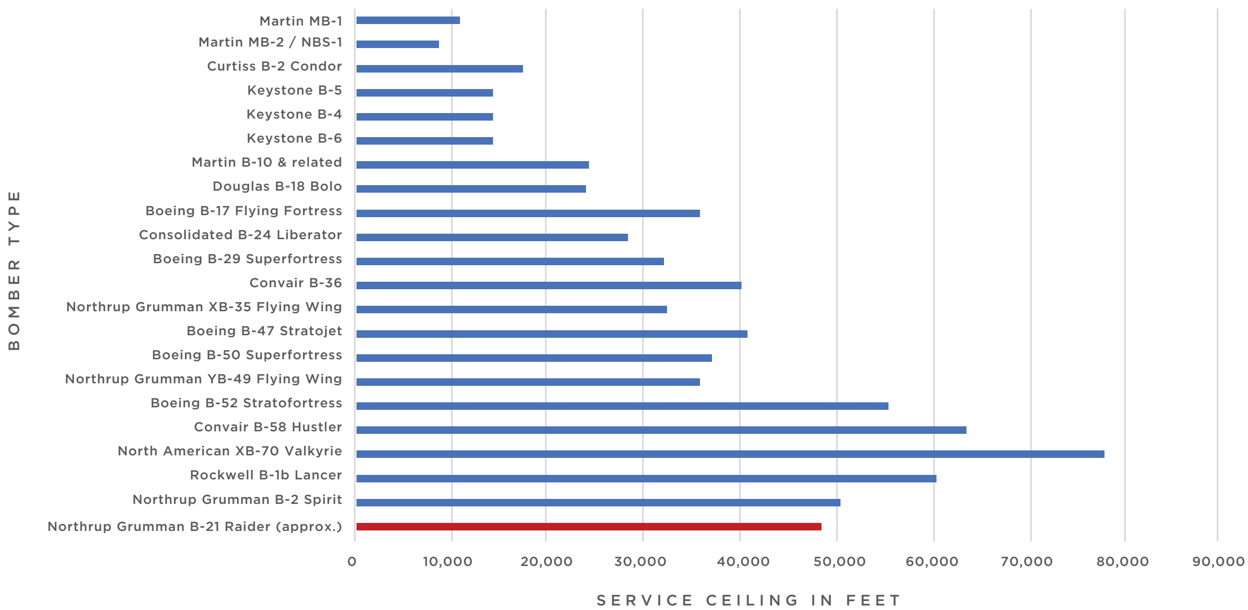
This presents a risk to the enemy, but it also presents a risk to the nation that might need to fight multiple enemies with limited airframes. When a nation has only 20 B-2s, with several in different stages of maintenance and others devoted to training and testing, losses are unacceptable. Like their predecessors, B-2s provide global reach and power. A more resilient and potent force will consist of 100 B-21s and potentially even more. They will be able to enter future A2/AD environments, safely operate for long periods, and keep the pressure on or eliminate the enemy leadership.

The strategic imperative to field long-range attack aircraft has not gone away. In fact, it may be more important than ever. True deterrence is still a credible bomber that can threaten any target anywhere around the globe from its protected hangar in the middle of its nation with either conventional or nuclear weapons. This force imposes cost on the enemy and causes the enemy to invest in defensive weapon systems to protect itself. Bombers hold the enemy at risk anywhere in the world with nuclear weapons or high-volume precision-guided conventional fires. The war in the Pacific in WWII is a great example of the power of global reach. The United States fought a long, hard, and costly combined naval and land campaign to establish bases close enough to take the fight to Japan and its leadership. Once those bases were captured, U.S. forces could directly strike the Japanese capital. In addition, in Europe, once Berlin and Hitler were held at risk, Germany's days were numbered. History shows that when you can take the war directly to enemy leadership, you shorten the war. When you fight around the periphery and nibble at the edges of the con-

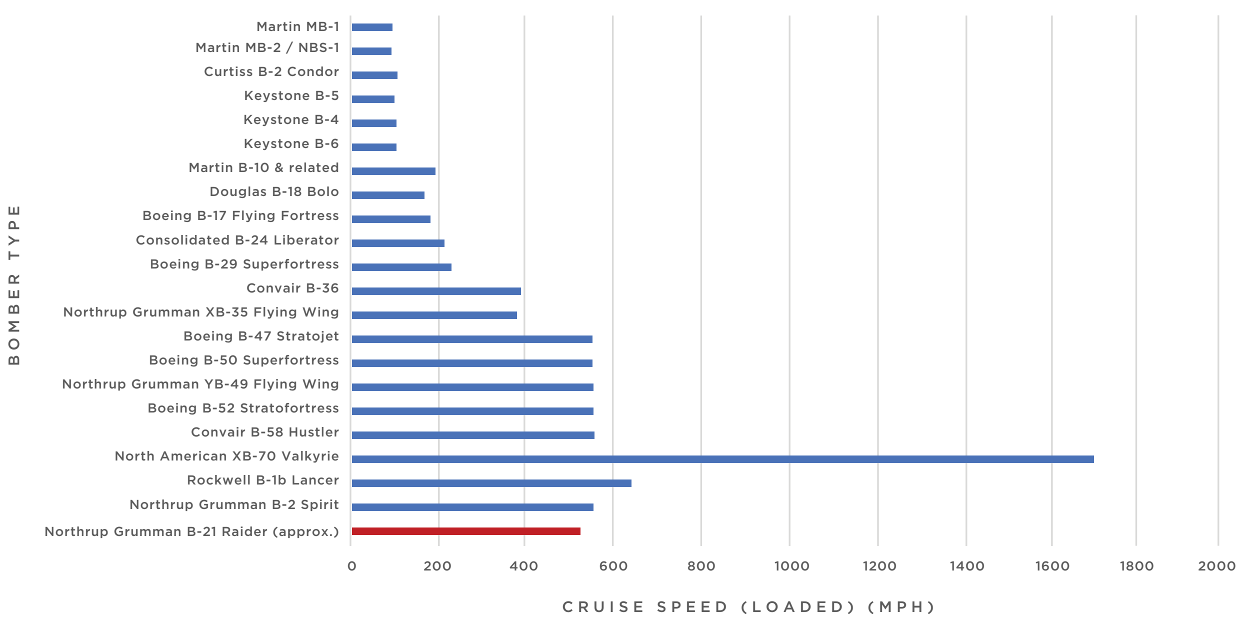
Today's modern stealth bombers, including the B-21, are one of the few tools that can be counted on to take the fight to exactly where it matters, inside the most heavily contested airspace.

flict, it will be a long one. Today's modern stealth bombers, including the B-21, are one of the few tools that can be counted on to take the fight to exactly where it matters, inside the most heavily contested airspace. The traditional range, payload, and lethality now combined with onboard intelligence-surveillance-reconnaissance sensors, precision-strike weapons, and stealth designs position the American heavy bomber at the forefront of future warfare.

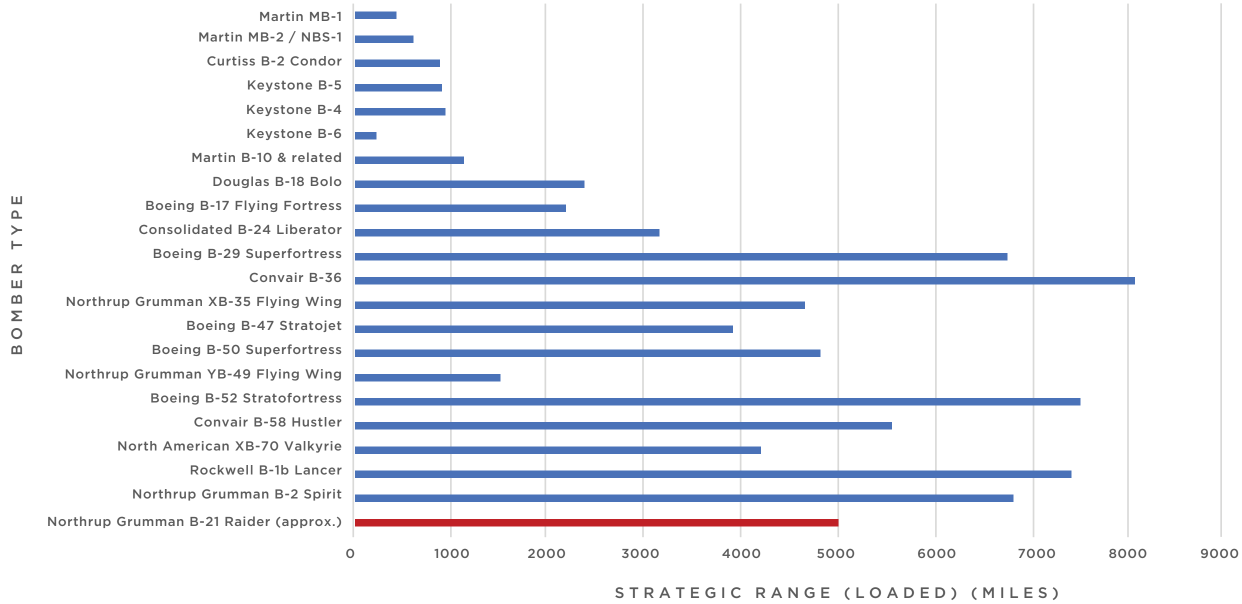
APPENDIX[191]



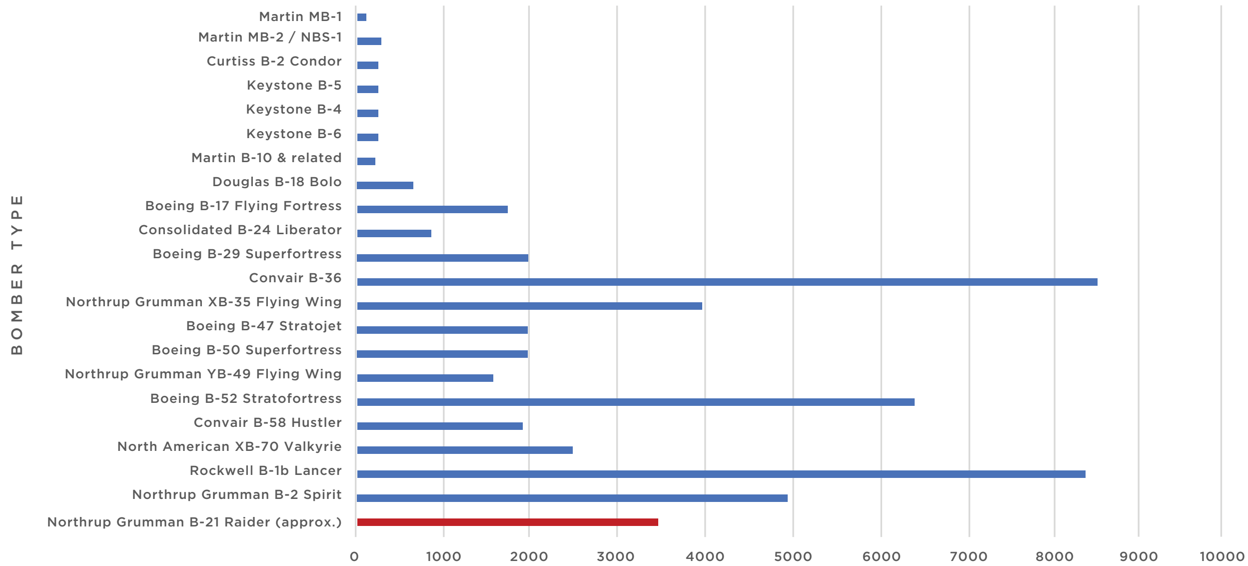
Service Ceiling



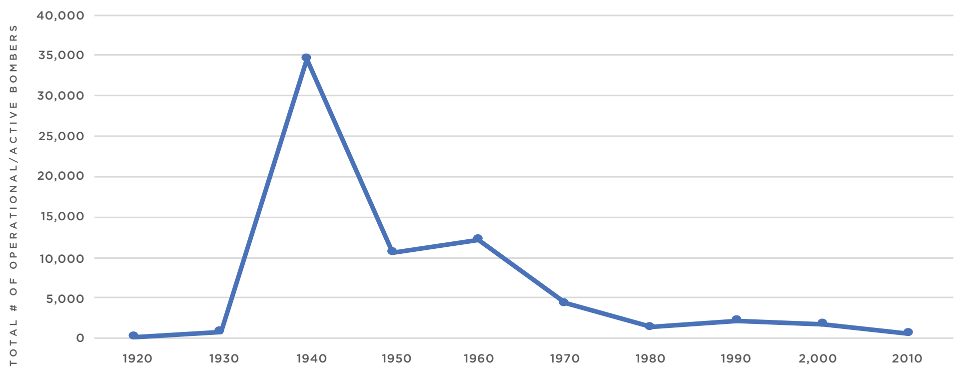
Cruise Speed



Strategic Range (miles)



Bomb Load (lbs)



Total # of Operational/Active Bombers

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