

THE NEED FOR SPEED
HYPERSONIC AIRCRAFT AND THE TRANSFORMATION
OF LONG RANGE AIRPOWER

BY

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DISCLAIMER

The conclusions and opinions expressed in this document are those of the author. They do not reflect the official position of the US government, Department of Defense, the United States Air Force, or Air University.

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ABSTRACT

Transformation to the next level of technology is a pressing issue for the Air Force's strategic planners. Just how much of a leap in technology do engineers try to take when designing a new system? The answer depends if new discoveries have increased the technology available when they design a new system. However, it makes little sense to build new equipment that does not provide an improved capability or a more reliable system. That being said, the next long-range strike platform could take that technological leap and be a very fast near-space vehicle. Past events, such as the 2004 X-43 launch, show that technological progress is occurring on critical hypersonic components. While this is not a paper on the technology per se, it covers the implications of building and operating a "hypersonic" bomber force. This paper addresses the question of whether or not the hypersonic bomber is worth the required investment and covers several aspects involved with hypersonic bomber operations. The purpose of this study is to determine if the advantages gained from developing a hypersonic fleet outweigh the disadvantages. The author concludes that the advantages gained from developing a hypersonic fleet outweigh the platform's disadvantages.

This study first covers several attempted hypersonic programs and how the strategic thought at the time affected them. The USAF's first and arguably largest hypersonic bomber project was the Dyna-Soar X-20. However, the Dyna-Soar program's mission changed multiple times in attempts to maintain funding at a time when the nation focused on other issues. Without a well defined strategy for the hypersonic bomber, the Department of Defense cancelled the program.

Hypersonic programs have since had various starts and stops. There have been several attempts to build an airbreathing hypersonic vehicle. They all have failed in part because they could not meet the technological challenges. Recent developments, however, hold more promise. Instead of building a large hypersonic bomber, agencies such as DARPA and NASA are working technological advancements on a step by step level. A further promising development is that the National Aerospace Initiative forces competing agencies to cooperate with one another.

A hypersonic bomber would give the USAF the capability to strike any place in the world within a couple of hours. It would enable parallel attack in locations without regional access and reduce the need to establish forward bases for every contingency. A hypersonic bomber would be survivable against current surface to air missile systems, and should be able to carry a variety of weapons. These advantages do not come without costs and problems. A hypersonic bomber will be very expensive. There are difficulties in the flight profile, surface heating, plasma fields and testing capabilities. Other facets in need of consideration before investing in a hypersonic bomber include the decision to make the bomber piloted or unpiloted. Overflight issues are also a potential problem that needs looking at.

However, there are returns on technology that compensate for the large costs of the system. Additionally, a hypersonic bomber fares well in a comparison to other strike assets. The evidence gathered in this study shows the advantages outweigh the disadvantages and that the USAF should invest in hypersonic technology.

CONTENTS

Chapter		Page
	DISCLAIMER.....	ii
	ABOUT THE AUTHOR.....	iii
	ACKNOWLEDGMENTS.....	iv
	ABSTRACT.....	v
	INTRODUCTION	1
1	DYNAMIC SOARING	5
2	THE ERA OF THE X-PLANES	17
3	THE GOOD, THE BAD, AND THE UGLY	36
4	PUZZLE PIECES	49
	CONCLUSION	64
	BIBLIOGRAPHY	66

Illustrations

Table		
1	Systems Comparisons	60

Introduction

Military forces have a need for speed. Striking a distant target in minimal time is a historical problem. Long transit times wear down navies, armies, and even air forces. Think of what might have happened during the Peloponnesian War if it had not taken the Athenians a year to travel to and attack Syracuse. Napoleon's Russian campaign might have ended differently if it had not taken so long to get to Moscow. The time it took the Eighth Air Force's B-17s to fly from their English bases to strike German targets and then return took its toll on the bomber crews. Higher speeds could have made a difference supporting ground troops or accomplishing time sensitive targeting in Kosovo, Afghanistan, and Iraq. In essence, speed equates to shorter long-range strike timelines.

The capability to strike distant targets from bases in the United States exists today. However, to carry out such global strike sorties requires long duration missions, tanker bridges to provide necessary fuel, and often diplomatic overflight clearances. These long sorties are taxing on both the aircraft and the crews flying them. B-2s flying Operation Enduring Freedom sorties flew 44-hour missions and were airborne over 24 hours before they were in the target area. The same airplanes and crews flying CONUS based sorties to Operation Iraqi Freedom flew 18 hours before they reached their targets. From a safety aspect alone it is difficult to guarantee that a weary aircrew will not make fatigue-induced mistakes. To shorten response times, it currently takes the deployment of a large number of forces. It can take days, weeks, or months to deploy and prepare these forces for combat.

There may be technology available in the near future to shorten the time required to strike these long distance targets. The next long range strike platform could be a bomber capable of hypersonic speeds. A hypersonic bomber can fill the Air Force's need for speed. A hypersonic bomber would transform the bomber force and give the United States the capability to affect operations worldwide in only a matter of a few hours. The purpose of this paper is to determine if the advantages gained from developing a hypersonic fleet outweigh the platform's disadvantages. Potential capabilities are weighed against limitations, and an investigation of such factors as manned and unmanned capabilities, overflight considerations, survivability

against current threats, and lost opportunity costs is included. In short, the question of whether or not the hypersonic bomber is worth the required investment is analyzed.

Hypersonic flight is defined as vehicle speeds greater than Mach 5. Assumptions are that a hypersonic bomber will fly at altitudes above 100,000 feet, and that released weapons will also be accurate enough to destroy sensitive and/or hardened targets. Therefore, a hypersonic bomber is a vehicle capable of dropping accurate bombs at high speeds and altitudes.

Technology obviously will play a vital role in hypersonic bomber development. The United States Air Force cannot build a reusable air-breathing hypersonic bomber unless significant technological breakthroughs occur. Although the USAF experienced many difficulties in past hypersonic programs discussed in this paper, an assumption of this study is that engineers will discover the needed technological requirements and the United States will therefore have the capability to build a hypersonic bomber within 20 years.

Long-range strike is an important USAF capability. Its bomber force gives the USAF the flexibility and firepower to strike at targets deep within enemy territory. Beyond traditional strategic bombing missions, operations in Afghanistan proved the USAF could convert a bomber's range to overhead battlefield presence. B-1s and B-52s spent many flight hours on call in orbits supporting troops on the ground. Long-range strike is a critical niche that no other service has the capability to fill. Therefore, long-range strike is and will continue to be an important USAF capability.

This study's greatest limitation is that it is unclassified. All the surveyed source material came from unclassified sources. The author did not have access to any classified data and therefore did not obtain data from any existing programs.

This paper begins with a discussion of the history of hypersonics. Chapter One covers the beginning of hypersonic aspirations until the cancellation of the first true United States hypersonic bomber project, the X-20A Dyna-Soar. The discussion shows that the idea of fast long-range strike originated as soon as man took to the sky. These ideas came closer to reality as the Germans studied the feasibility of hypersonic bombers in the World War II era. The USAF took those ideas and began development of its own hypersonic bomber, the Dyna-Soar. The hypersonic Dyna-Soar promised many things, particularly a quick response from takeoff to time over target. However, there was no steady overarching strategy to employ the weapon system.

The lack of a consistent strategy for the Dyna-Soar hypersonic bomber was a large factor in the systems cancellation.

Chapter Two continues the story of hypersonic historical development from 1964 to the present. The United States attempted to build several hypersonic vehicles, including bombers, but did not have the technology or correct roadmap to complete the process. Hypersonic bombing technology saw little advancement in the period during and immediately following the Vietnam War. The nation then set out to build a hypersonic national aerospace plane (NASP) during the Reagan Years. The program's goals overran the available technology, which led to NASA and the USAF to cancel the expensive project. In the early 1990's another investment flurry occurred and both the USAF and NASA invested in the X-33 and X-34. Both these hypersonic projects failed to meet initial expectations. In addition, NASA and the Air Force both pushed for different project end-states. NASA liked the idea of a single stage to orbit hypersonic vehicle. The Air Force did not need the single stage to orbit vehicle, only one capable of traveling great distances. This lack of cooperation and technological challenges cancelled these programs. We are currently on the midst of another hypersonic push. Recent test flights have had encouraging results.

Chapter Three covers both the advantages and disadvantages of a hypersonic bomber. The benefits to the USAF include an expanded long-range strike capability, reduced time from launch to strike, and survivability. Disadvantages include technological challenges, high costs, and plasma fields.

Chapter Four brings everything together. Significant operational decisions and implications necessary to employ a hypersonic bomber successfully are discussed. The chapter then covers the opportunity costs of investing in hypersonic technology, and includes a discussion in foreign investment. Finally, recommendations for hypersonic bomber development are presented.

Chapter One

Dynamic Soaring:

Opportunities

Missed

Long-range strike is not a new concept. Several visionaries foresaw the potential up to 100 years ago. British author H.G Wells foretold of ferocious power dealt from the air. Wells, concerned about the then 220-mile range of the Zeppelin, foresaw airships flying across the Atlantic Ocean and then destroying New York City, leaving terror in their wake.¹ Wells believed nations at war would destroy an enemy's great cities once they had the capability to navigate over them freely.² Bringing Wells' imagination to life, both the British and the Germans used long-range strategic bombing during World War I. The British felt they could attack the heart of Germany from their bases in France while Germany also bombed targets in Southeast England from bases in Belgium.³ Although the results had negligible impact on the war, these bombing campaigns stoked the fires of imagination among airmen throughout the world.

The idea of long-range strike burned brightly among United States airmen as they developed their doctrine, strategies, and aircraft prior to World War II. United States bombers began deep bombing missions over Germany on a daily basis by 1943. In the post-war world, the newly independent United State Air Force (USAF) initially relied on the marriage of the B-29 and nuclear weapons for their long-range strike capabilities.⁴ The USAF followed this initial

¹ H.G. Wells, *The War in the Air* (London, U.K.: George Bell and Sons, 1908), 208.

² Robert Wohl, *A Passion for Wings: Aviation and the Western Imagination 1908-1918* (Singapore: C.S. Graphics Ltd., 1994), 74.

³ Neville Jones, *The Beginnings of Strategic Air Power: A History of the British Bomber Force 1923-1939* (Totowa, N.J.: Frank Cass and Co. Ltd., 1987), i, 13.

⁴ Barry D. Watts, *Moving Forward on Long-Range Strike*, Center for Strategic and Budgetary Assessments (Washington, D.C.: Center for Strategic and Budgetary Assessments, 27 September 2004), 2.

capability by the development of the B-52, other long-range bombers, and intercontinental ballistic missiles (ICBMs).

In pre-WWII Germany, the idea of hypersonic long-range strike started as an hypothesized capability with the aim of increasing the range of rocket-powered weapons. Early German aviation pioneers helped develop the idea of hypersonic flight and then their military attempted to develop strategies to use these scientists' ideas. These ideas eventually led to hypersonic development in the United States, specifically a manned hypersonic bomber called the Dyna-Soar.

This chapter covers the early German attempts to develop a hypersonic bomber that could strike the United States and the resulting policies associated with the successes and failures this new field. It then walks through the first attempt to build a United States hypersonic bomber.

Early Pioneers

Hypersonic flight's genesis occurred in the mid-1930s when Dr. Eugen Sänger, a rocket expert at the University of Vienna, developed the concept of a winged vehicle that could fly into space and arrive anywhere on the planet in a little over an hour. His theoretical-winged vehicle, known as the Silverbird, would use liquid fueled rockets to propel itself to the upper atmosphere and then glide with no power until it hit denser air.⁵ The Silverbird would then use its kinetic energy to skip off the atmosphere back up to higher altitudes, much as a stone does when skipped along the water. Each skip would reduce the craft's available energy, or amplitude, until, unable to maintain itself above the atmosphere, it would glide to a normal landing. When launched from Germany, Sänger estimated the Silverbird would be over the eastern United States on its third skip.⁶ Sanger named the theory of skipping a vehicle in the upper atmosphere the "boost-glide" concept.

The Hermann Göring Institute in Germany recruited Sänger to develop rocket motors. While there, he modified his Silverbird concept to be an armed space plane capable of bombing

⁵ Gregory E. Moster and John G. Martin, *Oscillatory Trajectories applied to NASA's DF-7 Configuration*, AAIA Paper 99-4931 (Norfolk, Va.: American Institute of Aeronautics and Astronautics, November 1999), 1.

⁶ Dan Johnson, "Sänger Amerika Bomber Luft '46 entry." *Luft '46 – WWII German Aircraft Projects*, 28 November 2004, n.p. On-line, Internet, 11 December 2004, available from <http://www.luft46.com/misc/sanger.html>.

New York City.⁷ Sänger named it the Antipodal Bomber because of its ability to deliver a warhead to the opposite side of the globe.⁸ If the Germans had built Sänger's hypersonic Antipodal Bomber, it could have been a formidable weapon. There were also other German scientists developing hypersonic technology.

Independent of Sänger's work, Lieutenant General Walter R. Dornberger, the director of guided missile development for the German ministry of munitions, had his team refine the boost-glide concept.⁹ The Germans wanted more range for the A-4 (V-2 rocket), and Dr. Wernher von Braun, Dornberger's assistant, predicted a range increase for the A-4 of up to 360 miles by placing wings on the airframe. The winged A-4 was designated the A-9. Von-Braun also concluded that an added booster would allow the A-9 to travel 3,000 miles in only 17 minutes. The German rocket development division successfully launched an A-9 in January 1945.¹⁰

The German military initially ignored Sänger's antipodal bomber proposal. Even Air Ministry interest in the rocket airplane did not persuade the military to continue Silverbird's development. This was due in part to a temporary Army and Luftwaffe merger in rocket experimentation, which shut down the research at the Göring Institute and moved it to Peenemünde. Additionally, Von Braun recommended the Air Ministry not hire Sänger because their efforts would be duplicative. In reality, Von Braun may have seen Sänger as a rival.¹¹

The German Air Ministry eventually hired Sänger to create a rocket research institute away from Von Braun and the joint Army-Luftwaffe effort. Sänger's assignment was to test rocket motors and then develop large boosters. Luftwaffe chief Hermann Göring wanted a Luftwaffe rocket force independent of the Army and saw the strategic potential of the rocket bomber as a step in that direction.¹² However, in 1942 the war forced German research to concentrate on proven designs, changing the Luftwaffe effort, and ending Luftwaffe competition

⁷ *Hypersonic Glide Rocket Weapon System*, ARDC Abbreviated Development Plan, ARDC Report DD-R&D/A/119 (Baltimore, Md.: Air Research and Development Command, 24 October 1957), 26.

⁸ Robert Godwin, ed. *Dyna-Soar – Hypersonic Strategic Weapons System* (Burlington, Ontario: Collector's Guide Publishing, 2003), 7.

⁹ Clarence J. Geiger, *History of the X-20A Dyna Soar, Volume I (Narrative)*, AFSC Historical Publications Series 63-50-I, Document ID ASD-TR-63-50-I. (Wright Patterson AFB, Ohio: Aeronautical Systems Division Information Office, September 1963), 2.

¹⁰ *Ibid.*, ix, 2-3.

¹¹ Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (Cambridge, Mass.: Harvard University Press, 1995), 61.

¹² Dan Johnson, "Sänger Amerika Bomber Luft '46 entry." *Luft '46 – WWII German Aircraft Projects*, 28 November 2004, n.p. On-line, Internet, 11 December 2004, available from <http://www.luft46.com/misc/sanger.html>.

with the Army rocket program.¹³ Therefore, Sänger shifted his research from the Antipodal Bomber to other projects, and Germany failed to achieve any operational capability from the long-range hypersonic Antipodal Bomber concept.

The Advent of United States Hypersonic Research

The USAF started investigating hypersonic vehicles soon after WWII. In May 1946, RAND researchers determined it was feasible to design a capsule with wings for manned space flight. Former German scientist Walter R. Dornberger began working for the Bell Aircraft Company in 1950.¹⁴ Under his guidance, it took less than three years for the Bell Aircraft Company to propose a manned bomber-missile, known as the BOMI (short for Bomber-Missile). The Air Force was skeptical due to the fact that although the BOMI would advance the Air Force's technical bombing knowledge, the Atlas ballistic missile and the Navajo cruise missile offered more promise for successful deployment. However, the Air Force thought the BOMI also presented potential reconnaissance abilities far in advance of other programs. Therefore, the USAF funded a research study to determine if the piloted BOMI vehicle was more advantageous than an unmanned version and if a reconnaissance mission compromised the system's long-range striking ability.¹⁵ Hypersonic boost-glide technology promised to fuse the best characteristics of the unmanned Atlas and Navajo missiles with the best qualities of the manned heavy bomber and reconnaissance systems.¹⁶ Air Force officials considered the program somewhat radical but thought that it was not outside the realm of possibilities. As BOMI technology matured, the Air Force recommended Bell focus its efforts on a more advanced vehicle called the BRASS BELL.¹⁷ The BRASS BELL used BOMI technology, but changed the primary mission from bombing to reconnaissance and surveillance.

In the 1950s, strategic bombing was the pillar of the USAF Cold War strategy. Air Force doctrine described strategic bombardment as the most decisive use of air power yet developed. General Curtis E. LeMay also viewed strategic bombardment as the most decisive form of military power in the American arsenal. LeMay believed a properly manned, equipped, and

¹³ Michael J. Neufeld, 62.

¹⁴ Geiger, 5.

¹⁵ Geiger, 7.

¹⁶ Roy Franklin Houchin, "The Rise and Fall of Dyna-Soar: A History of Air Force Hypersonic R&D, 1944-1963" (PhD diss., Auburn University, 1995), 111.

¹⁷ Geiger12.

trained force in being with a universally recognized and unquestioned combat capability could only maintain Strategic Air Command's (SAC) deterrent influence on the Soviet Union.¹⁸ SAC bombers constituted a major, and initially the only, component of America's nuclear deterrent. The long-range strike capability embodied in heavy bombers was a key ingredient in United States strategy.¹⁹ Hypersonic bombers would have provided the next giant step in strategic bombardment.

The United States was not the only country involved in hypersonic flight. The Soviet military obtained copies of Sänger's analysis at the end of World War II and became interested in the possibilities of boost-glide flight. The Soviets even sent a team to Paris to find and "acquire" Sänger. Luckily, they failed.²⁰ Even without Sänger, the Soviets continued to pursue hypersonic flight for strike and reconnaissance missions. An article found in a 1958 Soviet aviation journal referred to a Russian glide-bombing system capable of reaching 295,000 feet and striking a target 3,500 nautical miles away. Later, an American aviation periodical reported that Russian scientists were developing an antipodal, glide missile, designated the T-4A. Intelligence estimates in 1960 determined the Soviets would be capable of performing both reconnaissance and bombing missions over the United States by 1967.²¹ As the Soviet Union developed nuclear warheads, ICBMs, and long range strategic airpower with a hypersonic potential, the need to maintain the superiority of USAF assets seemed all the more important in determining the outcome of a future conflict.²² The reaction to these estimates gave the United States the incentive to develop an offensive deep strike capability, helping push the USAF cause for a long-range hypersonic strike platform.

The Air Force wanted to develop an intercontinental vehicle with a range of 25,000 miles. Air Force leaders also believed such a high profile program needed other contractors in addition to Bell offering competitive concepts.²³ As a result, in 1955 the Air Force announced General Operational Requirement 12, calling on a study for a piloted, high altitude, reconnaissance, and weapon system to be available by 1959. By year's end, nine companies

¹⁸ Steven L. Rearden, "U.S. Strategic Bombardment Doctrine Since 1945," in *Case Studies in Strategic Bombardment*, ed. R. Cargill Hall (Washington, D.C.: U.S. Government Printing Office, 1998), 402 - 403.

¹⁹ Barry D. Watts, 2.

²⁰ Robert Godwin, 7.

²¹ Geiger, 4

²² Houchin, "Rise and Fall of Dyna-Soar," 8-9.

²³ Geiger, 8.

were in the race for Operational Requirement 12's lucrative hypersonic bomber contract.²⁴ These companies investigated the adaptability of boost-glide rockets and vehicles using air-breathing engines in the hypersonic near-space regime.²⁵

The Air Research and Development Command (ARDC) designated the hypersonic rocket-bomber study "ROBO" for rocket-bomber. ROBO's goal was to determine the feasibility of a manned, hypersonic, bombardment and reconnaissance system capable of intercontinental operation. The ROBO's main requirement was to circumnavigate the globe at a minimum of 100,000 feet, performing both intercontinental strike and reconnaissance roles.²⁶ The contractors presented their proposals for the ROBO vehicle in June of 1957.²⁷

The ROBO project competed for funding with five other programs and as a result, the ROBO ran into budget shortfalls in early fiscal year 1957.²⁸ However, ARDC still issued a hypersonic system requirement for an abbreviated systems development plan and changed the program's emphasis to the Hypersonic Weapons Research and Development Supporting System, or HYWARDS. The HYWARDS vehicle's purpose was to provide research data on aerodynamic, structural, human factor, and component problems. In short, HYWARDS was a research vehicle used as a test craft to develop subsystems employed on any future boost-glide systems.²⁹

The Dyna-Soar X-20

Shortly thereafter, the Air Force recommended consolidating the three separate hypersonic projects into one, where one company managed the entire boost-glide program. The Air Force then consolidated the HYWARDS, BRASS BELL, and ROBO studies into a three-step abbreviated development plan called System 464L, the Dyna-Soar. Each of the three research projects was now a phase of the Dyna-Soar program.³⁰ With Dyna-Soar, the Air Force

²⁴ Boeing, the Republic Aircraft Company, the McDonnell Aircraft Corporation, General Dynamics Corporation, Douglas, and North American Aviation all responded to the hypersonic request. Bell, Lockheed, and Martin later joined the study.

²⁵ Geiger, 13.

²⁶ *Ibid.*, 14.

²⁷ Bell and Douglas favored a three-stage, boost-glide vehicle. General Dynamics also proposed a three-stage system, but placed a control rocket and turbojet engine in the glider itself. North American advanced a two-stage vehicle using conventional rocket fuels. Republic supported an unmanned vehicle powered by a hypersonic cruise, ramjet engine, boosted by a single-stage rocket. Boeing also favored an unmanned version where its vehicle was an intercontinental glide-missile.

²⁸ The ROBO competed with the X-13, X-14, XB-47D, X-15, and vertical-takeoff-and-landing aircraft.

²⁹ Geiger, 15 - 18.

³⁰ Geiger, 20-21, 30-31. Thirteen companies bid on the first stages of the plan. A delta wing vehicle was the basis for every design but one's (North American proposed an X-15 like vehicle) and was the size of fighter jets like the

maintained its institutional attraction for a manned long-range bombardment role while it incorporated ballistic missile technology and reconnaissance satellite technology into a manned space weapon system.³¹ The Dyna-Soar project encompassed this goal, giving the Air Force a hypersonic boost-glide vehicle capable of both intercontinental bombardment and reconnaissance missions.

The next question was how large would the hypersonic forces need to be? General LeMay concluded it would be impractical to plan a bombardment campaign calling for sustained operations such as those conducted against Germany and Japan in WWII.³² There was just not enough money available anymore to build a force that large. The Air Force found part the answer in technology and the Dyna-Soar. Throughout the time-period, the Air Force pushed for a stronger military space policy. Having established itself as the aerospace service, the Air Force believed it had the strongest case for being the United States primary practitioner of space operations.³³ Events such as the Sputnik launch helped the Air Forces cause.

The Dyna-Soar built upon the foundation of strategic bombardment. The USAF leadership argued that the Dyna-Soar hypersonic, boost-glide vehicle offered a significant extension of speed, range, and altitude over other conventional Air Force systems. The hypersonic boost-glide concept represented a major step toward manned space flight, expanding the manned flight regime. A hypersonic bomber could also destroy missed intercontinental ballistic missile targets. The Dyna-Soar could penetrate hostile airspace easier than traditional air breathing bombers and could provide more detailed and accurate intelligence data than other Air Force reconnaissance systems under development. Operationally and tactically, it made sense. However, future administrations did not see the Dyna-Soar the same way.

The Department of Defense (DoD) directed the Air Force, not the National Aeronautics and Space Administration (NASA), to fund the Dyna-Soar project, since it was a military venture. This gave the military a manned space vehicle. However, the Eisenhower administration was determined to use space for exclusively peaceful purposes. The President did not want to start an armed space race with the Soviet Union, and would not fund the Dyna-Soar if it were a military vehicle. Therefore, in order to enable continued research on this program, the Air Force

F-106. The Air Force selected the Martin and Boeing designs as a basis for the first phase of the Dyna-Soar. These were the only two proposals with vehicles capable of reaching orbital velocities.

³¹ Houchin, 140.

³² Rearden, 408.

³³ Houchin, 411.

classified the Dyna-Soar a research platform in 1958. Nevertheless, if the USAF designated Dyna-Soar a research vehicle, funding would be less than half of what it would be if the system included military objectives. Hence, the development of an operational long-range strike system was in jeopardy before there was a working prototype.³⁴ The ideology of pushing the Dyna-Soar program to achieve a manned military space system would not fit in the government's space-for-peace policies.³⁵

The Air Force was at odds with the DoD over the Dyna-Soar. The Air Force still wanted a truly hypersonic high-altitude bombing system. In contrast, the DoD wanted to concentrate on a maneuverable intercontinental vehicle capable of controlled landings, with the function of weapons delivery and attaining orbital velocities secondary. The two departments compromised in November 1959. The Dyna-Soar project office formulated a three-step approach comprised of the development of a suborbital glider, an orbital system, and an operational weapons system. This allowed the Air Force to pursue a research vehicle and then use the findings to develop military capabilities later.³⁶ Additionally, the Air Force thought the shift toward the reconnaissance mission meant more funding for the program. Soon afterwards, the Secretary of the Air Force announced the contract.³⁷

John F. Kennedy was critical of Eisenhower's defense program and reliance on massive retaliation. The new President thought the United States was starting to lag behind the USSR in ICBM technology. Kennedy felt there was a need for a broader range of military options, including greater flexibility in the use of nuclear power and improved capabilities for conventional warfare.³⁸ "We have been driving ourselves into a corner," Kennedy contended, "where the only choice is all or nothing at all, world devastation or submission – a choice that necessarily causes us to hesitate on the brink and leaves the initiative in the hands of the enemies."³⁹

Secretary McNamara took to task the job of following through on Kennedy's wishes. McNamara launched a full-scale review of defense policy to determine how the United States could adjust strategic plans and doctrine to reduce dependence on nuclear striking power. He

³⁴ Geiger, 34-36.

³⁵ Houchin, 141.

³⁶ Geiger, 49. Boeing would develop the hypersonic vehicle and the Martin Company would produce the boosters.

³⁷ Houchin, 201.

³⁸ Rearden, 424.

³⁹ Quoted in Steven L. Rearden, "U.S. Strategic Bombardment Doctrine Since 1945," in *Case Studies in Strategic Bombardment*, ed. R. Cargill Hall (Washington, D.C.: U.S. Government Printing Office, 1998), 424.

placed greater emphasis on second-strike capabilities, on retaliation as opposed to preemption. He wanted to add flexibility in the choice of targets, timing, warheads, and bombs.⁴⁰

There were still debates over the research or military use of the system, but the DoD assigned \$16.2 million of fiscal year 1960 funds, and the development of the Dyna-Soar (now designated the X-20A) could proceed. The DoD continued to doubt the usefulness of the system. However, the Air Force convinced the Kennedy administration of its importance, and funding level for 1962 was set at \$70 million, later raised to \$100 million.⁴¹

Priorities again changed for the Dyna-Soar in late 1961. A new development plan characterized the program as a manned, orbital research system (almost a precursor to the space shuttle). The Air Force then formalized the plan to cancel the Dyna-Soar's bombardment mission in December, which Secretary of Defense Robert McNamara approved in early 1962. However, less than six months later the Dyna-Soar project again became a military space and suborbital hypersonic bomber. The projected budget increased to \$130 million in 1963 and \$125 million in 1964.⁴² Additionally, the Air Force projected manned flights to start in November 1964.⁴³ Total projected costs of the entire Dyna-Soar program were in the billions of dollars.⁴⁴ The USAF spent \$400 million on the program by 1963.⁴⁵

Secretary McNamara introduced the nuclear policy of assured destruction after the Cuban Missile Crisis. This policy sought to destroy Soviet government and military controls, plus a large percentage of its population and economy *after* a Soviet surprise attack.⁴⁶ This policy cost less and was thought easier to implement because it required only the maintenance and coordination of a smaller force with the ability to respond after a first strike. Therefore, for the first time, McNamara was able to count on ICBMs sitting in hardened shelters instead of bombers as the heart of the strategic weapons inventory. Nonetheless, the force structure remained larger than the one probably necessary for assured destruction. Still, considerable savings followed over what the nation would spend following previous nuclear strategies. McNamara therefore started to rely on targetable bombs and warheads as the most important

⁴⁰ Rearden, 425.

⁴¹ Geiger, ix - xiv. The vehicle was designed to be a low-wing, delta-shaped glider weighing approximately 10,000 pounds.

⁴² Geiger, xv-xvii.

⁴³ *Ibid.*, 61.

⁴⁴ *Ibid.*, 82.

⁴⁵ Godwin, 10.

⁴⁶ Rearden, 429.

strategic assets, not delivery vehicles.⁴⁷ Unfortunately, the Dyna-Soar fell in the offensive category of delivery vehicles.

Secretary McNamara seriously questioned whether Dyna-Soar represented the best expenditure of the nation's resources.⁴⁸ This again resulted in more changes. The secretary directed a review and a comparison of the Dyna-Soar with the Gemini program. The study showed that a modified Gemini might perform a military function in space better and cheaper than the Dyna-Soar.⁴⁹ Gemini's significance to the Air Force also increased because NASA allowed the Air Force to participate in the program. However, the Air Force still wanted a manned military platform and recommended continuing Dyna-Soar even after the release of the secretary's evaluation.⁵⁰

By mid-1963, the Kennedy administration directed NASA and DoD to not indulge in any manned programs without fully considering the other agency's needs. Consequentially, Secretary McNamara did not want to spend more money on the Dyna-Soar until the Air Force clearly defined the need for the system. He did not want to spend \$1 billion on a vehicle solely involved in basic hypersonic research where the program objectives were just too narrow.⁵¹ President Johnson took the oath of office on 25 November 1963. McNamara persuaded President Johnson to level off on the accelerated development of offensive strategic programs. The DoD then cut expenditures on strategic programs by almost half. Two weeks later the government officially cancelled the Air Force Dyna-Soar project.⁵²

The Air Force did all it could to save the Dyna-Soar program. General LeMay pointed out that the USAF would have to place increasing emphasis on the Dyna-Soar because it was the only military system capable of leading to manned space flight. Without the Dyna-Soar X-20A, there would be no manned military space program.⁵³ The Air Force also tried to change the Dyna-Soar's mission and place it where the money was, under the management of the Air Force Ballistic Missile and Space Committee. It appears the USAF was reaching for anything it could, even changing its strategy multiple times, to get the Dyna-Soar funded.

⁴⁷ Ibid., 430.

⁴⁸ Geiger, 87.

⁴⁹ Walter A. McDougal, *The Heavens and the Earth: A Political History of the Space Age* (Baltimore, Md.: The John Hopkins University Press, 1985), 340.

⁵⁰ Geiger, xvii – xviii, 115.

⁵¹ Houchin, 4.

⁵² Godwin, 11.

⁵³ Ibid.

Strategy, diplomacy, and bureaucratic politics all converged to make 1963 the great turning point in the United States military space program. The DoD cancelled the X-20A Dyna-Soar program along with all other space weapons systems with the exception of a crude anti-satellite program. While missile technology continued, the United States implemented a space sanctuary policy in an attempt to persuade the Soviet Union to follow suit.⁵⁴

The strategic decision to abandon the weapons program took away any tactical ability to employ the Dyna-Soar. If the Dyna-Soar X-20A had been operational in the late 1960's as planned, the hypersonic vehicle's intercontinental reconnaissance capabilities could have discovered that the probability of a Soviet bomber attack against the United States with nuclear weapons remained low. It also would have shown other factors that may have proved the Soviet Union was not as powerful as the United States thought, for it would have discovered that Soviet nuclear submarines were rarely at sea.⁵⁵

Conclusion

The Dyna-Soar X-20A had the potential to be a successful USAF hypersonic program. However, there was no clear mission and concept of operations for the hypersonic bomber. The bottom line shows there was no clear consensus of purpose, any single-minded and perceptive leadership, and no quick attainment of the advanced technology needed to ensure the Dyna-Soar survived.⁵⁶ The USAF changed policies too many times for it to develop strong enough to guide any hypersonic strategy. This lack of a defined hypersonic military strategy ultimately killed the Dyna-Soar.⁵⁷

⁵⁴ Walter A. McDougal, 341.

⁵⁵ Houchin, 21.

⁵⁶ *Ibid.*, v.

⁵⁷ Godwin, 11.

Chapter Two

The Era of the X-Planes: New Policies, Many New Directions

Both the USAF and National Aeronautics and Space Administration (NASA) have attempted various hypersonic vehicle projects since Dyna-Soar's cancellation. However, over the past 40-plus years airbreathing hypersonic flight efforts have suffered from a series of fits and starts. Therefore, there has not been a true, sustainable hypersonic vehicle built. The primary reason is that airbreathing hypersonic efforts have focused simply on getting somewhere faster. What does this mean? There has not been a clear requirement established making essential use of the time advantage gained through hypersonic flight. This chapter examines the repeated efforts of the United States to build a hypersonic vehicle from 1965 to 2005.

Although a small amount of research occurred during the Vietnam War era, a new round of hypersonic activity kicked off in the 1980 during which both NASA and the USAF unsuccessfully tried to build the X-30 National Aerospace Plane (NASP). A decade later, the United States again attempted to build several hypersonic vehicles. These included the X-33, X-34, and expendable launch vehicle (ELV) programs. NASA and the USAF are currently working a number of new hypersonic concepts today. NASA recently successfully flew its last X-43 Hyper-X mission, while the USAF is currently working with the Defense Advanced Research Projects Agency (DARPA) on a new military hypersonic vehicle through the Force Application and Launch from CONUS (FALCON) program. Recent events are promising because the push for transformation has benefited hypersonic research. In response to a challenge made by the Secretary of Defense (SecDef), the Department of Defense (DoD) issued an initiative that forces everyone working on hypersonic projects to coordinate their actions. The hypersonic world is finally receiving some direction.

60s to the 70s – a Period of Inaction

The USAF conceived of a hypersonic Aerospaceplane in the early 1960s and viewed it as a Dyna-Soar follow on.⁵⁸ Aerospace concepts of operation included radical ideas, including close formation flying and Mach 6 in-flight refueling inside of the tanker's shock wave. However, the Aerospaceplane's development did not include any off-the-shelf technology. Scientists and engineers had to invent and develop everything needed, the propulsion, materials, cooling, and aerodynamics.⁵⁹ The Aerospaceplane effort died around the same time as the Dyna-Soar, with Secretary McNamara's fiscal year 1964 budget cuts.

The cancellation of the Aerospaceplane and Dyna-Soar had two significant consequences. First, it temporally ended the Air Force's military exploration of hypersonic flight. The USAF's manned space priorities shifted to concentrating on the manned orbiting laboratory, a space station for military purposes. As a result, there were no hypersonic bomber projects on the drawing board. Second, NASA began to take over the Air Force's hypersonic research projects. Eventually the Space Shuttle offered the Air Force another chance for a joint venture equal in scope to Dyna-Soar.⁶⁰

The Space Shuttle

NASA developed the space shuttle as a means to provide a recoverable, reusable launch capability with a large payload. Although reusable, the shuttles do not takeoff and accelerate on their own to orbital velocity. Rather, they require two solid rocket boosters and need to carry a large expendable main propellant tank to lift them to orbit.⁶¹

The shuttle needed to be larger than the Dyna-Soar to be effective. Von Braun, among others, suggested that using the same vehicle repeatedly had to be cheaper than discarding it after one flight. In theory, the more the shuttle flies the cheaper it is to use. Therefore, using the shuttle repeatedly would lower the cost and allow for quick turn-around between flights. That

⁵⁸ Marquardt, General Applied Science Labs (GASL), General Dynamics, North American, Lockheed, and Douglas Aircraft participated in the early Aerospace plane research.

⁵⁹ Thomas A. Heippenheimer, "Origins of Hypersonic Propulsion: A Personal History," *Air Power History* 47, no. 3 (Fall 2000), 15.

⁶⁰ Roy F. Houchin. "The Rise and Fall of Dyna-Soar: A History of Air Force Hypersonic R&D 1944 – 1963" (PhD diss., Auburn University, 1995), 1.

⁶¹ John W. Hicks and Gary Tripensee, "Hypersonic X-Plane Flight Development of Technologies and Capabilities for the 21st Century Access to Space," Address, AGARD Future Aerospace Technology in Service to the Alliance, Paris, France, 18 April 1997.

was the core argument NASA used to sell the shuttle to Congress and the White House during Richard M. Nixon's first term.⁶²

Nixon's reasons for approving the shuttle and keeping people in space were convincing. He wanted to maintain a strong industrial base. The participating companies could then retain the technology developed and the economy could give high-tech jobs to the public. More pressing, Nixon did not want to break the legacy started during the Kennedy administration. It would be political suicide to leave manned space activity solely to the Russians.⁶³ In the meantime, testing continued on hypersonic capable lifting bodies.

The space shuttle made its first flight in 1981 and was the pinnacle of the nation's space program. However, the Air Force did not like the fact that the space shuttle was a NASA launch vehicle. NASA allowed Air Force personnel to fly in the shuttle as astronauts, but the USAF did not control the program. Another concern in Air Force plans was that the proposed shuttle replacement was a rocket. At the time, the replacement did not improve greatly on Air Force space operations. Therefore, the USAF had little to gain from the shuttle program.

Other Hypersonic Research

In addition to the space shuttle, the United States tested several subscale, piloted, low-speed (less than Mach 2) lifting-body demonstrators from 1963 to 1975. NASA funded the M2-F1, M2-F2, M2-F3, and HL-10 and the Air Force developed the X-24A and X-24B. These vehicles demonstrated that hypersonic lifting-body configurations could fly a powerless approach to a runway landing following a rocket boost into or a recovery from the hypersonic speeds experienced in the upper atmosphere. This research allowed the space shuttle development team to abandon the idea of incorporating landing engines in the shuttle design. However, more than this, these lifting-body demonstrators spawned further interest in developing a piloted hypersonic demonstrator aircraft.⁶⁴

The United States again displayed some hypersonic interest. In mid-1976, a variety of Air Force and NASA research studies eventually combined into a \$200-million development program for a National Hypersonic Flight Research Facility (NHFRF). The NHFRF could test a

⁶² William E. Burrows, *This New Ocean: The Story of the First Space Age* (New York, N.Y.: Modern Library, 1998), 518.

⁶³ *Ibid.*, 519.

⁶⁴ *Why and Wither Hypersonics Research in the US Air Force*, United States Air Force Scientific Advisory Board Report SAB-TR-00-03 (Washington, D.C.: United States Air Force, December 2000), 7.

variety of modular systems, including airbreathing propulsion concepts, weapons separation, and sensor developments, at speeds up to Mach 8. The NHFRF did not last long. NASA quit after the first year. It was obligated to the Shuttle program, and NASA could not afford both the shuttle and a hypersonic demonstrator. The Air Force also could not afford to tackle the project alone, so it had little choice but to follow suit and cancel the NHFRF program.⁶⁵ The hypersonic project again faded away as the money disappeared.

NASA's 1963-1980 hypersonic research primarily focused on bringing rocket-powered reusable spacecraft back to earth. The supersonic combustion ramjet (scramjet) was different. It opened up opportunities that the Air Force embraced. Antonio Ferri was a hypersonic specialist who believed there was no natural limit to aircraft speeds and performance. Ferri led a group who pioneered an idea for advanced jet engines to tap into the atmosphere's oxygen instead of carrying the fuel to very high speeds and altitudes. Hypersonic vehicles would not need to carry large fuel tanks for oxygen if this idea would work. These new engines could make it possible to accomplish space flight with vehicles resembling a supersonic airliner. Others took Ferri's idea and ran with it. They named the new engine the supersonic combustion ramjet, or scramjet.⁶⁶

NASA placed dummy scramjet engines on the X-15 so they could monitor airflows in and around the engine at hypersonic speeds. There, they discovered that engine pods at hypersonic speeds were dangerous after a pod fell off and nearly downed one of the X-15s. The engine needed to blend in with the fuselage.⁶⁷

Scramjet technology developed slowly. Furthermore, there were only two companies involved in scramjet research.⁶⁸ Their early research came up short and neither of them had a working prototype when the allocated funds ran out. Therefore, the government was forced to stop financing the research. Development also slowed because solid fueled rocket technology matured enough to become the primary means of getting items into space. However, the United States government took control of the hypersonic engine experiments and founded the Hypersonic Propulsion Branch at NASA-Langley where they conducted high-speed wind tunnel experiments with hypersonic engines.

⁶⁵ Ibid.

⁶⁶ Thomas A. Heippenheimer, 15.

⁶⁷ Ibid., 17-18.

⁶⁸ Lockheed and General Applied Science Laboratories were the only two companies investigating scramjet technology during the late 1960s.

Disjointed Space Policy

United States post-Apollo space planning was purposely vague. NASA thought it poor strategy to broadcast any long-range plans when the costs of new programs were unpredictable and the country's focus was on other priorities. High cost plans were sure to seem too excessive in the Vietnam/Great Society era. Additionally, USAF policy concentrated on both the Cold War and Vietnam. Any policy to fund research had to compete with these other factors where any long-range plans might be mistaken as an Air Force or NASA attempt to fish for big money.⁶⁹ Therefore, 1960s space diplomacy moved ahead on four principles. The first was the protection of United States military space programs. The second emphasized United States cooperation with the USSR in space arms control and space science. The third principle was to cooperate, and sometime compete with European allies. Lastly, NASA had to keep the communications satellites operating.⁷⁰ There was no national policy or attempt to produce a hypersonic vehicle.

The Outer Space Treaty of 1967 resulted in a collective *inaction* problem that affected hypersonic bomber development because it eliminated an important incentive for military space development, the country's personal gain.⁷¹ The treaty prohibited nuclear weapons in outer space and prevented military operations on the moon. However, it did not demilitarize space.⁷² What the treaty did do was to discourage productive competition between the United States and Soviet Union. This effectively drained away twenty years of Cold War energy from space.⁷³ Subsequently, the emphasis to continue hypersonic research waned.

The fears and hopes of 1969 also distracted United States hypersonic development. There was the fear of social disintegration fueled by the Vietnam War. It was difficult to invest in a hypersonic program while the nation focused on social control. However, there was a hope that the government could do the same thing to alleviate poverty, pollution, and decaying cities that it did to the Apollo program. It was the hope for human capability in the face of terrible challenges. Just as NASA helped the United States beat the Soviets in the space race, so the

⁶⁹ Walter A. McDougal, *The Heavens and the Earth: A Political History of the Space Age* (Baltimore, Md.: The John Hopkins University Press, 1985), 420.

⁷⁰ *Ibid.*, 345-346.

⁷¹ Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London, Great Britain: Frank Cass Publishers, 2002), 138.

⁷² Walter A. McDougal, 419.

⁷³ Everett C. Dolman, 137.

country wanted to see the government take on problems that were more down to earth. This took more attention away from high-priced technology based projects.⁷⁴ Space flight, including hypersonic research, now started to become dispensable.

Hypersonic interest increased briefly as the Vietnam War died down and more money became available.⁷⁵ However, the nation did not put an effort into building a hypersonic vehicle. In fact, the long-range bomber force was at its pinnacle. The nation could no longer afford to build and maintain large numbers of long-range, multiengine bombers. The results are evident today. The Air Force arsenal decreased from 624 B-52s and FB-111s in 1973 to 266 B-1s, B-2s, and B-52s in 1993, to approximately 140 heavy bombers in 2005.⁷⁶

The Roaring 80's and the X-30 NASP

President Reagan revitalized hypersonic thinking in the 1980s. Reagan was amazed (and saddened) that no technology existed to protect the United States from a single missile. He therefore directed his national security advisor, Daniel Graham, to try to come up with a solution. In 1982, Graham proposed a Global Ballistic Missile Defense System whose heart would be 432 space-based killer satellites. This was Reagan's "Star Wars" plan. In addition to a robust laser defense system, high-performance space planes were also included in the plan.⁷⁷ Reagan proposed a new space plane in his 1986 State of the Union address that could one day take passengers from New York to Tokyo in a little more time than it takes to watch an in-flight movie.⁷⁸ This space plane program took the name of the X-30 National Aerospace Plane (NASP). Secretary of Defense Casper Weinberger decided the X-30 would have bombing capabilities and proceed as a major Defense Department initiative. Both the USAF and NASA participated in its development. The projected first flight was to be in the early 1990's.

The NASP combined technology from the Dyna-Soar and Space Shuttle to produce a vehicle capable of both commercial and military uses. The NASP would be a seed-shaped lifting body that could take off and land like an airplane. The NASP was an attempt to develop a single stage to orbit concept using multiple propulsion cycles centered on the dual-mode ramjet-

⁷⁴ Walter A. McDougal, 413.

⁷⁵ Thomas A. Heippenheimer, 20.

⁷⁶ Richard G. Davis, "Strategic Bombardment in the Gulf War," in *Case Studies in Strategic Bombardment*, ed R. Cargill Hill (Washington, D.C.: U.S. Government Printing Office, 1998), 531.

⁷⁷ William E. Burrows, 534-535.

⁷⁸ Jim Wilson, "Two Hours to Tokyo," *Popular Mechanics* 178, no. 7 (July 2001): 65.

scramjet. Among the military missions identified for such a craft were strategic bombing, reconnaissance, in-orbit inspection, and even interdiction.⁷⁹ The previous decade's hypersonic scramjet work played a significant role in the NASP design.

There were expectations that X-30 technology would result in additional hypersonic developments.⁸⁰ The Air Force believed these follow-on vehicles would be capable of performing military missions with the speed of an ICBM and the flexibility of a bomber. It would be the ultimate Cold War asset. This vehicle could be on an alert status, where the crew could scramble the aircraft, quickly take-off, get into orbit, and then change its flight path as necessary to confuse any monitoring adversary. In theory, the Soviets could not get an accurate fix, let alone take an accurate shot at a penetrating hypersonic bomber.⁸¹

Troubled Times

Engineers counted on technological discoveries to build the NASP successfully. The technology to build a prototype did not exist, and thus, the design changed many times. The original plan was for a small vehicle weighing approximately the same as a large fighter aircraft. However, the initial designs lacked basic essentials such as landing gear, maneuvering rockets, and flight safety equipment. The NASP also needed much more fuel than the original designers envisioned. The NASP grew and grew from takeoff weight and thrust requirements of a fighter to a craft heavier than any current USAF bomber, over 550,000 pounds. Cost overruns and delays plagued the program. The original cost estimate was \$3.1 billion with a 1993 expected test flight date. By 1993, the price tag increased to \$15 billion and engineers postponed the first launch until at least 2004.⁸² In only seven years, the X-30 expenditures increased 5-fold and the prototype's first flight slipped 11 years.

There never was a leading X-30 supporter in the government since the program covered so many aspects of space. Only the researchers of Air Force Systems command truly advocated the system, and on the negative side, NASA saw the X-30 as a threat to the space shuttle.

⁷⁹ Paul B. States, *Space and National Security* (Washington, D.C.: The Brookings Institution, 1987), 43.

⁸⁰ Stephen L. Davis, "Speed Kills: Implications of Prompt Global Strike" (master's thesis, School of Advanced Air and Space Studies, June 2003), 9.

⁸¹ Rebecca Grant, "Is the Spaceplane Dead?," *Air Force Magazine* 84, no. 11 (November 2001), 69.

⁸² Thomas A. Heippenheimer, 21.

Thousands of shuttle related jobs would be lost if the NASP succeeded.⁸³ Furthermore, the Air Force's Strategic Air Command (SAC) and Space Command concentrated on operational issues, to include current bomber and missile forces in addition to the existing space systems.⁸⁴ SAC and Space Command therefore were reluctant to advocate a program that had no direct linkage to a future capability.

The X-30 NASP never got off the ground. It took early hits when the program underwent budget cuts within a year of President Reagan's announcement. Additionally, the contractors failed to build anything larger than the fuel tank. The NASP's biggest accomplishments were wind-tunnel tests of experimental scramjet engines. Then the Soviet Union collapsed and the immediate need for the bomber disappeared.⁸⁵ Therefore, it was no surprise that with design problems, escalating costs, diminutive support, and declining military spending, the DoD officially cancelled the X-30 NASP in 1995.⁸⁶ Steven Walker, the director of DARPA's FALCON program says the NASP's demise resulted in part from trying to do too much too soon in the push for a reusable hypersonic system. In other words, the designers were not willing to do a stair step approach. They tried to invent the multiple technologies necessary to build the X-30 all at the same time.⁸⁷

Mid-1990s Efforts

In 1994, a new United States Space Transportation Policy formally divided the effort on launch vehicles between the NASA and the DoD. NASA was given the responsibility to develop new reusable launch vehicles (RLV) and the DoD covered expendable launch vehicles (ELV). The X-33, X-34, and the evolved expendable launch vehicle (EELV) are programs that flowed directly from this space strategy. The USAF also dug up the Dyna-Soar. The USAF needed a manned spaceplane if it was going to control space, or somehow achieve space superiority. The Space Military Vehicle, renamed the Space Operations Vehicle (SOV) received its start during this period. A team of Air Force and NASA engineers worked on the concept and eight

⁸³ NASP program managers projected the X-30 follow-on could accomplish spacelift from anywhere between \$50 and \$400 per pound as compared to the Space Shuttles cost of \$4,300 per pound.

⁸⁴ Larry Schweikart, "Hypersonic Hopes: Planning for NASP, 1986-1991," *Air Power History* 41, no. 1 (Spring 1994), 39.

⁸⁵ Jim Wilson, "Two Hours to Tokyo," *Popular Mechanics* 178, no. 7 (July 2001): 67.

⁸⁶ Thomas A. Heippenheimer, 23.

⁸⁷ John Cost, "Weapons Delivery Goes Hypersonic," *Aerospace America* 42, no. 5 (May 2004), 40.

companies competed for the RLV contract.⁸⁸ NASA awarded the X-33 contract to Lockheed-Martin and the X-34 contract to Orbital Sciences.

The X-33 was a lifting body smaller than the space shuttle. The X-33 program focused on developing an operational demonstration of a low-cost, reliable aircraft-like single stage to orbit (SSTO) system that required a smaller footprint, or logistics trail, than the current space systems. NASA was involved because it was already planning a transatmospheric replacement for the shuttle.⁸⁹ The DoD was initially involved with the X-33 program, but dropped out after NASA awarded the contract to Lockheed-Martin.⁹⁰ Again, as with other proposed space vehicles, the X-33 was to make the old dream of hypersonic flight into reality.⁹¹

The X-34 was another RLV project. The X-34 was a derivative of Orbital Science's Pegasus launcher. It would be launched from an L-1011 airliner airframe and then propel itself to a low earth orbit. The X-34 then could deploy a satellite and then return to land on a runway.⁹² The X-34 theoretically could deploy weapons, but that was not its intended purpose. NASA looked to use the X-34 as a cheaper method to get satellites into orbit and was not concerned with the hypersonic bombing mission.

Both the X-33 and X-34 promised to test advanced technologies that could be used in future reusable launch vehicles, but they encountered major problems and delays.⁹³ The technology for the X-33's novel aerospike engine and composite fuel tanks did not exist. Engineers were unable to build lightweight fuel tanks that could hold the extremely cold liquid fuels required. An accident even damaged one of the hydrogen tanks during a 1999 load test.⁹⁴

The ELV (and Evolved ELV) is the DoD's launch system program and is in use today. The ELV is a family of boosters designed to lift payloads to space. The ELV also can serve as the first stage of a multi-stage hypersonic bomber. The ELV program survived the budget cuts,

⁸⁸ Kelly Spaec and Technology, Kistler Aerospace Corporation, Orbital Sciences, Pioneer Rocketplane, Rotary Rocket Company, Space Access LLC, Vela Technology Development, and Lockheed Martin Skunk Works are all developing commercial RLVs.

⁸⁹ NASA was the major partner. The Air Force only played a small part, trying to incorporate military-specific objectives into the X-33. The Air Force spent \$16 million of the \$163 million spent on the project.

⁹⁰ Peter L. Hays, *United States Military Space into the Twenty-First Century* (Maxwell AFB, Ala.: Air University Press, 2002), 24.

⁹¹ William E. Burrows, 615.

⁹² John A. Tirpak, "The Flight to Orbit," *Air Force* 81, no.11 (November 1998), n.p., on-line, Internet, 2 February 2005, available from http://www.afa.org/magazine/Nov1998/1198orbit_print.html.

⁹³ Jeff Foust, "NASA kills X-33 and X-34," *Spaceflight Now*, 1 March 2001, n.p., on-line, Internet, 29 January 2005, available at <http://spaceflightnow.com/news/n0103/index2.html>.

⁹⁴ *Ibid.*

but got the attention of Congress as the Air Force and Boeing are under investigation for conspiracy to possess and conceal trade secrets. The ELV class rockets can lift the current SOV to altitudes and speeds where it can achieve both orbital and hypersonic near-space operations.

The Air Force is developing a SOV, a reusable launch platform that can act as the base vehicle for a hypersonic military space vehicle. There are many potential SOV configurations, including launching other vehicles into low-earth or even higher orbits. The USAF chose the name SOV after President William J. Clinton cut funding to the space military vehicle, its predecessor. The President did not want to give the impression that the United States was using space for other than peaceful purposes. However, the USAF has not currently funded the SOV at levels that will produce an operating system in the near future. It hopes to start development in 2008 and have an initial operating capability by 2014.⁹⁵ The SOV will have many of the same technological challenges as a previous hypersonic bomber projects but will try to use existing technology to overcome them. For instance, an operating scramjet is not required to power the SOV. The SOV also does not rely on the SSTO requirements NASA puts on their hypersonic project.

President George W. Bush announced a new spacelift initiative on March 2001 and cut funding for the X-33 and X-34 even before NASA flew any test flights.⁹⁶ The government determined the benefits gained from testing the two X-vehicles (X-33 and X-34) did not justify the required expenditure. Higher priorities, such as developing the technology for the next-generation RLV and other programs under the spacelift initiative received funding.⁹⁷ The cancellation concerned the Air Force because Air Force Space Command (AFSC), thinking they could piggyback on some of NASA's technology breakthroughs, saw the X-33 as a major step in developing the SOV.

The X-33 and X-34 programs may have failed because they were too ambitious. Again, just as with the X-30, NASA cancelled the X-33 program in part due to a lack of technological developments, particularly in high temperature materials and structural concepts appropriate to

⁹⁵ Douglas J. Dolvin, "Integrating Vehicle Concepts and Critical Technologies for High-Speed Aerospace Vehicles," *AFRL Horizons*, September 2002, n.p., on-line, Internet, 4 February 2005, available at <http://www.afrlhorizons.com/Briefs/Sept02/VA0210.html>.

⁹⁶ Peter L. Hays, 23.

⁹⁷ Jeff Foust, n.p.

them.⁹⁸ The thinking was ahead of the time. Additionally, a military study conducted by the Air Force Studies Board determined there was not a firm military operational concept for applications of hypersonic aircraft.⁹⁹ Without an operational concept, or at least some sort of doctrine it is difficult to determine or even design capabilities and specifications into a hypersonic vehicle.

Hyper-X Program

The X-43 was NASA's first vehicle in the Hyper-X series of experimental hypersonic test vehicles. Hyper-X series started in 1996 as a follow up program of the X-30 NASP.¹⁰⁰ The Hyper-X program intent is to demonstrate scramjet operations at hypersonic speeds.¹⁰¹ NASA built the X-43A, the first of three vehicle types, to demonstrate air breathing engine technologies for future hypersonic aircraft and space vehicles achieving speeds greater than Mach 5. The more advanced X-43B and C were supposed to accelerate to the hypersonic window themselves without a rocket boost and explore even higher hypersonic speed operations.¹⁰² One thing was different about this program. It focused solely on flight evaluations and not on developing an operational vehicle. Therefore, there was no operational mission envisioned for the X-43 research vehicle, only research.¹⁰³

The first X-43A flight failed after two elevons fell off the Pegasus booster eight seconds after it launched from the B-52 mother ship. The vehicle and booster then went out of control and engineers triggered the booster's self-destruct mechanism.¹⁰⁴ NASA launched a second X-43A on 27 March 2004. The booster held together and the X-43 achieved a powered scramjet run at Mach 5 for a short time before fuel ran out and the vehicle glided to an ocean splashdown.

⁹⁸ Mark J. Lewis, "The Promise of Hypersonic Flight," *Physics World*, December 2003, n.p., on-line, Internet, 16 November 2004, available from <http://physicsweb.org/articles/world/16/12/6>.

⁹⁹ *Hypersonic Technology for Military Application*, National Research Council Report (Washington, D.C.: National Academy Press, 1989), 1.

¹⁰⁰ Michael O. Lavitt, "Hypersonic Successor," *Aviation Week and Space Technology* 140, no. 20 (16 May 1994), 13.

¹⁰¹ Allison Connolly, "The X-43A Streaks into Aircraft History," *The Virginian-Pilot*, 17 November 2004, n.p., on-line, Internet, 8 February 2005, available from <http://home.hamptonroads.com/stories/story.cfm?Story=78194&ran=85531>.

¹⁰² *Evaluation of the National Aerospace Initiative*, National Research Council of the National Academies Report (Washington, D.C.: The National Academies Press, 2004), 109-110.

¹⁰³ John W. Hicks and Gary Tripensee, "Hypersonic X-Plane Flight Development of Technologies and Capabilities for the 21st Century Access to Space," Address, AGARD Future Aerospace Technology in Service to the Alliance, Paris, France, 18 April 1997.

¹⁰⁴ "Hyper-X Setback," *Air and Space Smithsonian* 16, no. 3 (August/September 2001), 7.

¹⁰⁵ The third and final X-43A flight achieved Mach 9.8 (around 7,000 mph) for 10 seconds, flying almost 2 miles a second.¹⁰⁶ The third X-43A launch marked the end of the Hyper-X program as NASA cancelled the X-43B and C so the agency could concentrate on other technologies. NASA will gain much valuable data from the two successful X-43 launches. The key will be the matching of data taken from the flight and comparing it to the information extracted from the wind tunnel tests. Then NASA will compare the data to computer models and analyze it to design better engines.¹⁰⁷

The DoD is now the prime contractor for overseeing hypersonic research, but NASA will still contribute to scramjet research. The DoD started work on a second phase of Hyper-X by awarding a \$41.6 million contract to four developmental teams. However, the main effort will shift to developing small launch vehicle prototypes capable of carrying a 1,000-pound satellite into space for less than \$5 million by 2007.¹⁰⁸ This research will only benefit hypersonic bomber technology, as orbital speeds need to pass through the near-space hypersonic speed envelope. Additionally, the USAF and DARPA have teamed up to develop military applications of hypersonic technology under the FALCON program.

The FALCON Project

DARPA is searching for key technologies that will allow the United States to overcome the failure to successfully engage and destroy high value, time critical targets in conflict.¹⁰⁹ DARPA created the Force Application and Launch from CONUS (FALCON) program as a “long view” plan to provide the DoD with a reusable hypersonic cruise vehicle (HCV) by 2025.¹¹⁰ However, the USAF has learned from the past and made FALCON’s initial goals less ambitious than the X-30 NASP. The intent is to develop and validate in-flight technologies that will allow both near and far term capabilities to execute time-critical, prompt global-reach missions. FALCON will have a near term goal of developing a hypersonic military vehicle using existing technologies. The programs first aspiration is to build a capable hypersonic vehicle that will not require a national expenditure on the magnitude of the X-20, X-30, or X-33. To

¹⁰⁵ “Extreme Speed,” *Weekly Reader – Senior* 82, no. 25 (7 May 2004), 7.

¹⁰⁶ Guy Gugliotta, “NASA Scramjet Beats Air Speed Record Again,” *Washington Post*, 17 November 2004, A8.

¹⁰⁷ Thomas A. Heippenheimer, 25.

¹⁰⁸ Allison Connolly, “The Final Flight of X-43A,” *The Virginia-Pilot*, 8 November 2004, n.p.

¹⁰⁹ “USAF Invites Hypersonic Ideas,” *Professional Engineering* 16, no. 12 (9 July 2003): 12.

¹¹⁰ Ben Iannotta, “Paving the Way,” *Armed Forces Journal*, January 2004, 24.

accomplish this DARPA hopes to accomplish this first phase by building a small launch vehicle (SLV), a simpler and shorter-term version of the HCV.¹¹¹

The initial phase of FALCON was a six-month study to develop conceptual designs, performance predictions, and demonstration plans for the SLV. Nine companies participated in the first phase (29 contractors bid for it).¹¹² One proposed near-term SLV capability will be conducted by way of a rocket boosted, expendable munitions delivery system that carries its payload to the target by executing boost-glide maneuvers at hypersonic speeds. This concept allows the SLV to deploy a Common Aero Vehicle (CAV) capable of delivering up to 1,000 pounds of munitions to a target 3,000 nautical miles down-range. The use of rockets allows the FALCON program to concentrate on the technologies needed to make the reusable hypersonic cruise vehicle itself, and not the engine. Since there are no scramjet engines to develop, DARPA expects the SLV to fly by 2010.¹¹³ The powered HCV program can gain from knowledge obtained from the gliders and apply that understanding to future programs.¹¹⁴

FALCON's HCV capability entails developing a reusable, hypersonic bomber capable of delivering 12,000 pounds of payload to a target 9,000 nautical miles from a CONUS launch in less than two hours. In other words, DARPA and the USAF are trying to develop a true hypersonic bomber. The FALCON program also addresses many high priority mission areas and applications such as global presence, space control, and space lift.¹¹⁵ Four contractors received funding awards totaling more than \$41 million to conduct a 10-month preliminary design and developmental effort and move forward on their current launch vehicle designs.¹¹⁶

¹¹¹ Andrews Space Inc., Lockheed Martin Co., and Northrop Grumman have the contract to explore a hypersonic vehicle that an SLV could launch, or even takeoff from a runway.

¹¹² K. L. Vantran, "FALCON Phase 1 Contractors Selected," *American Forces Information Service News Articles*, 22 December 2003, n.p., on-line, Internet, 5 November 2004, available from http://www.defenselink.mil/news/Dec2003/n12222003_200312221.html.

¹¹³ Tariq Malik, "Going Hypersonic: Flying FALCON for Defense," *Space.com*, 23 July 2003, n.p., on-line, Internet, 9 November 2004, available from http://www.space.com/business/technology/darpa_falcon_030723.html.

¹¹⁴ John Cost, 40.

¹¹⁵ *Evaluation of the National Aerospace Initiative*, 114.

¹¹⁶ "Hypersonic Research," *Signal* 59, no. 3 (November 2004), 6. The four companies competing for the small launch vehicle contract are Airlaunch LLC, Lockheed Martin, Microcosm Incorporated, and Space Exploration Technologies.

Transformation and a New Push towards Hypersonic Planes

USAF interest in hypersonic programs appears to go in cycles. The USAF approves new proposals only to quickly cut funds after a prototype develops slower than required to justify the massive expenditure necessary to continue. This happens, in part, because prior to 2001 there was no clear statement on the mission needs for a hypersonic vehicle.¹¹⁷ In 2001, however, the National Aerospace Initiative, the Quadrennial Defense Review, and the resulting National Military Strategy made significant changes with major impacts on hypersonic flight programs.

National Aerospace Initiative

In 2001, the DoD and NASA joined forces and developed the National Aerospace Initiative (NAI). The NAI has three scopes of study and encourages sharing technology with other projects. The three scopes of study are hypersonics, access to space, and space technology.¹¹⁸ The initiative emphasizes the first two because the space technologies scope was too broad to focus on. The NAI brought together essentially all existing United States programs and attempted to lay out a high speed/hypersonics technology roadmap.¹¹⁹ This creates an environment where technologies from a different program, or pillar, can now benefit the development of another. For example, the space access pillar may use the hypersonic pillar's air breathing scramjet engine as the second stage in a two stage to orbit (TSTO) launch system. Therefore, the stage is now set for synergistic effects that can occur as technology gained from one pillar enables a system in another.

The near-space region again received a national focus. The NIA provided focus and critical mass to hypersonic science and technology development. It also offered the framework for the long-term commitment needed to develop this challenging technology.¹²⁰

¹¹⁷ *Why and Wither Hypersonics Research in the US Air Force*, vi.

¹¹⁸ *Evaluation of the National Aerospace Initiative*, vii.

¹¹⁹ *Ibid.*, 24. A few of the different hypersonic research projects in 2001 were Army Hypersonic Missile, the Navy Hypersonics Flight Demonstrator Program (HyFly), the Air Force Single-Engine Demonstrator, The Defense Advanced Research Projects Agency (DARPA) Responsive Access, Small Cargo, Affordable Launch (RASCAL), and NASA's Next-Generation Launch Technology (NGLT).

¹²⁰ Craig Covault, "Hypersonics Strategy Sets Stage for Next Great Step," *Aviation Week and Space Technology* 154, no. 13 (26 March 2001), 29.

Rumsfield's Plea

The Secretary of Defense called on the United States military to transform its forces and capabilities in the 2001 Quadrennial Defense Review (QDR). This continues the transformation called for in the 1997 National Military Strategy. The 2001 QDR claims increasing diversity in the sources and unpredictability in the location of potential future conflicts is going to be the norm of future conflict. Not only will the location and type of conflict be unpredictable, but it will also vary to such a degree that the United States will not be able to use deployed forces to access all future enemies.¹²¹ The QDR expounds several tenets that comprise the essence of United States defense strategy. These tenets are managing risks, developing a capabilities based approach, defending the United States and projecting military power, strengthening alliances and partnerships, maintaining favorable regional balances, and developing a broad portfolio of military capabilities. The Secretary also stresses the need to develop transformational capabilities to carry out new defense strategies and meet the demands of the 21st century.¹²² Hypersonic bombers fit right in.

The QDR creates an environment that promotes hypersonic research and development. Hypersonic bombers can fill the QDR proposition to ensure contact with enemies and places denying access to deployed forces. In addition, hypersonic bombers specifically help the 2001 QDR tenets “A Capabilities-Based Approach,” “Defending the United States and Projecting United States Military Power,” and “Developing a Broad Portfolio of Military Capabilities.” Capability based approaches include long-range precision strike. A hypersonic bomber can project power at long ranges to “deter threats to the United States and when necessary, to disrupt, deny, or destroy hostile entities at a distance.”¹²³ Hypersonic vehicles also create substantial margins of advantage across key areas of military competition and ensure access to distant theaters.

The National Military Strategy also mentions the need to transform to meet the challenges of the twenty first century. The strategy identifies the need to ensure access to distance theaters and protect United States space assets. It encourages innovation within the

¹²¹ *Quadrennial Defense Review Report*, Department of Defense Report (Washington, D.C.: Department of Defense, 30 September 2001), 12.

¹²² *Ibid.*, 13-14.

¹²³ *Ibid.*

armed forces and taking full advantage of science and technology.¹²⁴ Additionally, the Security Strategy identifies the need to create desired effects within hours of tasking, anywhere on the globe, including locations deep within an adversary's territory in its Prompt Global Strike Needs Statement. Other documents support a hypersonic bombing capability.

The USAF Posture Statement 2003 and America's Air Force Vision describe the tenets of Global Vigilance, Global Reach, and Global Power and the concepts of operations under which the Air Force operates. The fourfold objectives are first, to transform the Air Force into a capabilities-focused expeditionary air and space force. Second, to make warfighting effects the drivers for everything the Air Force does. Third, the Air Force will provide necessary resources expeditiously to the warfighters. Lastly, the Air Force is to guide planning, programming, and requirements reform. It is clear that a hypersonic bomber could contribute to the achievement of those objectives.

Where to Now?

President George W. Bush is steering toward dividing NASA and DoD responsibilities. He reinforced this split in a 2004 space policy speech where he outlined NASA's three major goals.¹²⁵ Although the goals included a replacement vehicle for the shuttle by 2014, there was no emphasis for NASA to accomplish hypersonic research. Theoretically, testing for the space shuttle's replacement, the new Crew Exploration Vehicle, will benefit the hypersonic world, but there is clearly no civilian hypersonic emphasis.

The President mentioned the need for technological breakthroughs, including engine propulsion, a key in a truly sustainable, maneuvering hypersonic bomber.¹²⁶ The scramjet is the next step in engine propulsion. Its promise of airbreathing flight to orbit stands today as an unresolved issue for the new century. There is still much to learn. The successful X-43 tests did not demonstrate that the United States could build anything like the X-30 NASP today. Significantly, a decade of NASP research in critical fields showed that as the engineers learned more, the prospects for a hypersonic vehicle grew weaker rather than stronger.¹²⁷

¹²⁴ *National Military Strategy of the United States of America*, Chairman of the Joint Chiefs of Staff (Washington, D.C.: US Government Printing Office, 2004), 18.

¹²⁵ President George W. Bush, Remarks by the President on United States Space Policy at NASA Headquarters, Washington D.C., 14 January 2004.

¹²⁶ President George W. Bush, 14 January 2004

¹²⁷ Thomas A. Heippenheimer, 26.

However, the technology is moving forward and tools for hypersonic flight are becoming more available each year. Plans are in the works for a new scramjet engine that should be ready for testing in 2008. These engines should be large enough to fly on prototype hypersonic cruise vehicles.¹²⁸ Scramjet technology is only a small piece of the hypersonic flight puzzle, but it has taken the center stage recently, particularly after the successful X-43 tests. These engines will be nice to have, and may alleviate other technological problems, but they are not a necessity. A vehicle can achieve hypersonic speeds without the scramjet. As the FALCON tests progress, there can be gains in other critical systems necessary for hypersonic flight.

The last 40 years have been a roller coaster for hypersonic bomber development. The development of the solid fueled rocket and the Cold War pushed the emphasis different directions and away from the hypersonic bomber. The technology did not exist when the United States finally attempted to develop the X-30 and X-33. There also was no USAF policy developed that defined a mission for hypersonic bombers other than the time advantages gained through speed. The Hyper-X and FALCON projects are attempts to gain lost ground using technology currently available to springboard future hypersonic activity. These two projects may be the key to fill the Air Force's need for speed. The transformation atmosphere in today's military provides the foundation needed for hypersonic bombers to take hold.

Conclusion

Airbreathing hypersonic projects in the last 40 years have been a series of starts and stops. Hypersonic research slowed almost to a standstill following the Dyna-Soar cancellation. The national space policy and other priorities all caused hypersonic research and funding to stagnate. A new surge of hypersonic activity occurred in the 1980s. The USAF and NASA unsuccessfully tried to build the hypersonic X-30 National Aerospace Plane. The designers wanted nothing less than a fully capable global hypersonic bomber. The X-30 technological requirements ended up being too much for the times. The same thing happened a little more than a decade later with the X-33. Technology again limited the X-33 development. The USAF and NASA cut funds after the program failed to produce any concrete results.

¹²⁸ Stanley W. Kandebo, "Bigger May be Better," *Aviation Week and Space Technology* 161, no. 7 (16 August 2004), 50.

There are recent bright spots. The NAI is forcing other agencies to cooperate. This allows developments in one hypersonic program to benefit others. The USAF is also taking a piecemeal approach to hypersonic development. Instead of trying to build an entire hypersonic vehicle in one shot, the USAF is conquering the technological challenges one-step at a time. This is evident with the recent X-43 test flights working specifically on scramjet technology. As the nation moves closer to having the technology to build a hypersonic bomber, the USAF will need to make tough decisions on the hypersonic program's research, development, and production. To make these decisions, a thorough knowledge of hypersonic flight's advantages and disadvantages is needed.

Chapter Three

The Good, the Bad, and the Ugly: Hypersonic Advantages and Disadvantages

The hypersonic bomber is a transformational system that can fill a critical niche within the Air Force's future global strike task force. Hypersonic flight offers the promise of new attributes for dramatically expanding and improving USAF capabilities and mission execution. Many publications expound hypersonic flight's exciting potential. Most give simple statements of tantalizing new capabilities, such as how terrific hypersonic speeds will be for global bombing. However, there are very few, if any sources listing both the advantages and disadvantages of a hypersonic bomber. This chapter is an attempt to contrast the good and bad characteristics of hypersonic flight in one location.

Advantages

Hypersonic flight is consistent with classic tenants of warfare. For instance, Sun Tzu declared, "Rapidity is the essence of war."¹²⁹ Hypersonic speeds offer the rapidity Sun Tzu spoke of over global distances. Furthermore, J. F. C. Fuller taught that a nation's combined tactics had to form around its weapon of greatest reach.¹³⁰ A hypersonic bomber clearly would be one of the USAF's weapons of greatest reach. A hypersonic bomber offers a blend of speed, range, and flexibility that is presently unequalled in other systems.¹³¹

Hypersonic bombers provide several advantages. First, their speed allows rapid global response, offering new capabilities in a crisis. They may even limit escalation by providing a rapid show of force in a few hours. Second, they may eliminate or at least reduce the need for

¹²⁹ Lionel Giles, *Sun Tzu on the Art of War* (London, England: British Museum, 1910), 72, 110.

¹³⁰ Colonel J.F.C. Fuller, *The Foundations of the Science of War* (London, England: Hutchinson and Company, 1926), 149-150.

¹³¹ *Why and Wither Hypersonics Research in the US Air Force*, United States Air Force Scientific Advisory Board Report SAB-TR-00-03 (Washington, D.C.: United States Air Force, December 2000), 9.

forward basing. Third, they are more survivable than other aircraft. Lastly, they could carry a variety of weapons. These weapons would be as accurate as today's munitions, and would bring incredible standoff distances.

Basic Capabilities

The most compelling reason to build a hypersonic bomber is speed. Speed gives the USAF the capability to respond to almost any crisis in a timely manner. A hypersonic bomber allows for rapid response times from either the continental United States or forward operating locations. The hypersonic bombers will allow the USAF to execute long-range strike operations without the need to deploy a large number of support or strike forces. This high speed additionally increases the USAF ability to respond to time sensitive targets (TSTs) with limited windows of vulnerability or attack opportunity.

A goal of DARPA's Force Application and Launch from CONUS (FALCON) hypersonic program is to develop the capability to strike anywhere in the world within two hours.¹³² Basic mathematics says this will require an average speed of 4,500 mph, or almost Mach 7 to strike a target 9,000 miles away.¹³³ Using the same guidance, it will require a speed of Mach 9 to reach targets on the exact opposite side of the earth within two hours. The craft would further need to fly in the near-space environment at altitudes between 100,000 feet to 300,000 feet.¹³⁴

Hypersonic bombers will improve the USAF strike capability. Planners can easily work hypersonic bombers into an Air Tasking Order (ATO) strike package. The hypersonic bomber can be on the leading edge of a global strike task force opening land, sea, and air corridors for joint strike packages in conflicts where there are anti-access issues and asymmetric threats to deal with. This provides the USAF with an impervious strike platform capable of precision engagement as well as gaining predictive battle space awareness throughout the theater in all conflict phases.¹³⁵

Hypersonic bombers will be more flexible than current space launch systems. A hypersonic bomber will be reusable consistent with other bomber operations today. The

¹³² "Hypersonic Bomber," *Popular Mechanics* 180, no 9 (September 2003), 23.

¹³³ John Cost, "Weapons Delivery Goes Hypersonic," *Aerospace America* 42, no. 5 (May 2004): 39.

¹³⁴ Seymour M. Bogdonoff, *Hypersonic Flight Vehicles: Perspective and Prognosis*, Princeton University Report (Princeton, N.J.: Princeton Department of Mechanical and Aerospace Engineering, 1999), 6.

¹³⁵ *The Military Spaceplane: Providing Transformational and Responsive Global Precision Striking Power*, One Team White Paper on the Operational Utility of a Military Spaceplane (Peterson AFB, Colo.: One Team, January 2002), 2.

hypersonic bomber will be able to takeoff and land from a conventional military runway and carry a 12,000-pound payload capable of a high-speed munitions release.¹³⁶ It will not be limited to static launch sites as today's land-based rocket force is. The fleet size will be similar to the B-2 bomber, measured in tens and twenties, and not hundreds.¹³⁷

Hypersonic engines will be air-breathing scramjets. Air-breathing engines have several advantages over rockets. NASA's recent X-43 test flight showed that vehicle technologies might someday yield sustained air-breathing cruise speeds of Mach 7 or more.¹³⁸ Mach 7 is an important number because it is the minimum speed guaranteed survivability in today's threat environment. An air-breathing engine uses oxygen from the atmosphere instead of a carried oxidizer. Therefore, to produce the same thrust, air-breathing engines require less than one-seventh the propellant that rockets do. This results in lighter, smaller, and cheaper launch vehicles. Missions can also be more flexible because a hypersonic vehicle will be more maneuverable than a long-range rocket. Furthermore, there is a higher safety factor. A hypersonic flight can takeoff from a typical bomber runway, abort on the climb out, and then glide back to a multitude of landing fields. The sortie does not need to launch over the ocean as space flights do now and hence, will not be restricted by the distance to a suitable landing field.

Something needs to accelerate an air-breathing bomber to hypersonic velocities, since scramjets only work at high speeds. One method to accelerate the hypersonic vehicle to high speeds is to use a two-stage system. The first stage would accelerate both the booster and vehicle to high speeds. The hypersonic bomber would then separate and continue its mission. Today, the first stage is normally a rocket booster that falls into the atmosphere or into the ocean when its fuel is spent. However, future first stages need to be reusable if there are going to be quick and efficient turnarounds.

There could be some advantages for a reusable two-stage launch system. For instance, the USAF could employ both stages for global attack missions. The first stage could even continue on a different mission after launching the hypersonic bomber, performing the same missions envisioned for the regional bomber. The second stage would be the long-range hypersonic bomber. These two-stage dual-use vehicles could also augment conventional

¹³⁶ *Military Spaceplane System Roadmap: Operationally Responsive Spacelift for the 21st Century, Volume 2* (DRAFT), Air Force Space Command White Paper (Colorado Springs, Col.: AFSPC, 31 May 2003), 40.

¹³⁷ John Cost, "Weapons Delivery Goes Hypersonic," *Aerospace America* 42, no. 5 (May 2004), 39.

¹³⁸ John Cost, 42.

transport aircraft. For instance, after separation, the first stage could employ to the theater in minutes rather than hours to deliver equipment, spare parts, or personnel during time-critical circumstances.¹³⁹

The capability exists for a hypersonic vehicle to have other missions besides bombing. A hypersonic bomber can be equipped to conduct surveillance and reconnaissance. Pre and post strike reconnaissance is a necessary part of bombing missions. A hypersonic reconnaissance capability will augment and replenish space-based ISR capabilities. The hypersonic bomber can help ensure that commanders can see the enemy while effectively commanding and controlling their own forces from peacetime through war termination.¹⁴⁰

Anti-Access Environments

Hypersonic bombers can be the key enablers that knock down the door for follow on forces. An enemy's long-range strike assets may hold USAF regional combat assets at risk. The USAF must have assured access to gain strategic control. A hypersonic bomber is vital in this environment because of its ability to strike high-priority targets such as air defense batteries, command and control infrastructure, and missile batteries that keep current United States forces out of striking distance. A hypersonic bomber can strike these targets without regard to asymmetric threats that further impede conventional forces.¹⁴¹ Directly striking these threats may allow the United States to act at anytime, any place, without its adversary dictating the pace or flow of USAF operations. In doing so, a long-range hypersonic bomber will contribute to strategic control.¹⁴²

Hypersonic capabilities will free the military from relying on overseas air bases to station bombers and tankers to support them.¹⁴³ The current and future international political environment severely constrains this country's ability to conduct long-range strike missions on high value, time critical targets from outside the continental United States. It is easy to imagine

¹³⁹ *Why and Wither Hypersonics Research in the US Air Force*, 51-52.

¹⁴⁰ *The Military Spaceplane*, 2.

¹⁴¹ Jack Spencer, "Guidelines for Modernizing America's Armed Forces," *The Heritage Foundation Background*, 28 March 2001, 10., on-line, Internet, 4 January 2005, available from <http://www.heritage.org/Research/NationalSecurity/BG1422.cfm>.

¹⁴² *Long Range Global Precision Engagement Study*, Department of Defense Planning Guidance (Washington, D.C.: Department of Defense, 1 April 2003), 8.

¹⁴³ Andrew Bridges, "U.S. Military Seek Global-Reach Bomber," *The Honolulu Advisor*, 8 December 2003, n.p., on-line, Internet, available from <http://the.honoluluadvertiser.com/article/2003/Dec08/mn/mn01a.html>.

a critical need to project United States power worldwide without waiting for permission to use overseas bases or for overflight permission. Access to facilities is likely to be a problem in future conflicts. Host nations also will likely have a say in target selection. A hypersonic bomber will give the United States the capability to project United States uninhibited power worldwide without waiting for either permission to use overseas basing or overflight rights, thus allowing unfettered access to strike every target. Furthermore, it can be difficult to base strike aircraft close enough to adversaries so that the strike assets will not tie up valuable tankers.

Early warning and other aircraft detection capabilities are increasing. The Chinese are developing a passive defense system that can detect the slight turbulence of commercial radio and television waves caused by aircraft flight. This capability could prove effective against stealthy aircraft.¹⁴⁴ A hypersonic aircraft has the potential to survive without dependency on stealth. By the time it is detected in the atmosphere, it is too late for an enemy to react. Speed, altitude, and standoff all ensure survivability. Lastly, it provides a surveillance capability when the enemy compromises other assets.¹⁴⁵

Survivability

Survivability in a high threat environment is one of the hypersonic bombers most important characteristics.¹⁴⁶ The hypersonic bomber's high operating speed and flight altitude provide inherent defenses against fairly robust and integrated air defense systems (IADS). Current fighters will not be able to engage a hypersonic bomber. Few surface-to-air missiles (SAMs) have the capability to intercept a highflying hypersonic bomber successfully.

Consider for example, a Mach 7 hypersonic bomber against capable threats. The SA-5, SA-10, and SA-12 are used because they are capable high-altitude missiles that have unclassified parameters listed in Jane's publications. Using the last test of the X-43 as an example a hypersonic bomber, parameters are 4900 mph (Mach 7) at 100,000 feet.¹⁴⁷ Jane's claims the SA-

¹⁴⁴ Jack Spencer, "Guidelines for Modernizing America's Armed Forces," *The Heritage Foundation Background*, 28 March 2001, n.p., on-line, Internet, 4 January 2005, available from <http://www.heritage.org/Research/NationalSecurity/BG1422.cfm>.

¹⁴⁵ Michael W. Kehoe and Rodney H. Ricketts, "Getting Up to Speed in Hypersonic Structures," *Aerospace America* 30, no. 9 (September 1992), 19.

¹⁴⁶ *Peregrine Hypersonic Strike Fighter Weapons System*, A proposal in response to the AIAA Foundation Graduate Team Aircraft Design Competition request for proposals (Atlanta, Ga.: Georgia Institute of Technology, 5 June 2000), i.

¹⁴⁷ Mach 1 at standard day conditions at sea level is approximately 761 mph. The speed in mph decreases to 660 mph around 40,000 feet and then slowly increases again to above 700 mph at altitudes greater than 120,000 feet.

5's best missiles fly at speeds up to Mach 8 and are capable of striking targets at 130,000 feet.¹⁴⁸ However, the maximum target velocity for the SA-5 is approximately 2600 mph, and therefore cannot hit a hypersonic bomber.

The SA-10 can fly at speeds up Mach 6 and hit targets as high as 150,000 feet but its maximum target speed is 2610 mph and thus cannot hit a hypersonic bomber at 100,000 feet. However, Jane's claims the SA-12's maximum target speed is over 6500 mph, or Mach 9.5. This is greater than the notional Mach 7 hypersonic bomber speed. Nevertheless, Jane's claims the SA-12's maximum effective altitude is 98,000 feet. Therefore, a hypersonic bomber can also operate unimpeded near an SA-12 "Giant" surface-to-air missile system.

The previous examples demonstrated that a hypersonic bomber stands a good chance of surviving against the best air defenses currently available. Survivability chances only go up as the speed increases. The Air Force Scientific Advisory Board claims a Mach 15 hypersonic bomber could elude any enemy missile defense systems.¹⁴⁹ An anti-ballistic missile system (ABM), such as Russia's Gazelle ABM-3 system could be a threat, but standoff weapons can counter it. Thus, it appears that air defense systems will have considerable difficulty against a hypersonic bomber and its fast flying warheads.

Weapons Type and Payload

The United States continually demonstrates the need for a weapons platform that can respond in a timely manner to take out high value, time critical targets from a standoff distance. A hypersonic bomber will be able to accomplish this. The USAF desires a 12,000-pound payload for its hypersonic bombers. This allows the bomber to carry a payload equivalent to six 2,000-pound Joint Direct Attack Munitions (JDAMs).

The hypersonic bomber primary weapon will be the common aero vehicle (CAV). A CAV can deliver several different types of explosives or warheads.¹⁵⁰ The CAV is a maneuvering reentry vehicle designed to bring weapons down through the atmosphere making it

Mach 1 is 675 mph at 100,000 feet on a standard day. For this paper, the author chose to approximate Mach 1 at 700 mph to average the time a projectile traverses the entire airspace spectrum.

¹⁴⁸ The author used unclassified data taken from "Jane's Land-Based Air Defense documents" for this study.

¹⁴⁹ Jim Wilson, "Two Hours to Tokyo," *Popular Mechanics* 178, no. 7 (July 2001): 67.

¹⁵⁰ Airlaunch LLC, Andrews Space Inc, Exquadrum, Inc., KT Engineering, Lockheed Martin, Mococosm Inc., Orbital Sciences Corp., Scafer Corp., and Space Exploration Technologies each received a contract to propose a small launch vehicle that would launch FALCON weapons.

possible to withstand the extreme heats associated with the friction of the atmosphere.¹⁵¹ The CAV denotes a common, aero thermodynamic, maneuvering reentry vehicle that could carry multiple payloads for dispensing or direct impact. The hypersonic bomber would launch the CAV into a suborbital trajectory.¹⁵² The CAV will then act as a reentry “shell” that can maneuver to deliver one or more accurate munitions.¹⁵³ CAV development is currently underway with four companies receiving federal contracts to study hypersonic weapons.¹⁵⁴

Each CAV will carry a variety of submunitions. The payload can vary from low-cost autonomous attack submunitions to small bombs to a single penetrating warhead. One of these warheads is a 1,000-pound class designed to penetrate into deeply buried targets. It will have an impact speed of up to 4,000 feet per second (approx. 2,700 mph, or Mach 3.5) and be accurate to within three meters.¹⁵⁵ CAV’s can even supplement ISR assets. A CAV can carry small-unmanned aerial vehicles (UAVs) for possible use as a battle damage assessment tool or to look for targets of opportunity for subsequent aircraft.¹⁵⁶

Hypersonic impact speeds allow for smaller weapons. Weight comparisons of a large gravity bomb and an equivalent hypersonic penetrator indicate the weapon can achieve the same effects with reduced weights. For example, a 250-pound bomb can do the same damage as a 5,000-pound bomb. Since the penetration depth is proportion to its kinetic energy (equal to $\frac{1}{2} M \times V^2$, where M is the weapons mass and V is its velocity), a reduction of 20 times in weight can be traded for a $20^{1/2}$ (or square root of 20) increase in velocity. For example, the GBU-28 bunker buster’s impact velocity can be as high as 1,300 feet/second. Using the above scaling, a 250-pound hypersonic penetrator’s velocity must be approximately 4.5 times faster, or approximately 5,800 ft/second to achieve the same effects. In practice, the velocity scaling is more favorable, and the scaled velocity needs to be only about 3,000 ft/sec. This is in the CAVs capability since

¹⁵¹ *Military Spaceplane System Roadmap*, 11.

¹⁵² John Cost, 41.

¹⁵³ Frank Colucci, “FALCON Aims at Global Striking Power,” *Military Aerospace Technology* 3, no. 2 (25 June 2004), n.p. on-line, Internet, 8 Mar 2005, available from <http://www.military-aerospace-technology.Com/article.cfm?DocID=518>.

¹⁵⁴ “Four Military Contractors to Study Hypersonic Weapons,” *New York Times*, 26 November 2003, C4. The four companies are Northrop Grumman, Lockheed Martin, Boeing Co., and Andrews Space

¹⁵⁵ Ben Iannotta, “Paving the Way,” *Armed Forces Journal*, January 2004, 24.

¹⁵⁶ *Why and Wither Hypersonics Research in the US Air Force*, 51.

they have the potential of achieving impact velocities of approximately 4,000 feet per second.¹⁵⁷ This could be an important advantage for use with hypersonic strike aircraft. A booster motor on a hypersonic penetrator can increase the desired weapons effects.¹⁵⁸

Another option is an inert glide bomb. It would weigh less than current munitions. However, the mass of the glide bomb alone would be sufficient to destroy a target upon impact because of the high impact speeds resulting from a hypersonic weapons delivery.¹⁵⁹ Friction would not significantly slow the inert weapons to where there would be a need for explosives. This is very similar to the concept of space based inert weapons.

A significant advantage is the range from which a hypersonic bomber can deploy a CAV. A hypersonic CAV release may be over 3000 miles away, while the cross-range, or capability to strike offset the target, can be as much as 800 miles.¹⁶⁰ All this should occur in 800 seconds, or a little over 13 minutes from launch to strike.¹⁶¹ Plans call for an enhanced CAV (ECAV) with even more capability. The ECAV will be able to glide for over 10,000 miles with a cross-range of over 3,400 miles.¹⁶² The ECAV's time of flight is 3,000 seconds, or 50 minutes.¹⁶³ The ECAV gives the hypersonic bomber true global reach.

The extended CAV and ECAV flight times seem to negate the hypersonic time sensitive targeting (TST) capability, but there are other capabilities. Fixed targets will not be the only available strike option. A CAV can take en route targeting updates or even wave off orders based on TST procedures. Therefore, hypersonic bombers can strike mobile targets. A CAV may also maneuver around terminal defenses, giving the weapon additional flexibility.¹⁶⁴

Hypersonic bombers also increase the USAF's nuclear options. The bomber will be able to deliver a nuclear weapon quickly to the other side of the world. However, unlike intercontinental ballistic missiles (ICBMs), it will be recallable independent of a man in the loop or not. A hypersonic bomber will bring a better balance to the USAF bomber fleet. It will bring

¹⁵⁷ Frank Colucci, "FALCON Aims at Global Striking Power," *Military Aerospace Technology* 3, no. 2 (25 June 2004), n.p. on-line, Internet, 8 Mar 2005, available from <http://www.military-aerospace-technology.com/article.cfm?DocID=518>.

¹⁵⁸ *Why and Wither Hypersonics Research in the US Air Force*, G-7.

¹⁵⁹ "Hypersonic Bomber," *Popular Mechanics* 180, no 9 (September 2003), 23.

¹⁶⁰ Major Jake Porter, "CAV benefits to the Warfighter," AFSPC/DRMF Presentation, 3 Feb 03.

¹⁶¹ John Cost, 41.

¹⁶² Ben Iannotta, 24.

¹⁶³ John Cost, 41.

¹⁶⁴ Frank Colucci, "FALCON Aims at Global Striking Power," *Military Aerospace Technology* 3, no. 2 (25 June 2004), n.p. on-line, Internet, 8 Mar 2005, available from <http://www.military-aerospace-technology.com/article.cfm?DocID=518>.

the USAF a platform capable of high speed and altitude, high payload, long range, survivability, and quick global response with the ability to recall after launch.

Disadvantages

The hypersonic bomber, like anything else, has its disadvantages. High development costs, flight profile problems, surface heating, plasma fields, and testing capability can challenge any potential military advantage gained by hypersonic speeds.¹⁶⁵ This section discusses these disadvantages associated with hypersonic flight. Several technological problems are important enough to warrant discussion even though the paper assumes the technology will be available to overcome them.

Cost

High costs have been a major issue with hypersonic development since the beginning. The government cancelled the Dyna-Soar X-20 in part because of cost. The X-30 and X-33 experienced cost overruns. The projected cost of building X-30 National Aerospace Plane prototypes was between \$5 and \$15 billion in 1980's dollars, plus an additional \$1 billion in research.¹⁶⁶ It will only be higher today. NASA cancelled the last two series of X-43 testing because they needed to spend the money elsewhere. Finally, ACC worries about the huge developmental costs and the number and type of facilities required to support the research, development, and testing of hypersonic systems.

The Skip-Glide Reality

The hypersonic bomber concept originally called for continuously skipping out of the atmosphere on a periodic trajectory to allow the vehicle to cool in areas of less friction and possibly extend its range by transiting in areas with lower drag. Engineers initially felt this boost-glide or skipping concept was a feasible method of operation. This is the very concept called for by Sanger's Silverbird bomber. However, there are several problems associated with the skip-glide concept.

¹⁶⁵ *Hypersonic Technology for Military Application*, National Research Council Report (Washington, D.C.: National Academy Press, 1989), 1.

¹⁶⁶ Pat Jackson, "Gold in the skies?" *Ad Astra* 2, no. 10 (November 1990), 10.

Oscillatory trajectories reduce a hypersonic vehicles range by as much as 30 percent. The drag at the lower portion of the periodic trajectories is too strong to maintain energy. The stresses put on the hypersonic airframe are strong enough that it is questionable whether the vehicle can survive the large changes in angle of attack, airflow, and intense heating. The pull-up maneuvers also produces higher peak heating, with repeated thermal and mechanical cycling.¹⁶⁷ The boost-glide concept also has problems. Engineers doubt whether the propulsion system can safely shut down and restart without inducing large pitching moments.¹⁶⁸ In addition, rockets are not reliable enough to safely launch and sustain boost-glide operations. There are no potential improvement advantages over steady state cruise, where the hypersonic vehicles angle of attack can manage the heat buildup.

Heat

The hypersonic bomber faces major challenges in areas of high-temperature structures and thermal protection – the thermal protection system being the most difficult.¹⁶⁹ The technical challenges of thermal protection increase dramatically as the vehicle speed increases.¹⁷⁰ Technology development and demonstration are required to mature critical hypersonic technologies before building a hypersonic bomber.

A global hypersonic bomber will experience a severe cooling problem. The vehicle flies its entire flight in the harsh environment that space vehicles only transit through. The whole flight profile is only a re-entry problem for space vehicles, such as the space shuttle. A hypersonic bomber is going to experience long exposure times to the high temperatures caused from the friction of the atmosphere. Thermal protection systems only delay heat build up, and hypersonic heating problems are more than skin-deep. Designers need to manage the heat that builds up inside the vehicle also.¹⁷¹ This high-friction, high-temperature environment is a tough environment in which to operate, as shown with the space shuttle Columbia accident.

¹⁶⁷ Gregory E. Moster and John G. Martin, *Oscillatory Trajectories applied to NASA's DF-7 Configuration*, AIAA Paper 99-4931. Norfolk, Va.: American Institute of Aeronautics and Astronautics, November 1999, 9.

¹⁶⁸ *Military Spaceplane System Roadmap*, 40.

¹⁶⁹ John Cost, 41.

¹⁷⁰ *Evaluation of the National Aerospace Initiative*, National Research Council of the National Academies Report (Washington, D.C.: The National Academies Press, 2004), 3.

¹⁷¹ Frank Colucci, "FALCON Aims at Global Striking Power," *Military Aerospace Technology* 3, no. 2 (25 June 2004), n.p. on-line, Internet, 8 Mar 2005, available from <http://www.military-aerospace-technology.Com/article.cfm?DocID=518>

The heat problem differs from the ballistic missile re-entry problem. A ballistic missile experiences higher temperatures than a hypersonic vehicle, however, the hypersonic bomber experiences a higher total heat flux.¹⁷² One penalty for a hypersonic bomber is the weight of the coolant required to withstand aerodynamic heating over a longer period.

Plasma Fields

A hypersonic bomber flying above Mach 5 produces an ion sheath that produces plasma and prevents communication with the vehicle. The plasma shield is the direct result of compressed shock waves very close to the aircraft's surface. Shock waves cause friction, friction increases with speed, and air temperatures get so high chemical reactions change both the composition and behavior of the airflow over the hypersonic vehicles surface. In other words, the air gets so hot it ionizes. The ionized air molecules then form a plasma sheet that blocks communication. This is the same reason why returning spacecraft lose communication when reentering earth's atmosphere. There is no particular speed where this occurrence takes place. It is a function of the vehicle's geometry.¹⁷³ However, since vehicles will need to communicate in the plasma environment, antennas can be built that double as parts of the thermal protection system.¹⁷⁴ Another disadvantage to plasma is that the presence of ionization trails could facilitate enemy detection of the hypersonic vehicle.¹⁷⁵ The detection will be a greater problem if adversaries develop new defensive systems.

There is a bright spot to plasma. Plasma fields provide the prospect of extracting incredibly high levels of electrical power, in the range of tens of megawatts, from the hypersonic vehicle propulsion exhaust stream. A hypersonic bomber can utilize these plasma fields for power production. Such power levels are high enough to drive directed-energy (DE) weapon systems. DE weapons have a wide area of possible uses, including space control, SEAD, surface attack, and counterair missions. Offensive and defensive hypersonic DE weapons could include

¹⁷² *Hypersonic Glide Rocket Weapon System*, ARDC Abbreviated Development Plan, ARDC Report DD-R&D/A/119 (Baltimore, Md.: Air Research and Development Command, 24 October 1957), 28.

¹⁷³ J. Lewis, "The Promise of Hypersonic Flight," *Physics World*, December 2003, n.p., on-line, internet, 16 November 2004, available from <http://physicsweb.org/articles/world/16/12/6>.

¹⁷⁴ Frank Colucci, "FALCON Aims at Global Striking Power," *Military Aerospace Technology* 3, no. 2 (25 June 2004), n.p. on-line, Internet, 8 Mar 2005, available from <http://www.military-aerospace-technology.com/article.cfm?DocID=518>

¹⁷⁵ Clarence J. Geiger, *History of the X-20A Dyna Soar, Volume I (Narrative)*, AFSC Historical Publications Series 63-50-I, Document ID ASD-TR-63-50-I. (Wright Patterson AFB, Ohio: Aeronautical Systems Division Information Office, September 1963), 19.

high-energy laser and microwave systems. DE advantages include a zero-time of flight, wide area coverage, long-range, a surprise factor, selective targeting abilities, and the capability to hit many soft targets on a single sortie.¹⁷⁶

Testing Restrictions

The need for test facilities that fully simulate the hypersonic flight problems is a key element in hypersonic vehicle construction. This requires a long-term commitment to build as well as a commitment to long-term hypersonic programs to use the facilities. In other words, there needs to be a stable program to make the testing facilities feasible. Ground facilities need to test vehicle prototypes because a flight test is not the time to determine whether there are major problems that a ground test facility could have identified. If for some reason the test vehicle is lost, the program stands a greater chance to lose future funding. The idea of building a flight vehicle without the capability to test most of the known problems on the ground seems unreasonable.¹⁷⁷

Conclusion

The USAF is not going to build the hypersonic bomber without making sacrifices. The technological breakthroughs needed to enable this technology require the USAF to make a dedicated effort over the next several decades. There needs to be facilities capable of ground testing vehicles at hypersonic speeds. The USAF cannot make the decision to build a hypersonic bomber by merely weighing the advantages and disadvantages alone. Chapter Four will cover other important aspects weighing into the design and decision to build a hypersonic bomber.

¹⁷⁶ *Why and Wither Hypersonics Research in the US Air Force*, 53-54.

¹⁷⁷ Seymour M. Bogdonoff, *Hypersonic Flight Vehicles: Perspective and Prognosis*, Princeton University Report (Princeton, N.J.: Princeton Department of Mechanical and Aerospace Engineering, 1999), 6-7.

Chapter Four

Puzzle Pieces: Other Items Requiring Evaluation

Developing revolutionary technology is not an easy task. There are tough decisions on how to apply breakthroughs. These decisions go beyond just the technology required to accomplish the groundbreaking advancement. There is more to consider than just speed, range, survivability, and payload. This chapter presents other important factors including manned and unmanned configurations; near-space overflight; opportunity costs; and potential threats that might warrant the continued research and eventual construction of a hypersonic bomber.

Manned vs. Unmanned

The proposal for unmanned hypersonic vehicles is not new. The USAF considered making an unmanned hypersonic vehicle at the beginning of program development. However, unmanned instrumentation at the time did not provide sufficient system flexibility or reliability. On Bell Aircraft's BOMI project, the company decided the manned system held the advantage. However, current and projected technological advances over the next 20 years make an onboard pilot an option rather than a requirement.

A large technology jump is not required to make an unmanned hypersonic vehicle. Most space missions are currently unmanned now. They rely on an automated flight control systems. An internal navigation system (INS) coupled to a GPS would make the system capable of flying without any required sensor platform to update the bombers position. Bombing systems are already automatic in other airframes. The technology also exists to land the vehicles either remotely or even with an automated landing system.

One of the design difficulties of a manned system is the window placement. The extreme heat makes it impossible to have a forward facing window. A window on a hypersonic vehicle

would only allow the pilot to look directly out the top of the vehicle. There would be no forward visual ability for takeoffs or landings. Enroute clearing would not occur because there is no cockpit forward visibility. The window would only give the pilot a good view of the stars. However, a hypersonic vehicle could utilize a video system for takeoff, refueling (if necessary), and landings. NASA is developing an external system that gives windowless takeoff and landing visibility. This system, designed for fast jets where the nose gets in the way of the landing picture, would work well with a hypersonic system. These displays use video images enhanced by computer-generated graphics to take the place of the view out of the front windows.¹⁷⁸

Losses of unmanned vehicles generate fewer problems. Downed unmanned vehicles do not produce grieving mothers, spouses, or children.¹⁷⁹ The idea of unmanned bombers is particularly appealing to an Air Force that spends millions of dollars to train a pilot and suffers periodic pilot shortages.¹⁸⁰ The national media coverage of such incidents such as the 1995 shoot down of an F-16 over Bosnia was much more intense than the loss of a Predator UAV the very same day. The Predator loss had almost no coverage. The F-16 shoot down occupied the media for weeks. The F-117 loss over Serbia in the Kosovo campaign and the loss and capture of pilots in Iraq also illustrate the point. The USAF took great care to avoid losing a pilot during Operation Iraqi Freedom. This compares to UAVs flying over heavily defended areas at will during the same time. A UAV loss diminishes USAF capability. However, the psychological impact caused from a downed pilot is just not present.

An unmanned hypersonic bomber will be lighter than the manned version. Additionally, unmanned flights are also cheaper to accomplish because computers can perform all the functions considered beneficial to the support of military forces without having to sustain a human body above 50,000 feet.¹⁸¹ This results in a reduced aircraft size, increased operations capability, and an obvious increase in crew safety. The smaller unmanned hypersonic system also needs less fuel. Conversely, a manned systems additional weight necessitates a significant increase in the fuel load required to travel the same distance. The hypersonic bomber will be operating at altitudes above 100,000 feet. The U-2, the only operational manned high-altitude military aircraft, requires the pilot to wear a pressure suit in case of a cabin depressurization.

¹⁷⁸ NASA's *High Speed Research Program – The External Vision System Concept*, NASA pamphlet, March 1998, 1.

¹⁷⁹ Barry D. Watts, *Moving Forward on Long-Range Strike*, Center for Strategic and Budgetary Assessments Document, Washington, D.C.: Center for Strategic and Budgetary Assessments, 27 September 2004, 22.

¹⁸⁰ Steve Douglass, "B-3 and Beyond," *Popular Science* 256, no. 2 (February 2000), 50.

¹⁸¹ Paul B. States, *Space and National Security* (Washington, D.C.: The Brookings Institution, 1987), 43.

The SR-71, XB-70, and B-58 also required either pressure suits or heavy pressurized emergency capsules, all adding weight to the vehicles. In addition, pressure suits require a time-consuming preflight routine for the pilot and increase the number of required support personnel and possibly the turn around time for the bomber. Such systems increase a bombers size and gross weight and limits flexibility.¹⁸² The weight of the life support systems may prevent the hypersonic bomber from meeting the stringent performance requirements, while the reduction of gross weight associated with an unmanned system may allow the bomber to have a higher payload or fuel capacity.

Overflight Considerations

Airspace sovereignty has long been an important issue. However, the principles governing sovereign airspace overflight do not pertain to outer space. States can put satellites in orbit over the territory of other states. The precise location of the point where airspace ends and outer space begins is uncertain and until now was unimportant. This is because the minimum heights where satellites can remain in orbit were at least twice as high as the maximum altitude an airplane could fly.¹⁸³ This definition becomes fuzzier with the advent of hypersonic vehicles because the altitude where a hypersonic bomber flies blurs the distinction between air and space. The weapons they deploy, and even the bombers themselves will need to cruise or glide to a landing where they may need to cross numerous national boundaries in the near space environment. This is how the Space Shuttle lands.¹⁸⁴ The major problem is what defines the airspace hypersonic bombers operates in. There are two possible answers, the sovereign airspace of a nation, or the freedom of navigation afforded by space.

Air Force Space Command defines near space as the altitudes between 65,000 ft (20 km) and 325,000 ft (100 km). However, there are only two legally defined categories of airspace, air space and outer space; the term near space has no meaning in domestic and international law. The present international understanding of air and outer space is the only method to analyze

¹⁸² *Peregrine Hypersonic Strike Fighter Weapons System*, A proposal in response to the AIAA Foundation Graduate Team Aircraft Design Competition request for proposals (Atlanta, Ga.: Georgia Institute of Technology, 5 June 2000), 18.

¹⁸³ Michael Akehurst, *A Modern Introduction to International Law*, 5th ed. (London, Great Britain: George Allen & Unwin, 1984), 289.

¹⁸⁴ Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London, Great Britain: Frank Cass Publishers, 2002), 115.

activities conducted in near space currently.¹⁸⁵ The United States does not recognize a specific altitude at which air space ends and outer space begins. The United States believes any attempt to define or delimit outer space would be an unnecessary theoretical exercise that could complicate existing activities. A treaty might not be able to anticipate continuing technological developments.¹⁸⁶ It does not benefit the USAF to have a set definition without giving advantages to other states or taking away capabilities from the United States. Therefore, the United States has preferred to avoid setting an official space boundary. Other analysts claim that the boundary of space is of negligible importance, since aircraft and spacecraft operate in very different mediums.¹⁸⁷

There are two approaches to definitions of the outer space boundary, spatial and functional. The spatial approach explains that space begins just below the point where a satellite can maintain orbit. Another name for this point is the “Karman primary jurisdiction line.” The Karman line is the point where aerodynamic flight ends and centrifugal forces take over.¹⁸⁸ The significance of this altitude is that this is the lowest altitude where an object can sustain orbit without outside force and matches the definition of the Karman primary jurisdiction line.¹⁸⁹ There is an international push to set the demarcation of outer space at 325,000 ft (100 km). The spatial approach is the most precise, because it is measurable. The functional approach is propulsion based. It originates from the 1919 and 1944 International Air Conventions, which defined aircraft as any machine that can derive support from air reactions. The functional approach defines space as the area just beyond the maximum height of possible aerodynamic flight.¹⁹⁰

Hypersonic bombers will require an accepted and precise definition of the air and space environments. For nothing else, it sets determinations of legal responsibility in cases including noise and environmental infringements. A definition of outer-space limits will be necessary to prevent misunderstandings and future catastrophes.¹⁹¹ However, since there is no formally accepted definition, other nations will likely view hypersonic flights operating below 325,000 ft

¹⁸⁵ Walker, Mary, “Legal Regime Applicable to Near Space,” Memorandum to the Secretary and the Chief of Staff of the Air Force, 2 September 2004, 1.

¹⁸⁶ Walker, Mary, 1.

¹⁸⁷ Everett C. Dolman, 114.

¹⁸⁸ Everett C. Dolman, 116.

¹⁸⁹ Walker, Mary, 1-2.

¹⁹⁰ Everett C. Dolman, 116.

¹⁹¹ Everett C. Dolman, 115.

above their country without permission as an infringement of sovereign rights and a violation of their territorial integrity.¹⁹²

The United States may want to treat the near space environment like sovereign airspace until the strategic landscape indicates otherwise. The USAF needs to question if it would be a good precedence to start near space overflights. The United States might want to exercise restraint with self-imposed limitations to respect airspace sovereignty unless there is a war. This might protect the United States' asymmetrical advantages. It may be a good idea to wait for others to start flying over other nations in the near space environment and then follow suit just as the United States did with Sputnik and space. North Korea may already have set the precedence with a rocket launch transiting Japan's airspace at near-space altitudes. If the United States waits, the missile defense system should be capable of stopping an enemy hypersonic vehicle strike.

Opportunity Costs

Every budgetary decision comes at the expense of something else. The something else is the cost of the number one thing you did not do. Therefore, an opportunity cost is the price of the best-forgone alternative. The decision to build a hypersonic bomber will cost the USAF something in lost opportunity. Developing a fleet of hypersonic bombers is expensive and requires at least a \$25 billion investment over the next 20 years. Developmental costs alone are approximately \$2 billion per year. The dwindling Air Force budget cannot accommodate this expense without a major impact on other programs.¹⁹³ Hence, a hypersonic bomber will come at the expense of other weapons systems. Therefore, the USAF needs to analyze the tradeoffs between those other systems and a hypersonic bomber.¹⁹⁴ The development of hypersonics technology must take its place among other science and technology efforts and priorities to ensure the proper balance between current, near term, and future combat capabilities.¹⁹⁵

¹⁹² Walker, Mary, 1-2.

¹⁹³ *Why and Wither Hypersonics Research in the US Air Force*, United States Air Force Scientific Advisory Board Report SAB-TR-00-03 (Washington, D.C.: United States Air Force, December 2000), 61.

¹⁹⁴ *Future Strategic Strike Forces*, Report of the Defense Science Board Task Force (Washington, D.C.: Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, February 2004), 1-9.

¹⁹⁵ *Evaluation of the National Aerospace Initiative*, National Research Council of the National Academies Report (Washington, D.C.: The National Academies Press, 2004), 17.

Funding a hypersonic bomber is about hope for the future. This ensures the United States gives its brightest scientists and engineers a challenging mission. America depends upon its position as the world leader in science and technology. National economic survival depends on spinning off high technology down to the low-technology industries. Space exploration and exploitation is a major driving force in advancing the frontiers of knowledge. High-tech industries, particularly aerospace, always have been net contributors to the international balance of trade of the United States. A lack of investment will only increase the trade deficit. Without any investment, the United States aerospace technology lead will not hold forever.¹⁹⁶ Every time the United States gives up on a major aspect of this effort, another nation or alliance can take up the slack.¹⁹⁷

There is a positive spin on the cost issue. Economic benefits can justify the enormous costs of hypersonic technology. Hypersonic industrial spin-offs will be a large economic plus. For example, a few technological spin-offs will include new ice-prevention concepts, better cryogenic materials handling techniques, machinery able to run at much hotter temperatures than now possible, lightweight ceramic automobile engines and better automobile brakes. Even water transportation will benefit. There will be a better understanding of computational fluid dynamics, allowing for superior hull configurations on large ships. Propeller design also benefits. The result will be faster, more fuel-efficient ships. Other industries gaining from hypersonic technology include chemical and allied products, rubber and plastics, non-electrical machinery, photo and optical goods, motor freight transportation, plus fabricated and primary metal industries. The top ten industries benefiting from hypersonic technology transfer could improve the sales income by at least one percent a year for ten years.¹⁹⁸ In 1990, the revenue for the top ten companies was \$1.77 trillion a year. One percent is almost \$18 billion. That translates to a \$180 billion impact over 10 years.¹⁹⁹ From these results, the \$25 billion spent will make \$180 billion in revenue. The taxes recovered alone should exceed the \$25 billion spent.

Another opportunity cost to consider is the environment. The USAF needs to weigh the effects hypersonic flights will have on the atmosphere. German officials studied the impact of nitrogen oxides and the generated water vapor released into the upper atmosphere by hypersonic

¹⁹⁶ Pat Jackson, "Gold in the skies?" *Ad Astra* 2, no. 10 (November 1990), 10.

¹⁹⁷ Taylor Dinerman, "The Real Cost of the New Space Plan," *Ad Astra* 16, no. 3 (July-September 2004): 27.

¹⁹⁸ Pat Jackson, 10.

¹⁹⁹ *Ibid.*

vehicles. They also researched the combustion effects of hydrogen fuel. They found these items might trigger problems within the stratosphere. The Germans also found that there would likely be very little environmental damage, mainly because of the low numbers of projected hypersonic missions. However, if hypersonic flight leads to commercial development, the increased traffic could damage the upper layers of the atmosphere.²⁰⁰

Do hypersonic Capabilities Mesh with Threats/Needs of the Future?

The United States is seeking to dissuade rising powers from challenging its military dominance while at the same time trying to re-equip itself to fight low-tech insurgency threats.²⁰¹ Although weapons systems designed to fight guerillas tend to be fairly cheap and low-tech, the United States must retain its dominance in key high-tech fields, such as stealth technology, precision weaponry, and manned and unmanned surveillance systems in order to dissuade countries from trying to compete in these areas.

Secretary Rumsfeld is attempting to make the military far more engaged in heading off threats prior to hostilities and serve a larger purpose of enhancing United States influences around the world. There are newer challenges and problems, such as battling terrorists and insurgents, over conventional military problems. Rumsfeld tells the military to focus on four “core problems.”²⁰² The military services need to develop forces that can first, build partnerships with failing states to defeat terrorism. Second, defend the homeland, including offensive strikes against terrorist groups planning ground attacks. Third, influence the choices of countries at a strategic crossroads, such as China and Russia. Lastly, Secretary Rumsfeld wants to prevent the acquisition of weapons of mass destruction by hostile states and terrorist groups.²⁰³

The military must be responsive in order to produce the desired operational effects required of air and space forces in a modern conflict. As the B-2 is today, a hypersonic bomber will be a high-value, low-density strike and support asset. There are only 21 B-2 bombers. Of those, only 2/3, or approximately 14 of them can be combat ready at any given time because training sorties, depot maintenance, and other issues limit their availability.

²⁰⁰ David Leonard, “Hypersonic High-Anxiety,” *Ad Astra* 3, no.3 (March – April 1991), 5.

²⁰¹ Jaffe, Greg, “Rumsfeld Details Big Shift in New Document,” *Wall Street Journal*, 11 March 2005, A1.

²⁰² *Ibid.*

²⁰³ *Ibid.*

The air tasking order (ATO) can task B-2s to strike targets daily during combat operations. B-2s fly combat sorties mainly from the continental United State (CONUS) and from a few select bases worldwide. It takes many hours, if not days just to complete one B-2 mission. A formation from one night's strike can be on the way home while the next days sorties are outbound toward their targets. This makes it difficult to sustain B-2 missions with a high level of persistence.

Consider the same situation, only using hypersonic bombers. Assume there are 21 hypersonic bombers with 2/3 of them mission capable, similar to the B-2. These 14 mission capable bombers could deploy from home station or even forward deploy to the same airfields the B-2 uses. The ATO could task two hypersonic bombers, and they could complete their mission before the B-2s, or any other long-range strike asset for that matter, left CONUS airspace. The hypersonic bomber turn-around time alone already has a greater than 24-hour advantage on current long-range strike capabilities. Therefore, the hypersonic bomber can support a wide range of military missions quickly, with a higher level of persistence than current assets can.

The United States is not the only nation developing hypersonic technology. Several organizations throughout the world are pursuing and already have developed significant scramjet-powered hypersonic vehicle expertise. Fortunately, no one has developed any successful systems yet.²⁰⁴ However, these new developments can put the United States behind in a race to develop a very capable threat. Hypersonic technology may offer possible aggressor nations an important means of countering traditional American access strategies. For instance, the emergence of a hypersonic anti-ship missile would be of great concern to the United States Navy.²⁰⁵

At this writing there are well-established hypersonic research, development, and testing activities in Russia, France, Germany, Japan, China, India, England, and Australia. Russia has the most extensive hypersonic research program. It includes advanced computation, ground testing, and flight-testing capabilities. Russia is still investing in this area despite their economic difficulties. Russian researchers could achieve a significant breakthrough in hypersonics at any time. In fact, in late 2004, President Putin announced a new breakthrough in rocket technology.

²⁰⁴ *Why and Wither Hypersonics Research in the US Air Force*, E-3.

²⁰⁵ *Ibid.*, 26-27.

He did not elaborate on any specifics, but it could be a scramjet launch system. If there is a foreign hypersonic space launch system, it could easily capture most of the world's commercial space launch market. This would have a devastating impact on the United States' market and could drive up the price of the existing United States expendable launching systems.²⁰⁶

The Russian Space Agency manages the Oryol hypersonic flight-test program which is investigating hypersonic airbreathing propulsion systems. Two conceptual designs are in the works, the two-stage to orbit (TSTO) MiG design (MIGAKS) and the single stage to orbit (SSTO) Tupolev Tu-2000 concept.²⁰⁷ Both designs employ horizontal takeoffs and landings. To aid in the development of these designs, Russia can rely on its hypersonic ground-test infrastructure for supporting aerodynamic and propulsion development. French and American researchers have used Russian flight-test capabilities to conduct their own low-cost hypersonic flight tests. Russia has also accomplished captive carry flight tests of a hydrogen fueled dual-mode scramjet in the Mach 3.5 to 6.5 ranges using the "Kholod" hypersonic flying laboratory. Russia also has the potential to use a second-generation flying test bed that will expand the tested flight regime to Mach 12 or 14.²⁰⁸

Russia is conducting the world's most extensive work on the utilization of weakly ionized gas phenomena to control internal and external flow fields that may provide breakthrough hypersonic weapons technology. They are also in the latter stages of developing a hypersonic missile along with an intercontinental weapon that works as a boosted cruise missile after a larger rocket launches it. The Russians claim this new weapon is primarily for self-defense. The hypersonic boost enables the cruise missile to maneuver and avoid any surface to air missiles and obviously increases a weapons kinetic effect.²⁰⁹

France has teamed with Russia to investigate a variable-geometry ramjet engine concept that operates between Mach 3 and 12. This program aspires to provide a ground-test engine to demonstrate the potential engine performance of an air breathing space vehicle. In addition, France has been working on a hypersonic anti-ship missile. France and Germany have also teamed on a Joint Airbreathing Propulsion for Hypersonic Research program. Additionally, the

²⁰⁶ Ibid., 11.

²⁰⁷ Robert Wall, "U.S. Hypersonics Know-How Eroding," *Aviation Week and Space Technology* 154, no. 2 (8 January 2001), 26.

²⁰⁸ *Why and Wither Hypersonics Research in the US Air Force*, 36.

²⁰⁹ "Russia alerts world of new mobile N-missile by 2006," *Russian American National Security Advisory Council*, 13 December 2004, n.p., on-line, Internet, 7 March 2005, available from <http://www.ransac.org/Projects%20and%20Publications/News/Nuclear%20News/2004/1216200412647PM.html#4H>.

Germans and Japanese have hypersonic aircraft in the preproduction stage.²¹⁰ Japan has built new ground-test facilities that significantly increase their ground-test capabilities. India and China both possess ramjet-powered missiles and are they are actively exploring scramjet-powered vehicles.²¹¹

An Australian team at the University of Queensland is accomplishing hypersonic engine research. They used a sounding rocket to catapult its experimental scramjet to Mach 7.6. They claimed to have the first-ever combustion with an air-breathing engine at hypersonic speeds.²¹² On the good side, the United States is cooperating and participating with the Australian's research.²¹³

A developed foreign hypersonic system is a threat to United States security. Missiles developed overseas can disrupt shipping traffic and adversely affect United States military options. Russia, France, India, and China already have ramjet-powered missiles. The German defense ministry recently decided to proceed with development of a hypersonic weapon. Most of the work has concentrated on cruise missiles, although several countries claim they are developing a high-speed air vehicle.²¹⁴ There is a threat that the United States could lose its leadership role and resulting advantages in the near-space and even outer space environment.

Comparison with Existing and Competing Systems

A comparison between the hypersonic bomber concept and other existing and future weapons systems is necessary before proceeding on such an expensive project. The comparison measures several different weapon systems against each other on simple qualitative, system level bases as shown in Table I.²¹⁵ The comparison consists of three system aspects, capability, estimated cost, and employment. Different capability assessments include weapons payload, combat mission radius, plus both cruise and combat speed. These capabilities received ratings from 1 to 5. A rating of one represented far below desired threshold, three stood for meeting

²¹⁰ Everett C. Dolman, 115.

²¹¹ *Why and Wither Hypersonics Research in the US Air Force*, 26-27.

²¹² David Malakoff, "Mach 12 by 2012?" *Science* 300, no. 5621 (9 May 2003), n.p.

²¹³ Michael A. Dornheim, "Hypersonics Push," *Aviation Week and Space Technology* 159, no. 25 (22 December 2003), n.p.

²¹⁴ Robert Wall, 26.

²¹⁵ The idea for a comparison came from the study *Peregrine Hypersonic Strike Fighter Weapons System*, A Proposal in Response to the AIAA Foundation Graduate Team Aircraft Design Competition Request Proposals (Atlanta, Ga.: Georgia Institute of Technology, 5 June 2000), 10-11. The author changed several systems, subjects, methods, and ratings to better match capabilities to current and future weapons systems.

threshold, and a rating of five means the capability far exceeds desired thresholds. Two and four fall in place between their respective ratings.

Measurements for the second comparison phase, estimated cost, include purchase cost, operation and maintenance costs, and the cost per sortie in combat. A rating of one in this category represents the highest cost and five symbolizes the lowest price. A five is the best rating in both categories. The last aspect is a simple comparison between the operational area, reusability, and survivability asset. A completely mobile staging area in two mediums (land and sea) received a rating of 5. A rating of 4 meant one of the basing systems, land or sea, is immobile. A rating of three means the system is mobile in one staging medium. A rating of 1 is completely immobile and stages in only one medium. A reusable system received a 5, a one time use weapon receives a 1. The survivability is an unclassified estimate of the systems against the threats covered in Chapter Four. Stealth assets received a rating of 4 only because they do not travel in the threat areas at hypersonic speeds and in the daytime they can be seen. The overall rating gives the average of all the measurements in the capability and estimated cost categories.

		Strike Fighter	Stealth Strike Fighter	Heavy Bomber	Stealth Bomber	Cruise Missile	Hypersonic Cruise Missile	Conventional ICBM	Hypersonic Bomber
CAPABILITY	Payload	2	2	5	5	1	1	2	3
	Combat Radius	1	2	3	3	2	4	5	5
	Cruise Speed	1	1	1	1	1	4	5	5
	Combat Speed	2	1	1	1	1	5	5	5
ESTIMATED COSTS	Purchase Cost	3	2	3	1	5	3	3	1
	Sustainment Costs	4	3	4	3	4	4	4	3
	Cost per Combat Sortie	5	4	5	4	2	1	1	4
EMPLOYMENT	Operation Area	Land / Sea (5)	Mobile Land (3)	Mobile Land (3)	Mobile Land (3)	Land / Sea (5)	Land / Sea (3)	Unmobile Land / Sea (4)	Mobile Land (3)
	Reusability	Yes (5)	Yes (5)	Yes (5)	Yes (5)	No (1)	No (1)	No (1)	Yes (5)
	Survivability	Maneuverability (2)	Stealth (4)	Standoff + Jamming (1)	Stealth (4)	Low Altitude (4)	Speed (5)	Speed + Trajectory (5)	Speed + Altitude (5)
Overall		3.00	2.70	3.10	3.00	2.60	3.10	3.50	3.90

Table I: System Comparisons

The overall result from this basic comparison shows hypersonic bombers are the most effective strike asset. They have the highest projected capability for the estimated associated cost, or in other words, they are the best value. A hypersonic bomber will be able to respond quickly and not be limited by the time of the day when attacking highly defended targets.

Conventional intercontinental ballistic missiles (ICBMs) and hypersonic cruise missiles are the next two overall highest rated systems. However, they are not reusable or recallable, two crucial capabilities required for future operations. ICBMs also have political ramifications since they have always been associated with nuclear weapons. It will be difficult for peer nuclear powers to distinguish a nuclear from a conventional launch.²¹⁶

Current USAF strike capabilities rank the lowest overall. On the positive side these assets provide reusability, are recallable, and overall cheaper to develop and sustain. In addition, heavy bombers can and will carry the largest payloads. However, they do not possess the same response times and range as a hypersonic bomber. Additionally, the USAF bomber force is already very old. The bomber force consists of 1950's era B-52s, 1970's technological era B-1s, and B-2s built using 1980's technology. All three bombers' computer systems are antiquated when compared to today's equipment. Thus, it would appear that the USAF needs a new bomber if it is to keep a persistent, long-range strike option open. The guiding principle dealing with a new bomber should be that modernization must secure a competitive advantage for the United States over current and potential adversaries. As a result, development of the hypersonic bomber appears to be a rational and reasonable choice.

The USAF is going to face several other long-range strike capability shortfalls in the near future. First, it is going to become more difficult to operate effectively *at long ranges* against an anti-access environment. The USAF could lose its capability to single-handedly engage a robust integrated air defense system (IADS), or even modern maritime defenses. Second, the USAF will probably have a more limited ability to conduct long-range strike operations. It will be difficult and require long lead times to establish the forward infrastructure needed to carry out these strikes. Factors limiting USAF global reach include the lack of forward basing, limited air refueling assets, and strategic and operational lift limitations. Third, the USAF will have a limited ability to affect mobile targets prior to an adversary employing or moving them. The USAF does not have a capability to meet a 0-12 hour prompt global strike timeline other than ICBMs. A *prompt* conventional global strike can currently only be conducted with forward deployed alert aircraft. Even with the F/A-22 and F-35 it is going to be very difficult to achieve

²¹⁶ *Peregrine Hypersonic Strike Fighter Weapons System*, A proposal in response to the AIAA Foundation Graduate Team Aircraft Design Competition request for proposals (Atlanta, Ga.: Georgia Institute of Technology, 5 June 2000), 10-11.

any persistence over a highly defended deep battlefield. Additionally, sustained time sensitive strikes deep within enemy territory are difficult to accomplish without air superiority.²¹⁷

How Do We Do It?

There are three possible solutions to these problems. The first is to increase weapons speed. Increasing weapon speed decreases the time required to strike a target. High-speed weapons are also more difficult for an enemy to counter. However, there are some limitations. At fast weapon speeds, maneuvering targets may compromise desired accuracy. The weapon may be going too fast to correct against last minute defensive maneuvers. Increasing the weapon speed may create shorter response times, however it may limit the target sets these weapons can strike.

The second option is to increase the speed of the delivery platform. Increasing the vehicle speed also decreases the time required to strike a target. It is also more difficult for an enemy to defend against hypersonic speed strike aircraft. However, a fast strike vehicle must have the range to penetrate long distances in an anti-access environment or reach a remote, inaccessible area faster than current strike platforms.

The third option is to decrease the distance of the aircraft to the target. One method to accomplish this is forward basing. However, forward basing puts an airfield or carrier at a greater risk to a countries tactical ballistic missile (TBM) and weapons of mass destruction (WMD) threat.²¹⁸ Another method is to develop a vehicle with the persistence to loiter near the target set. This vehicle will be in an orbit preferable close to a target area and can theoretically strike a target within a matter of minutes. However, an airplane will not be able to persist near a target area if modern weapons defend it.

A hypersonic bomber launching high-speed weapons enables prompt global strike from considerable ranges and reduces forward basing's associated risks. The reusability of hypersonic vehicles increases both their utility and cost-effectiveness. Forward-based assets have a greater potential for persistent operations with response times similar to hypersonic vehicles, all without the need for speed. However, they bear the risk of being closer to the threat, and thus they are more vulnerable. They might not be able to be stationed close enough to the adversary to have

²¹⁷ Air Force Doctrine Document (AFDD) 2-1, *Air Warfare*, 22 January 2000, 17..

²¹⁸ House, *Testimony by Andrew F. Krepinevich, Jr. Before the House National Security Committee Subcommittees on Military Procurement and Research and Development*, 105th Cong., 1st Session, 1998, 3.

any significant responsiveness or even persistence. Consequently, the best solution is to build a hypersonic bomber capable of transiting long ranges in a short time period.

Conclusion

The USAF must consider many factors concerning a hypersonic bomber. The USAF needs to determine if the hypersonic bomber will fly with or without a pilot. The technology is available for a remotely piloted vehicle. A pilot gives the hypersonic bomber added flexibility but it comes at a high cost. The USAF also needs to consider another nation's airspace sovereignty. The hypersonic bomber will fly below low earth orbit altitudes and will cause an international response when it deploys. The glide path of weapons dropped thousands of miles from the target will also concern most third party states. Additionally, there are opportunity costs to consider. An expensive system will require cuts in other systems. However, the USAF must consider lost opportunities also. The 10-year tax revenues collected from the United States hypersonic base will be higher than the dollars spent on system development. There are several nations working on hypersonic weapons, the United States could be at a technological disadvantage, and perhaps be threatened by those new weapons. The United States could lose its strategic leadership in the space and near-space arenas. Finally, a hypersonic bomber stands up well against other weapons systems. It fills several future long-range strike capability shortfalls. The hypersonic bomber is worth the investment.

Conclusion

To meet current and future threats, Defense Secretary Donald Rumsfeld wants to focus the military on four core problems, none of them involving traditional military confrontations.²¹⁹ The hypersonic bomber could help the military counter three of the four core problems. First, a hypersonic bomber can defend the homeland by conducting preemptive strikes against terrorist groups planning attacks against United States assets. A hypersonic bomber could strike quickly from the United States once credible intelligence pinpoints a terrorist threat. This strike could occur without much warning and have devastating effects on an unsuspecting terrorist cell. Second, the hypersonic vehicle can influence states at strategic crossroads. The deterrence value resulting from a hypersonic bomber capable of a quick, long-range strike might affect a potential adversary's strategic plan. A state may think it cannot compete against the technological superior United States, or may reconsider the expense required to build facilities susceptible to hypersonic bomber strikes. Lastly, a hypersonic bomber could prevent the acquisition and storage of weapons of mass destruction (WMD) by hostile states and terrorist groups by striking a WMD site with either kinetic or directed energy weapons. Again, this can happen with only a small lead-time. The USAF would have the capability to locate, identify, target, and then strike a WMD site with United States based assets all within any given afternoon.

This paper included the question whether it was worthwhile for the United States to invest in a hypersonic bomber. A hypersonic bomber offers the potential for revolutionizing aerospace warfare. However, the road to achieving hypersonic flight will not be an easy one. It will take an enormous amount of effort. The Air Force will need to initiate significant technology development programs if there is ever going to be an operational, reusable air-breathing hypersonic bomber.

The presented evidence in this paper demonstrates that the USAF needs to invest in hypersonic technology. There are several technological difficulties to overcome, but nevertheless, the Air Force must take the steps to overcome the technological challenges.

²¹⁹ Jaffe, Greg, "Rumsfeld Details Big Shift in New Document," *The Wall Street Journal*, 11 March 2005, A1.

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