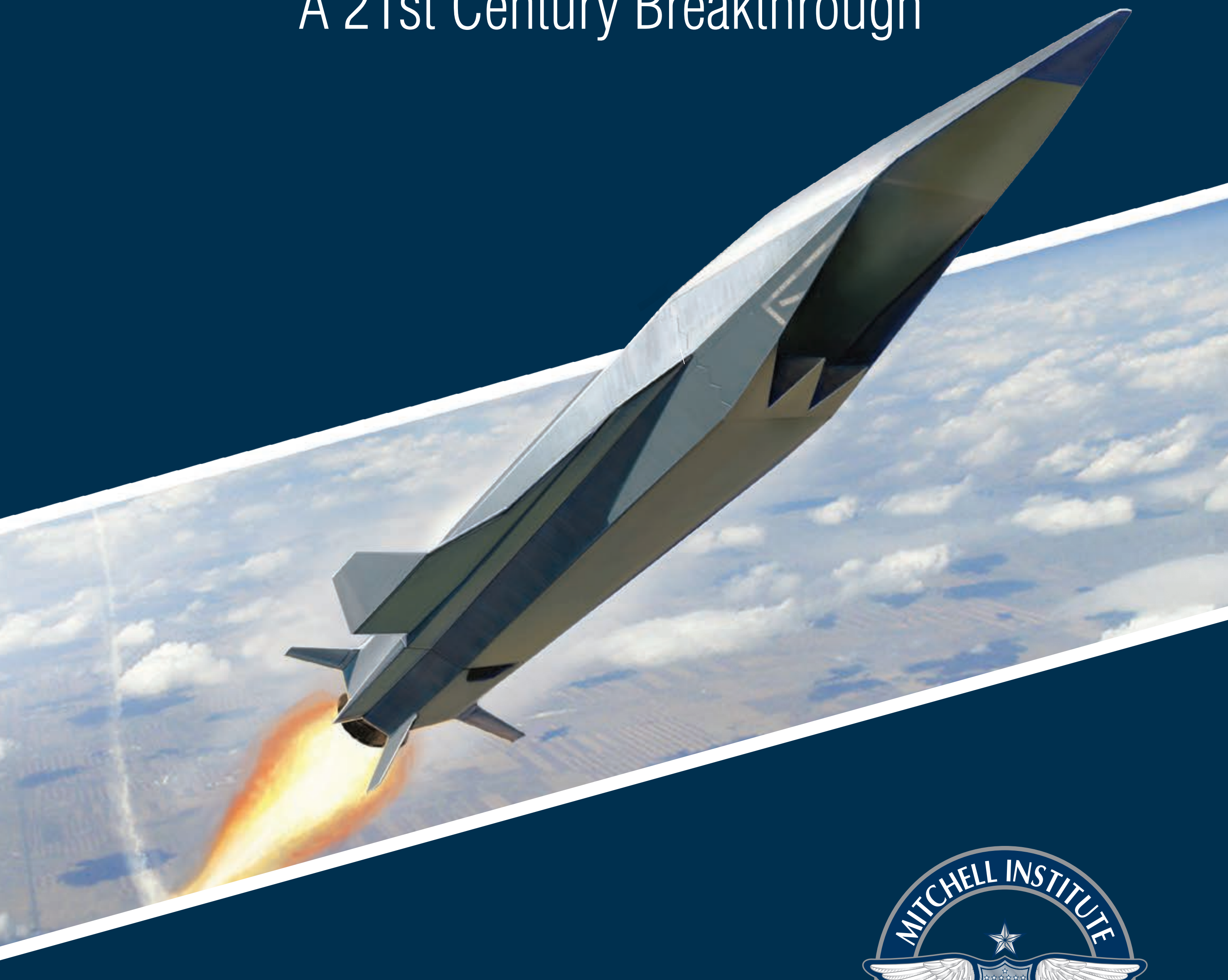
HYPERSONIC WEAPONS AND US NATIONAL SECURITY:

A 21st Century Breakthrough



By Dr. Richard P. Hallion
and Maj Gen Curtis M. Bedke, USAF (Ret.)
with Marc V. Schanz

MITCHELL INSTITUTE for Aerospace Studies

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Concept illustration by Andrey Zhirnov

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About the Authors

Richard P. Hallion, Ph.D, is a historian who specializes in the study of aerospace science and technology, and is the author of numerous books and publications. He received a doctorate in history from the University of Maryland in 1975. Among his academic positions, he has served as curator at the Smithsonian Institution's National Air and Space Museum, and as a historian with the National Aeronautics and Space Administration and the US Air Force. Hallion also served as a senior policy analyst for the secretary of the Air Force, senior advisor for air and space issues for USAF's directorate for security, counterintelligence, and special programs, as well as special advisor for aerospace technology for the Air Force chief scientist. He is a fellow of the American Institute of Aeronautics and Astronautics, the Royal Aeronautical Society, and the Royal Historical Society.

Maj Gen Curtis M. Bedke, USAF (Ret.) is a defense, aerospace, and federal science and technology consultant. He retired from the US Air Force in 2010 after 32 years of service, with extensive experience in defense science and technology, acquisition, operations, and experimental flight-testing. His assignments have included serving as commander of the Air Force Research Laboratory at Wright-Patterson AFB, Ohio, commander of the Air Force Flight Test Center at Edwards AFB, California, and director of the National Security Operations Center at the National Security Agency, Fort Meade, Maryland, among others. A command pilot, Bedke was an operational B-52 wing commander and an experimental test pilot, having flown 80 different aircraft over his career.

Marc V. Schanz is the Mitchell Institute for Aerospace Studies' director of publications.

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Foreword

The field of hypersonics is an important emerging area of applied science and technology in the 21st century which holds great potential both to protect Americans from a wide range of threats, or in the wrong hands, could endanger the United States and its deployed forces around the world.

In an era of constrained defense budgets and increasing modernization needs, it is understandable any new concept requiring taxpayer investment must be rigorously examined. After discussions with a variety of decision makers in government and the defense community, we believe present and emerging security requirements call for a clear understanding of what this technology could entail for our national defense, by addressing the following questions:

- What is hypersonic technology?
- Why is this technology important now?
- How can it benefit the United States, its allies, and partners?
- What is a reasonable path forward to realize these benefits?

The Mitchell Institute for Aerospace Studies is an independent, nonprofit research and analysis organization founded by the Air Force Association, which has advocated for aerospace power in defense of our nation since its incorporation in 1946. This paper does not advocate specific programs or industrial initiatives, in keeping with this tradition. In this study, we aim to reveal the value of hypersonics, evaluate the field's import for our defense, and propose a focused way ahead to realize success.

R. Hallion and C. Bedke

November 14, 2015

Executive Summary

Hypersonics—flight at five times the speed of sound (3,600 mph and above)—promises to revolutionize military affairs in the same fashion that stealth did a generation ago, and the turbojet engine did a generation before. By fundamentally redefining the technical means of power projection, the US can circumvent challenges facing the present force.

... all evidence shows hypersonic weapons ... are now within a decade of operational fielding

Though piloted, inhabited aircraft making routine use of hypersonics are still years away, all evidence shows hypersonic weapons capable of launch from aircraft, surface vehicles, ships, and submarines are now within a decade of operational fielding, with aerospace industry claiming this is possible in half that time—provided the United States makes a necessary commitment to steady, disciplined investment to realize this technology.

Hypersonic weapons offer advantage in four broad areas for US combat forces. They can project striking power at range without falling victim to increasingly sophisticated defenses; they compress the shooter-to-target window, and open new engagement opportunities; they rise to the challenge of addressing numerous types of strikes; and they enhance future joint and combined operations. Within each of these themes are other advantages which, taken together, redefine military power projection in the face of an increasingly unstable and dangerous world.

To make real progress, policy leaders and decision makers must lay out a consistent and disciplined path to close remaining technology gaps, foster the conditions for concepts of operation to develop, and allow robust testing and deployment of hypersonic weapons.

Hypersonic weapon technologies are surprisingly close to maturity. As such, we must commit to sustained hypersonic research, development, test and evaluation (RDT&E) efforts leading to technology transition, and cultivate programs designed to improve our combat power and capability. Those efforts must be driven by focused and achievable weapons programs that provide our military steadily improving capabilities over the next decades. We must break from old habits of overly aggressive, expensive failures and lack of follow-on to our successes in this field. Government and military leaders with vision will need to work with the service laboratories, industry, and academia to achieve these goals.

A successful path forward to realize this is achievable. This study makes recommendations in five critical areas of focus.

First, the US government and defense leaders must **understand the state and near term potential of hypersonics**, and **commit to a steady path to practical weapons capabilities with clear goals and consistent funding.**

Second, we must establish a **realistic acquisition strategy** and guide a **practical requirements assessment and development process** for concepts of operation, science and technology, research and development, testing, and life cycle management activities.

Third, we must **conduct the remaining technology maturation efforts** to bring required subsystems to sufficient readiness to begin actual weapon development with high confidence.

Fourth, we must ensure the **construction and refurbishment of proper test facilities and range infrastructure** and provide resources to support this effort.

Finally, we must **create and sustain an educated, motivated cadre of hypersonics professionals** to keep our nation on the leading edge of this field.

Hypersonics technologies and weapons are both vitally important and inevitable—for those who prioritize their development. We must ensure the United States secures this technological advantage, and secures the military advantage to protect our interests for decades to come.

The Coming Age of Hypersonic Power

The United States today faces numerous global security challenges that threaten its interests, and those of its allies and partners. Traditional tools of military power projection—large ground intervention forces, conventional air attack, and strikes by sea via cruise missiles—are either impractical or increasingly problematic due to advances in modern weaponry. Arguably, America's military power today is postured much like it was in the 1970s, when the first radar-guided surface-to-air missiles (SAMs) and radar-based air defense systems threatened to make air campaigns increasingly costly, forcing planners to rethink many of their operational assumptions. In the later years of the Vietnam War, modern SAMs took a toll on US airpower over Southeast Asia, downing over 1,000 aircraft, leading to the capture of hundreds of prisoners of war, and altering the conflict's conclusion.[1]

But a notional future US and allied air strike scenario could play out very differently, with a new capability to wield against future opponents. A hardened, dispersed, and well defended nuclear weapons program hundreds of miles inside a notional adversary nation, for example, could be quickly dismantled with the aid of hypersonic strike weapons. Traveling at speeds exceeding Mach 5 not long after launch, these weapons would circumvent many of the challenges a modern day strike force now faces. Instead of working to establish air superiority, establish tanker support, position personnel recovery assets, establish airborne command and control networks, prosecute electronic warfare, and infiltrate attack platforms through myriad defenses, a hypersonic strike would unfold far more rapidly, with far fewer support requirements. Unable to intercept these high speed weapons, a first strike wave could simultaneously eliminate the most heavily defended enemy nuclear facilities and key targets in a fraction of the time, at a much lower threshold of risk to attackers.

Hypersonic strike weaponry is an emerging arena that with investment, focus, and support, could contribute to renewing the United States' strategic military advantage.

Without change, though, a similar dynamic to the later years of the Vietnam War could emerge today. Pursuing linear development of existing technologies will afford diminishing returns, at greater cost, and is not sustainable in the long term. Today, US power projection is searching for a "game changer" in the era of the "third offset," as Deputy Secretary of Defense Robert Work declared, to gain desired strategic aims in a more effective manner. Like America's investment in nuclear weaponry to offset conventional Soviet power in the 1950s, and the pursuit of precision and stealth in the 1970s fundamentally changed US military power projection, the search for a 21st century

1 John Schlight, "A War Too Long: The USAF in Southeast Asia, 1961-1975," Air Force History Support Office, Washington, D.C., 1996, 103.

technological edge is under way.[2] Hypersonic strike weaponry is an emerging arena that with investment, focus, and support, could contribute to renewing the United States' strategic military advantage.

The advantages which emerged from the "second offset" era of the 1970s, stealth aircraft advances and precision attack, are still fundamental components of US military power today. The first of these rendered moot the Soviet Union's investment in radar-based air defense technology, and the second gave combat air forces the ability to strike targets anywhere, anytime, and with weapon impacts less than ten feet from aim points. Stealth and precision weapons imposed massive costs on potential adversaries, with the US reshaping conditions necessary to generate decisive effects.

Stealth and precision proved critical to the United States' swift victory in the 1991 Persian Gulf War, beating an Iraqi military equipped with then-modern armaments. F-117s enabled the simultaneous takedown of Iraq's air defenses, without exposing non-stealth aircraft like the B-52, F-111, F-16 and others to undue risk. Stealth aircraft could achieve desired effects more effectively and efficiently than their legacy counterparts. On the opening night of Operation Desert Storm, for example, 20 F-117s struck 28 separate aim points, while it took a strike package of over 40 legacy aircraft to hit a single target. Precision and survivability proved invaluable to modern power projection, and have since been inseparable from the American way of war.[3]

A quarter century has elapsed since the 1991 victory, however, and technological progress has caught up with these once uniquely American advantages. Potential adversaries have assiduously studied the Persian Gulf War and subsequent US interventions, concluding they must adapt their defensive technologies and techniques. Today, the advent and proliferation of more sophisticated surface-to-air missiles (SAMs), advanced radars, and sensor systems increasingly endanger US advantage in stealth and precision. When joined with advanced computer technology, these advances pose serious threats to the US military's inventory of strike systems.

In 1991, the SA-2 and SA-6 SAM systems were the common currency of much of the world's air defenses, and Soviet-built MiG-25s and MiG-29s had proliferated to former Soviet allies. Today's air defense systems now boast "double digit" SAMs such as the SA-10 and the more advanced SA-21, a series of Russian long range SAMs which are proliferating around the world to countries such as China, Iran, North Korea, Syria, and Venezuela. These missiles feature modern electronics and sensors, with some variants able to hold targets at risk from up to 250 miles away.[4] In the air, modern fighter aircraft, such as the Sukhoi Su-30, now perform as well as the leading American fourth generation air superiority fighter, the F-15C Eagle.

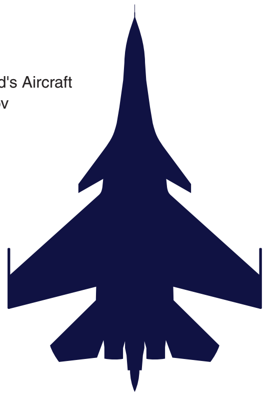
2 Robert Work, "The Third US Offset and Its Implications for Partners and Allies, as delivered by Deputy Secretary of Defense Bob Work, January 28, 2015, Willard Hotel, Washington, D.C.," http://www.defense.gov/News/Speeches/Speech-View/Article/606641/the-third-us-offset-strategy-and-its-implications-for-partners-and-allies (accessed November 18, 2015).

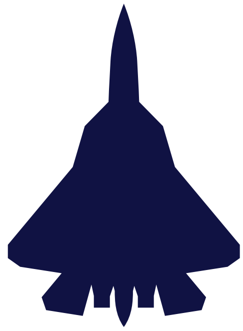
3 David Deptula, "Effects Based Operations: Change in the Nature of Warfare, Defense and Airpower Series," (Arlington, Virginia: Aerospace Education Foundation, April 2001), 1.

4 S-300P (SA-10 Grumble/SA-20 Gargoyle), MissileThreat.com, George C. Marshall Institute, Arlington, Virginia, April 25, 2013, http://missilethreat.com/defense-systems/s-300p-sa-10-grumblesa-12-gargoyle/ (accessed November 20, 2015).

These aircraft are also significantly younger, with far less structural wear. Fifth generation fighters are also under development in both Russia and China, which will challenge US stealth dominance once they become operational. These capabilities are expected to proliferate to states around the world, in the years ahead.[5]

Source: Jane's All the World's Aircraft
Graphic by Zaur Eylanbekov





Type	Sukhoi Su-30	Sukhoi PAK FA	Shenyang Aircraft Corporation J-31
Operators	Russia, China, India, Others	Russia	China, export customers
Year Entered Service	1996 (Russia)	Projected 2017	Projected 2019
Capabilitites	• Thrust vectoring • AA-10 air to air missiles • Phased array radar	• Stealth technology • Internal bays for AA-12 air to air missiles • Advanced Electronically Scanned Array radar	• Stealth technology • Fly by wire capability • Internal weapons bays

A promising answer to these challenges lies with the maturation of hypersonic weapons—precision standoff munitions that fly five times beyond the sound barrier. What stealth technology accomplished for America's military advantage in the 1980s and since, hypersonics could be for the challenges of 2020, and beyond. These weapons will vastly extend the speed and range of precision attack, dramatically increase the flexibility of airpower, and sharpen its utility against modern opponents.

What stealth technology accomplished for America's military advantage in the 1980s and since, hypersonics could be for the challenges of 2020, and beyond.

5 US Department of Defense, May 8, 2015, Annual Report to Congress on Military and Security Developments in the People's Republic of China 2015, Washington, D.C. http://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf. 55. (accessed November 20, 2015).

The Hypersonic Environment: Supersonic Isn't Fast Enough

Key to understanding the game-changing potential of hypersonics is seeing how this capability is fundamentally different from even supersonic aviation, and other standoff approaches. Thus, it is necessary to explore the science.

Aerospace engineers and scientists will nearly always refer to the speed of an aerospace vehicle—an airplane, spacecraft, or missile—in terms of "Mach number," relating how fast a vehicle moves relative to the local speed of sound, or "Mach 1." Mach 1 is approximately 760 miles per hour at sea level, decreasing to approximately 660 mph at high altitudes. Speeds below Mach 1 are termed subsonic, while speeds above Mach 1 to about Mach 5 are termed supersonic. Although there is no fixed definition, flight speeds beyond Mach 5, are typically termed hypersonic.

Hypersonics involve various kinds of flight vehicles. The first were simply rocket-boosted, following a ballistic path, like early military rockets and spacecraft such as Project Mercury. The second were "boost glide," which use a rocket engine to accelerate to hypersonic speed, then make a gliding return through the atmosphere. This is what powered the X-15 transatmospheric research aircraft in the 1960s. The third, enabled by breakthroughs in air-breathing propulsion such as the scramjet (a supersonic combustion ramjet) are "boost cruise," which use a rocket to accelerate to hypersonic speed, then sustaining that speed by moving to an air breathing engine and cruising for the remainder of its flight.

Hypersonic flight is very different from even supersonic flight, with intensely hot airflows featuring surface temperatures on an aircraft running up to thousands of degrees Fahrenheit. Visitors to the National Air and Space Museum can see how the rigors of hypersonic flight test a hypersonic vehicle, by examining the North American X-15, or the Apollo Command Module. Both of these vehicles feature heat-tempered nickel alloy panels and charred ablative heat shield panels, scarred from hypersonic flight.

Though the hypersonic environment is a searing one of extreme temperatures and thermal loadings, the design requirements for hypersonic vehicles are generally well understood. Through an established track record of creative design and engineering dating back over six decades, the US has the ability to create boost glide and boost cruise weapons, and associated air vehicles.

Because of the speed and altitude possible with these vehicles, the practical flight environment extends from the mid-stratosphere—approximately 60,000 feet—into space, and from a range of just a few hundred miles to distances around the globe. For hypersonic flight, leaving the atmosphere is a matter of simple acceleration. But reentering the atmosphere poses a series of thorny problems involving positioning of the returning vehicle, its ability to withstand peak reentry loads and temperatures, and its ability to transition from a blazing-hot reentry to a prosaic terminal descent. These vehicles are essentially human-designed meteors, pitting engineering ingenuity and skill against nature's unforgiving stresses and temperatures. Enabling these systems to survive and thrive in this hellish environment are sophisticated on-board computers informed by a variety of sensors and other instrumentation to furnish crucial guidance and control for the vehicle and its propulsion system.

At hypersonic speeds, aircraft and other vehicles require protection from potentially destructive melting and structural burn-throughs, and from flight loadings caused by thermal expansion and structural distortion. Just a few seconds' exposure to a hot hypersonic airflow can destroy a conventional aluminum or composite-structure airplane or missile. Hypersonic vehicles require high-temperature materials—nickel alloys, graphite-based composites, and ceramics—coupled with shaping that minimizes the destructive effects of sustained blowtorch-like heating.

If not adequately designed, as the loss of two DARPA HTV-2 hypersonic research vehicles in 2010 and 2011 indicate, hypersonic aerothermodynamic heating can quickly trigger disaster. But advances in the science of these problems have occurred in just the last few years. After a series of successful 2013 tests, the Air Force indicated it is applying engineering lessons from its X-51A Waverider program towards the High Speed Strike Weapon effort, or HSSW, a concept which service officials hope will demonstrate a successful hypersonic expendable weapon. Air Force officials said data from X-51A testing would specifically improve aspects such as guidance, heat resistance, and warhead integration on a future hypersonic weapons program.[6]

Hypersonics: Great Promise and Potential Threat

Hypersonic strike holds a great deal of potential to transform airpower in the 21st century, and could revolutionize military affairs by offering more effective, inexpensive, and low-risk approaches to counter opponents attempting to foil US forces via anti-access and area denial (A2/AD) technology. Hypersonic weapon advances afford long-term potential to address "pop-up" threats requiring rapid response, threats often outside the purview of the present US aircraft and munitions inventory.

Specifically, hypersonic weapons will largely solve time and distance challenges that often bedevil less responsive weapons, like conventional cruise missiles. The US has made great strides building highly capable intelligence, surveillance, and reconnaisance (ISR), and command and control (C2) networks to enable global vigilance across military operations. The introduction of hypersonic weapons now affords the ability to more thoroughly exploit engagement opportunities with these networks, as it does no good to identify a target without the means to strike it. The speed of hypersonic weapons allows development of better targeting solutions, enabling commanders more opportunity to assess targets correctly and accurately, and then act. The speed of a hypersonic weapon greatly compresses the so-called "find, fix, track, target, engage, and assess" (F2T2EA) process, enabling US commanders the ability to penetrate an opponent's decision making process, and as a result, rapidly put an adversary on the defensive.

The requirement for hypersonic weapons technology is approaching an inflection point today. Thanks to over seven decades of research and flight testing, the American aerospace community now understands the hypersonic arena better than at any point in modern aviation history.[7] But other nations do as well, and are pressing forward with their own programs. If unanswered, these efforts threaten to outpace US advances.

6 Marina Malenic, "USAF Using X-51 Lessons Learned to Weaponize Hypersonic Vehicles," *Jane's Defense Weekly*, May 15, 2015.

7 USAF Scientific Advisory Board, *Report on Why and Whither Hypersonics Research in the USAF*, SAB-TR-00-03 (Washington, D.C.: HQ USAF, December 2000), 8-9.

China and Russia are attempting to advance the hypersonics state of the art—doing more designing, prototyping, testing, and investing in newer facilities ...

Challengers have made their intentions very public. Chinese researchers conducted three high-profile tests of the Wu-14 hypersonic strike vehicle in 2014 alone (with two more flights revealed in 2015).[8] In 2014, Russia also reiterated its plan to test a new hypersonic weapon by 2020. Open press accounts reveal China and Russia are attempting to advance the hypersonics state of the art—doing more designing, prototyping, testing, and investing in newer facilities, as well as establishing an educated cadre of young aerospace engineering professionals who will form a future human capital infrastructure.[9]

These developments portend severe costs for the loser in this competition. The US not only would cede decades worth of investment, test, research, and experimentation in this arena, but would also face strategic vulnerability if other nations field a successful hypersonic weapon first. The United States' investment in hypersonics research and development is now at risk due to indecision and vacillation. Having pioneered hypersonic flight, the United States must redouble its efforts to retain its lead in hypersonics.

The US cannot afford to lose this emerging competition. An opponent who could field modern hypersonic weapons could hold any attacking force at great risk, on land, at sea, and in the air. There are few effective defenses to this capability. Alan Shaffer, then the acting assistant secretary of defense for research and engineering stated plainly in 2014, "We, the United States, do not want to be the *second* country to understand how to control hypersonics."

The Practical Reality of Hypersonic Strike

Hypersonic flight today is a practical reality, vice an expensive taxpayer-supported science project. Recent test success reveals this technology is maturing rapidly, and could be utilized in the near future for long-range strike purposes.

On May 1, 2013, the fourth test mission for the X-51A Waverider air vehicle set a record for the longest ever air breathing hypersonic flight to date, traveling more than 230 nautical miles in just over six minutes after its release from a B-52 at 50,000 feet. Off the coast of Southern California, the X-51's booster accelerated the test vehicle to Mach 4.8, before separating. Its supersonic combustion ramjet engine then engaged and propelled it to Mach 5.1 at 60,000 feet before running out of fuel and splashing into the Pacific Ocean.[10] The following September, Air Force Maj Gen Thomas Masiello, commander of the Air Force Research

8 Bill Gertz, "China Conducts Fifth Test of Hypersonic Glide Vehicle," *The Washington Free Beacon*, August 21, 2015, http://freebeacon.com/national-security/china-conducts-fifth-test-of-hypersonic-glide-vehicle/ (accessed November 22, 2015).

9 Daniel Marren, "Why Programs Fail (and, Conversely, Why Programs Prevail)" (White Oak, MD: AFRL Tunnel 9, December 23 2014), 12; Richard P. Hallion, *Hypersonic Power Projection* (Arlington, VA: Mitchell Institute), 9, 20-23.

10 Staff Report, "X-51 Sets Air Breathing Hypersonic Record," *Air Force Magazine Daily Report*, May 6, 2013, http://www.airforcemag.com/DRArchive/Pages/2013/May%202013/May%2006%202013/X-51A-Sets-Air-Breathing-Hypersonic-Record.aspx (accessed November, 2015).

Hypersonics no longer require breakthrough technologies nor budget-breaking investment.

Laboratory (AFRL), said the successful tests proved "hypersonics and scramjets are real," and could be adapted into standoff weapons as soon as the early 2020s.[11]

Hypersonics no longer require breakthrough technologies nor budget-breaking investment. America has significant experience with operational aspects of hypersonic flight, particularly the engineering knowledge and fabrication of associated materials. The NASA X-15 effort and even the development of US nuclear missile forces pioneered routine hypersonic operations in aspects of flight years before the X-51A. Building technology to afford an offensive strike platform is a natural evolution of these experiences. New hypersonic military requirements center upon theater-ranging missiles capable of employment on aircraft, ships, submarines, and mobile land-based launchers. After decades of research, hypersonic weapons are within a decade of being reality—but the US must first make some necessary investments.

Hypersonics and Requirements

The pursuit of hypersonic strike is firmly rooted in emerging military requirements. Hypersonic weapons address a steady decline in the power projection capabilities of the United States and its global partners. Existing technologies fielded by potential adversaries around the globe are reducing strike options against key targets. The US must maintain the ability to project decisive combat power simultaneously into crisis regions, in the face of robust opposition. One of the best alternatives to meet these power projection demands is to develop a new generation of air, surface, and sub surface launched hypersonic weapons which could be released at great distance—outside of the "threat rings" of modern SAMs and modern fighter aircraft.

Hypersonics offer several major combat advantages. They effectively circumvent the challenges of A2/AD threat environments, and can strike time-sensitive targets anywhere in the world. Hypersonic weapons also meet the challenge of distance, shrinking flight times to targets, and can evade sophisticated air defenses, which would intercept weapons such as cruise missiles.

But making the promise of hypersonics a reality requires policy and budget leaders to adequately set forth consistent objectives to realize operational capability and fund the US' national hypersonic infrastructure. This means support for component testing to achieve a requisite technology level applicable to operational weapons, and initiation of follow-on flight test demonstration programs which continue the breakthrough work undertaken with recent programs such as the X-43 and X-51. If these efforts are supported and

... within a decade the United States could have a hypersonic weapon capability in place that will definitively deter potential opponents, hold targets at greater risk, and enhance stability in key regions around the world.

11 John Tirpak, "Beyond Perpetually Promising," *Air Force Magazine Daily Report*, September 17, 2014, http://www.airforcemag.com/DRArchive/Pages/2014/September%202014/September%2017%202014/Beyond-Perpetually-Promising.aspx (accessed November, 2015).

enhanced, within a decade the United States could have a hypersonic weapon capability in place that will definitively deter potential opponents, hold targets at greater risk, and enhance stability in key regions around the world.

Restoring the Edge of America's Joint Forces

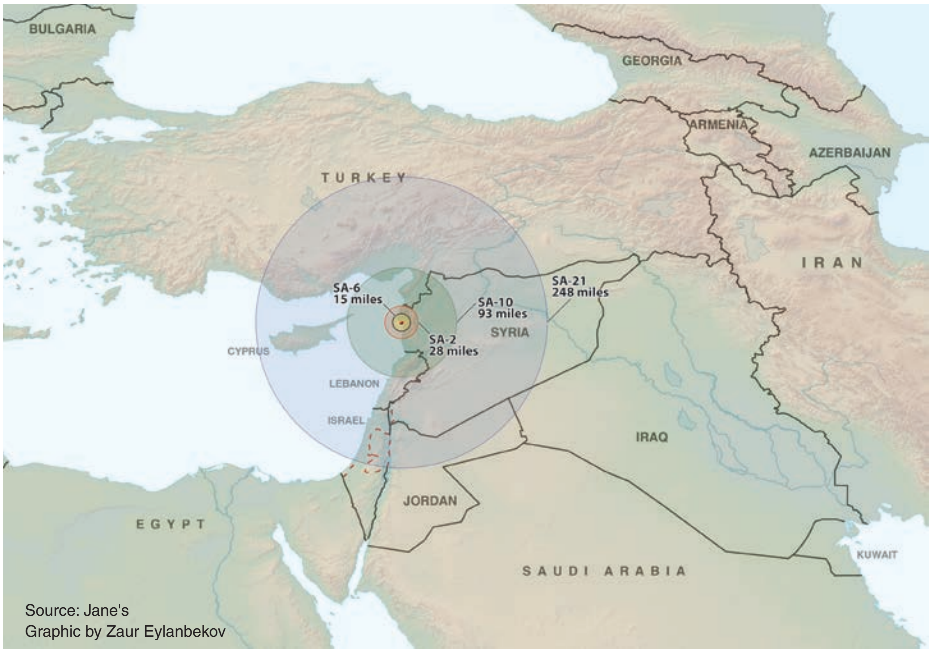
Any discussion of hypersonics' potential value must include a holistic assessment of America's current ability to project decisive combat power. The US must deter potential adversaries, reassure allies, shape key regions, and project decisive combat power when needed. This requires the ability to project kinetic power at targets anywhere in the world at any time. This mission is fundamental to preserving America's global interests. Failing to secure the long range strike advantage of hypersonics will translate into increased operational risk, interests surrendered, and increased likelihood of conflict escalation will rise in the decades ahead.

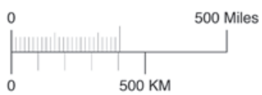
Over the past 20 years, the US has yet to responsibly recapitalize its aging aerospace forces—most notably, US Air Force fighter and bomber wings, Navy carrier air wings, Marine aviation assets, and joint service standoff weapons such as surface and submarine-launched cruise missiles. At the same time, potential rivals have rapidly upgraded their own capabilities, including defensive and offensive architectures. By any assessment, America's ability to project rapid and responsive global power has diminished.

Recent events in Syria, with Russia deploying advanced SAMs to protect its expeditionary forces defending the Syrian government, show how these A2/AD tools are used to take away potential intervention options.[12] Evolving defenses, such as fourth generation and even fifth generation aircraft under development in Russia and China, are altering the military balance. Modern SAMs coupled with phased-array radars and their exceptional discrimination, pose a more potent threat to US aircraft. Combined with elements such as modern infrared sensors, anti-aircraft artillery, and informed by modernized C2 and ISR networks, the air defense systems of the 21st century are a growing challenge to US power.

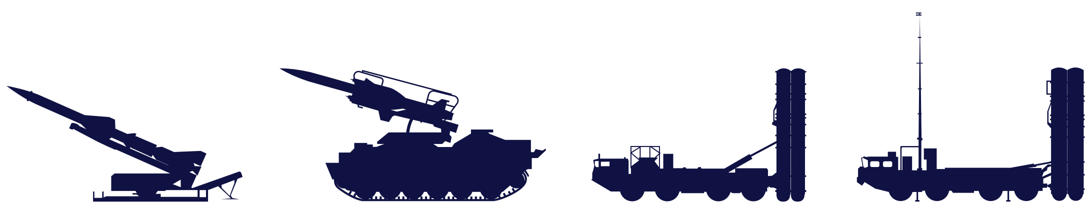
The narrowing technology gap has great impact on the military toolkit available to the US in the coming years. Ground defenses and aircraft are growing the "threat rings" military planners must take into account when examining potential scenarios. More capable SAMs and fighter aircraft force operations from greater distance, increasing transit time to targets, and shrinking windows to respond to "pop up" threats. Theater range weapons—such as new ballistic and cruise missiles, and cyber attacks from deep within protected territories—are themselves posing a time and distance challenge to conventional means of standoff attack. While these trends are continuing, the US also no longer has aircraft fleets large enough to pursue conflicts that could involve attrition, a factor taken into account in operations plans prior to the emergence of stealth and precision weapons.

12 Dan Williams, "Russia is Sending Advanced Air Defenses to Syria," Reuters, September 11, 2015, http://www.businessinsider.com/russia-is-sending-advanced-air-defenses-to-syria-2015-9 (accessed November, 2015).





Effective maximum surface to air missile ranges, from the SA-2 to the SA-21, as notionally depicted at the Bassel Al Asad airfield in Latakia, Syria.



Type:	SA-2	SA-6	SA-10	SA-21
Max Range (miles):	27	16	93	268

Source: Jane's Missiles and Rockets
Graphic by Zaur Eylanbekov

The sum of this threat picture has combined into a simple equation in the 21st century—distance + time + defenses × age = true capability. Older assets, often having to stand off at great distance, are increasingly unable to project necessary power against targets, many of which are mobile. Anemic modernization over the past three decades has yielded high-demand, low-density fleets of America's most capable combat aircraft for the toughest operational problems, the F-22 and B-2. Both these capable assets lack the capacity in numbers to project decisive power simultaneously in multiple combat scenarios.

In the near term, hypersonic weapons are well-suited to address this challenging situation. Successes in hypersonic research—real world live tests of vehicles surviving hot hypersonic airflows, not just simulations and experiments—have produced increased confidence from key leaders and advocates that practical weapons which can operate at speeds over Mach 5 are feasible, and in mass if needed. The November 2011 test of the Army's Advanced Hypersonic Weapon constituted a notable step forward toward future hypersonic battlefield and theater systems, and indicated the time has arrived for weaponization of hypersonics for national defense. Recent work with NASA's X-43 Mach 10 vehicle and the USAF's X-51 WaveRider tests have demonstrated the near term practical potential for making this technology operational, while affording needed attention and support from the Department of Defense. The Defense Advanced Research Projects Agency (DARPA) and USAF are now teamed on their own follow-on programs, but need continued support to see success.

What Hypersonics Offer

Hypersonic weapons offer several advantages for America's combat forces and those of its global friends and partners, facilitating operations in difficult threat environments, holding targets at greater risk, and enabling the striking power of legacy air assets.

Hypersonics afford unprecedented rapid reach: The driving reason why the US and its potential adversaries are pursuing this capability is its potential to shrink the "time to target" window. At over a mile per second or even faster, a hypersonic missile is, at a minimum, six times swifter than a conventional cruise missile. This enables a more effective intelligence and targeting cycle when dealing with targets that previously could not be held at risk for long, due to weapons constraints.

Hypersonics afford global target access: A theater-ranging hypersonic missile will reach a target 1,000 miles distant within 17 minutes or less.[13] Once hypersonic weapons are fielded, the lessons from their operations could inform future efforts. A hypersonic intelligence, surveillance, and reconnaissance (ISR) system could one day reach an area of interest faster than a satellite could be repositioned, and overflying contested airspace with a great degree of survivability.

Hypersonics provide "fourth dimension" effects: Hypersonic warfare is, in effect, time warfare. A hypersonic weapon compresses a foe's decision-making window, effectively enabling the hypersonic attacker to get inside an adversary's command, control, and battle management cycle. This will go a long way towards solidifying US command and control superiority in numerous potential scenarios, as a result.

Hypersonics offset air defenses: Hypersonic weapons counter adversary air defenses in two ways. First, by enabling older fourth generation aircraft to attack targets in heavily defended areas, and, second, enabling survival of the weapon itself as it seeks the target.

13 USAF Scientific Advisory Board, *Why and Whither*, 64-65. By definition, a hypersonic weapon moves at approximately one mile a second or faster. In 20 minutes, it can reach at least 1,200 miles.

Over time, air attackers have overcome increasingly sophisticated air defenses, but often at high costs in lost airmen and aircraft. Advances in electronic warfare (EW), active jamming of radars, the development of infrared countermeasures, and the maturation of stealth were driven by combat experiences going back to the Vietnam War, and have proved their value in US conflicts since the 1991 Gulf War.

But the capability gap today has narrowed. Hypersonic weapons can be added to the military toolkit in order to ensure the survivability of strike packages. composed of aircraft of varying capability and stealthiness. By enabling hypersonic weapons strikes at range, older and more vulnerable aircraft that otherwise could not operate in such high-threat areas have renewed potency and lethality — and modern US fifth generation aircraft would greatly multiply their own lethality. This radically complicates an enemy's defensive calculations, increasing the reach and lethality of the US' entire combat air fleet.

Finally, Israel's experience with the Iron Dome missile defense system has proved advances in computational technology, sensors, guidance, and small rocketry have enabled highly effective mobile SAM systems that can discriminate between incoming transonic and low-supersonic rockets, and can target missiles posing a threat to defenders.[14] This development has implications for future air defense technology. The Iron Dome technology can be expected to eventually proliferate to other nations, and will erode the value of traditional "fly-over" strike weapons, such as subsonic cruise missiles. A hypothetically similar system could target US precision-guided weapons aimed at potential adversaries. A hypersonic weapon, however, with its higher approach speed and terminal maneuvering, could evade these defenses, restoring the balance of advantage to the attacker.

Hypersonics and the Sensor-to-Shooter Factor

One of the key advantages hypersonic weapons will leverage is their potential to compress the time it takes for a weapon to travel to its target, redefining engagement opportunities and allowing more operational flexibility. The reduction of so-called "shooter-to-target" time in an age of increasingly more lethal and mobile weapons is critical to preserving military power. US efforts to perform targeted strikes on terrorist groups and their leadership have embodied the challenge of weapon transit time in the recent past, as these groups have rarely used fixed bases of operation and often vary the location and duration of their meetings in order to complicate targeting efforts.

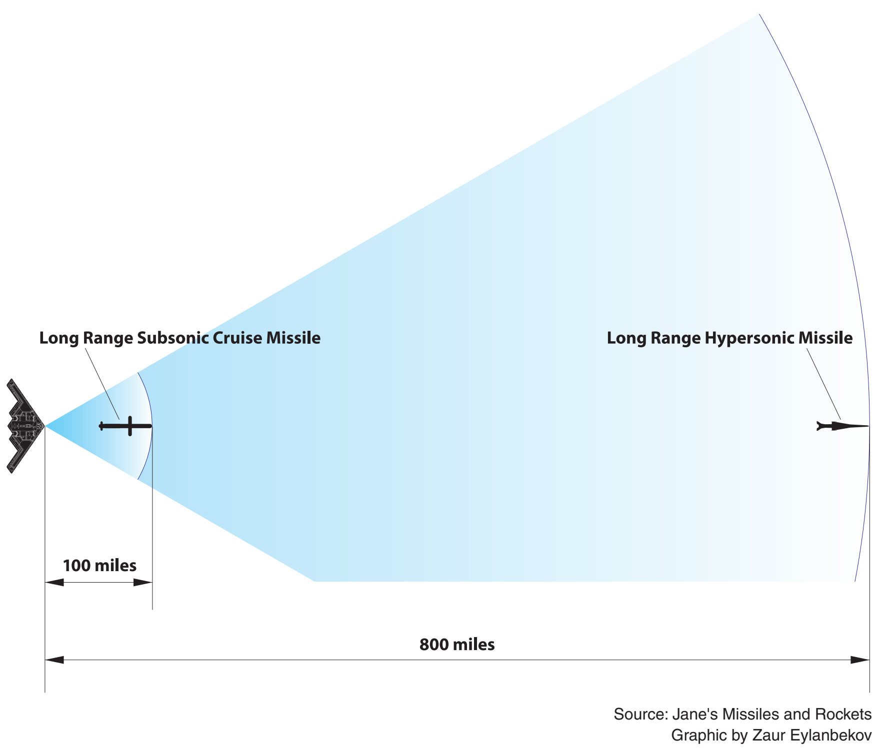
America's early experience with the Al Qaeda organization, in the years before the 2001 attacks, revealed the effect of this dynamic in action. The extended flight times of existing standoff strike weapons risked lost opportunity against even moderately distant targets, as just one fateful experience from the 1990s revealed. A subsonic cruise missile attack in August 1998 against a meeting of terrorist leaders failed to kill Al Qaeda head Osama bin Laden, who reputedly left the meeting just prior to the missiles' impact.[15] Had hypersonic

14 Yaakov Katz, "Iron Dome Successful in Downing 75 Percent of Rockets," *The Jerusalem Post*, December 30, 2011, http://www.jpost.com/Defense/Iron-Dome-successful-in-downing-75-percent-of-rockets (accessed November 17, 2015).

15 Bill Gertz, "Inside the Ring: Missing bin Laden," *The Washington Times*, September 18, 2008, http://www.washingtontimes.com/news/2008/sep/18/inside-the-ring/?page=all (accessed November 19, 2015).

missiles been employed, bin Laden would likely have been killed in the strike, potentially affecting the chain of events that led to the September 11, 2001 terror attacks.

But high value terrorist targets are only one problem set addressed by hypersonic weapons. Advanced mobile missiles are a serious, rapidly proliferating regional threat featuring profound targeting challenges. Currently, intelligence may detect the movement and launch preparation of a mobile missile, but the US lacks strike options of sufficient speed to eliminate the missle and launcher. The performance of PATRIOT air defense missile systems in the Gulf War of 1991, deployed to intercept Scud-Bs, revealed when adversary missiles are at or beyond their highest point in flight, even with a successful intercept the missile debris falls on ally territory. A hypersonic standoff weapon could strike the launcher with minutes to spare prior to launch.[16] This adds an important layer of defense, and an intimidating threat to any potential aggressor. A hypersonic scramjet cruise missile, for example, has approximately an eight-to-one advantage in speed over a subsonic cruise missile.[17] In the time a subsonic missile flies 100 miles, a hypersonic missile could go 800. Because of this speed and reach, targeting intelligence collected from a variety of systems—surface, airborne, space, and even human intelligence (HUMINT)—are rendered more exploitable.



Approximate distance traveled ten minutes after launch of an aerial long range subsonic cruise missile next to a notional long range hypersonic missile.

16 US Air Force Scientific Advisory Board, *Why and Whither*, Fig. 25, “Notional Deployment Launch Timelines for TBM and Associated AHM,” 46.

17 The subsonic cruise missile operates at speeds between Mach .75 and .85. A hypersonic missile would penetrate at speeds of at least Mach 5, and more typically at Mach 6 or higher.

In the era of subsonic or even short-range supersonic munitions, such detailed information often becomes non-actionable, simply because targets are too far away or require a time-constrained window of attack. Introducing hypersonic weapons into the portfolio of a planner and targeteer could have great implications across potential operations.

By increasing the utility of intelligence to build actionable targets, military commanders would have a more diverse pallet of targeting options, enabled by hypersonics. Locating, engaging, closing with, and destroying the opponent has always defined successful military operations. In modern campaigns, this unfolds as the find, fix, target, track, engage, and assess process—or the "F2T2EA chain." Advanced ISR and C2 systems have evolved and improved the US military's ability to find, fix, target, and track a host of potential aim points. But the tools of engagement—gravity bombs, short-range standoff missiles, and subsonic cruise missiles, among others—are becoming less decisive as more opponents begin to field modernized versions of these weapons themselves.

With its military advantage eroding, the US' command flexibility and freedom of action in operations is increasingly affected. Hypersonic weapons would reverse this trend. A commander who possesses hypersonic strike capability can choose to exercise a wider range of options, with the speed of hypersonics allowing more reflective decision-making, instead of reflexive decisions driven by tight windows of opportunity.

With its military advantage eroding, the US' command flexibility and freedom of action in operations is increasingly affected. Hypersonic weapons would reverse this trend.

Hypersonics and Target Sets

The speed and flexibility afforded by the development of hypersonic weapons will go a long way towards addressing the challenge of targeting and hitting multiple aim points.

Hypersonic strike weapons are key to addressing the number one threat to future air campaigns—integrated enemy air defenses and counter-air operations. An operational hypersonic weapon would confound adversary investment in an Integrated Air Defense System (IADS), in particular those built around older legacy aircraft and short-range anti-radar missiles. These IADS would be overwhelmed by missiles traveling to their targets at hypersonic speed, unable to effectively track or target them. Hypersonic air-to-surface missiles would effectively target radars, launch sites for aircraft and SAMs, command and control facilities, and other elements of defense networks. These targets pose extreme risk to the vast majority of legacy US aircraft and the present standoff munition inventory.

Hypersonic weapons could effectively engage enemy air assets on the ground, before they could engage US attackers. A US-led air campaign, equipped with hypersonic weapons, would target airfields, destroying hardened shelters, support facilities, and other infrastructure. These initial strikes would open an opponent to attack by other assets, such as older nonstealth strike aircraft. Hypersonic weapons could effectively prosecute command, control, and communications (C3) points, key leadership, and key ground, naval, and maritime targets.

Hypersonic strike weapons could more effectively engage high value targets, such as weapons of mass destruction or anti-satellite weapons threatening US and allied space networks. The speed and reach of hypersonic strike could preempt the launch of a theater ballistic missile, for example, as well as render an ASAT (anti-satellite weapon) site ineffective before it could engage US orbital assets.

Hypersonic weaponry could also address the challenge of hardened and buried targets. To evade US airpower, potential adversaries have attempted to "go deep," in many cases, putting key elements of command and control and air defense assets in hardened shelters or fortified facilities dug in geography such as mountains.[18]

In the 1991 Gulf War, the challenge of hitting Iraqi deep bunkers forced the rapid development of the non-standoff penetrating GBU-28.[19] Today, a hypersonic weapon is ideally suited for attack on deep hard targets such as nuclear laboratories, manufacturing sites, storage and processing facilities, and other high value targets. The speed of a hypersonic weapon gives it great utility to strike these hardened targets. With decades of experimentation and testing data on penetrating warheads amassed, there is strong potential for the development of a penetrating hypersonic strike warhead in the near future to address just this challenge. [20]

Hypersonics and the Future of Joint Operations

The effective development and deployment of hypersonic weapons would have vast implications for future joint and combined air operations, increasing survivability and enhancing the lethality of the full spectrum of air assets.

The effective development and deployment of hypersonic weapons would have vast implications for future joint and combined air operations, increasing survivability and enhancing the lethality of the full spectrum of air assets. The range and speed of a hypersonic weapon renders any launch platform largely invulnerable to opposing IADS or coastal defenses. Bombers, remotely piloted aircraft, maritime patrol aircraft, other special purpose attackers, and surface vessels and submarines could loiter hundreds of miles away, holding enemy targets hostage, and destroying them, if necessary, in minutes.

Though air launched hypersonic weapons are certainly within the natural domain of the Air Force, their development and utilization is consistent with the requirements of modern joint service operations. After maturation, there are conceivable applications across the services. US Army mobile launchers could fire deep-attack boost-glide rounds, US Navy ships could be equipped with hypersonic missiles for fleet attack or fleet defense, and submarines would enhance their lethality with faster hypersonic strike missiles. Sea and

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18 Alan Vick, *Air Base Attacks and Defensive Counters: Historical Lessons and Future Challenges*, (RAND Corporation: Santa Monica, California), September 2015, 51.

19 Richard P. Hallion, *Storm Over Iraq*: *Airpower and the Gulf War,* (Washington, D.C.: Smithsonian Institution Press, 1992), 243, 306.

20 USAF SAB, *Why and Whither*, Appendix G: "Physical Considerations for Hard Target Penetrators," G-1.

land–based aircraft could readily launch hypersonic air-to-surface and air-to-air weapons. Just as the Joint Direct Attack Munition (JDAM) is synonymous with US military aviation operations today, so, too, should be the hypersonic munitions of tomorrow.

Hypersonic weapons stand to increase the survivability and power projection options of the US military, across platforms. In particular, these weapons could preserve the security and effectiveness of naval aircraft carriers and surface battle groups, in an era where anti-ship missiles and A2/AD tools are increasingly putting naval assets at risk. Combined with joint force airpower, hypersonic weapons afford America the opportunity to conduct globally ranging operations with a strong degree of assurance against the most sophisticated opponents. Whereas in the past stealth and standoff subsonic cruise missiles were employed as force multipliers, now hypersonic weapons can hold targets at risk via avenues which cannot be adequately defended. These tools will help technology prevent the needless loss of life and materiel in the most challenging potential future conflict scenarios.

One does not have to look too far back to see how the military balance could be altered permanently by introducing hypersonic weapons into the air warfare toolkit. In the 1991 Gulf War, when the US led coalition flew into what was dubbed the most lethal air defense network ever devised, the ratio of electronic warfare "suppressors" to strike aircraft for non-stealth attackers was four to one.[21] In conflicts since, from Operation Allied Force over Serbia to Operation Inherent Resolve over Syria, the options and flexibility presented through modern stealth aircraft have ensured success in the opening phase of every conflict and helped ensure freedom of action for American forces.

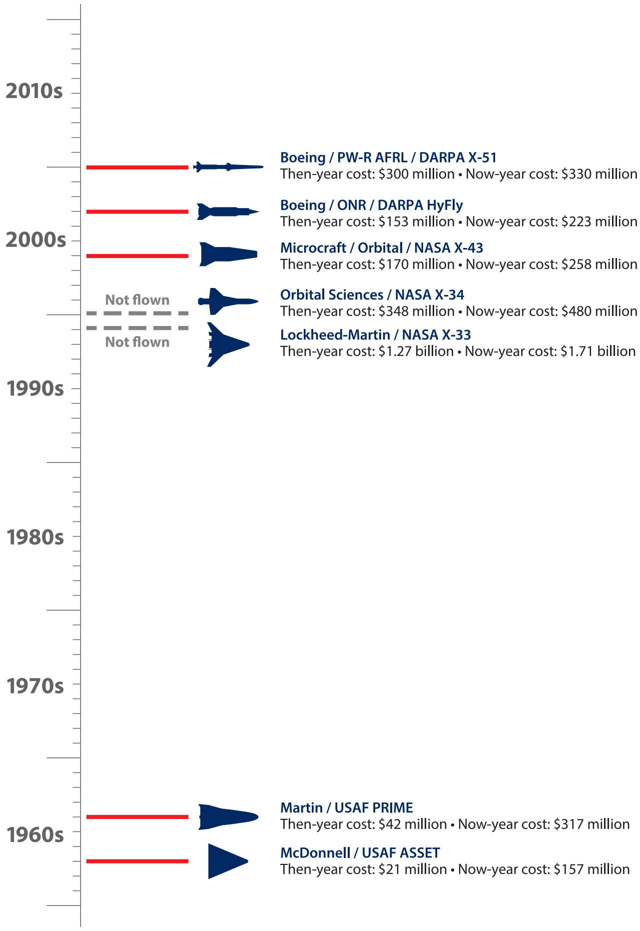
Today, hypersonic weapons stand to extend this joint force dominance into the 21st century, by providing a credible and effective answer to the toughest threats arrayed by potential adversaries.

The Situation We Face

Today, the United States is losing its technological edge in defense due to a combination of factors: the globalization of markets and ideas, the rise of near peer and peer nations, and the growing ability of even small businesses and non-governmental organizations around the world to invest in and capitalize on advanced technologies. A lack of focused science and technology budgets and programs to rapidly advance viable, revolutionary hypersonics technology to near term product transition is adding to this dynamic.

As a result, our adversaries have made great improvements in military technology over the past 20 years. These include radars, terminal seekers, SAM networks, fighter aircraft with advanced air-to-air missiles, electronic warfare countermeasures, and command and control networks which integrate these tools into an increasingly difficult defensive shield, raising the risk of loss in both materiel and personnel rarely considered in conflicts since the first Gulf War.

21 Hallion, *Storm Over Iraq*, 249.



Hypersonic initiatives over the past few decades have shown great promise. However, the sporadic occurrence of programs has hindered attaining desired capabilities in an efficient, rapid fashion. Every time a program ends, teams disperse, knowledge is lost, and new efforts must begin from scratch to regain momentum. Future efforts will only succeed if executed with consistent policy guidance, stable technical specifications, and dependable funding streams.

Source: Jay Miller, *The X-Planes*; Richard Hallion, *The Hypersonic Revolution, Vol. 1*; Richard Hallion and Michael Gorn, *On the Frontier: Experimental Flight at NASA Dryden*; Allen Li, “Space Transportation,” GAO-01-826T (2001); Andrew Butrica, *Single Stage to Orbit.*

The US continues to improve its own capabilities in all these areas, but at increasing risk and without the confidence of success we have grown accustomed to in the modern era of military overmatch. The successful fielding of hypersonic weapons could provide a new asymmetric advantage to the United States, by allowing our military forces and allies to penetrate and defeat advanced threats at extremely high speed, enhancing our ability to deny adversaries the ability to effectively react to protect their combat capabilities, or to use them against us.

Though hypersonics, in particular hypersonic strike weapon technology, is ripe for exploitation as a theater and global strike game changer, it is not yet clear whether America will own that advantage first. Though the US is investing in hypersonics and their maturation, it is not on a guaranteed path to near term success. Clear and consistent commitment to a disciplined plan to address remaining technology challenges has yet to emerge from America’s recent efforts in this field.

Though the US has amassed a great deal of knowledge and expertise in hypersonics, it has thus far not yet realized its practical military advantage. The US has completed several complex, risky, and overly expensive hypersonics programs that more often than not have fallen short of success, such as the X-30[22], the X-33[23], and the Blackswift reusable hypersonic test flight vehicle.[24] These programs were often very ambitious, such as the Blackswift, which attempted a complex combined turbojet and ramjet/scramjet engine to power a survivable, remore piloted hypersonic aircraft. The vision, however, was unmatched with the

22 “X-30,” Encyclopedia Astronautica, http://www.astronautix.com/lvs/x30.htm (accessed November 17, 2015)

23 “X-33,” Encyclopedia Astronautica, http://www.astronautix.com/lvs/x33.htm (accessed November 17, 2015)

24 Ward Carroll, “DARPA Cancels Hypersonic Blackswift,” *DefenseTech.org*, October 14, 2008, http://defensetech.org/2008/10/14/darpa-cancels-hypersonic-blackswift/ (accessed November 17, 2015)

appropriate level of funding to take on all these technology challenges at once, and the project floundered.[25] Other efforts have afforded success, but gains were not cemented with follow-on incremental investment in programs of record, such as the X-43 and the just concluded X-51 Waverider tests. This has proved frustrating for maturation efforts, as the science and technology teams with the freshest knowledge and developmental lessons from these efforts are disbanded, and moved on to other projects. The path to success would be better served by tackling challenges incrementally, which is why it is important to focus on developing workable hypersonic weaponry before tackling the larger and more complex challenge of hypersonic aircraft.

Since solving the hypersonics puzzle is about recognizing and integrating several different technologies, there is a need for a clear vision for creating a path to bring these disparate tools together. This has yet to be articulated in policy or legislation. The result is Congress and defense decision makers have failed to recognize the real and impressive successes which have occurred in the last several years with regards to hypersonics research and development, and few outside of the aerospace and defense research community recognize or appreciate that the US stands on the cusp of a breakthrough in practical weaponization of this technology.

At the present rate, the United States is roughly four to five years from flying its next air-breathing hypersonic vehicle, the Hypersonic Air Breathing Weapon Concept (HAWC), which will incorporate lessons learned from the successful X-51 Air Force-NASA-Defense Advanced Research Projects Agency (DARPA)-aerospace industry team. This effort will attempt to achieve what is known as Technology Readiness Level (TRL) 6. This means building a representative model or prototype system that is successfully tested in a relevant or simulated operational environment, a milestone that will help bridge the gap towards weaponization. But this program must remain on schedule if it hopes to succeed.[26]

Meanwhile, competitors are advancing rapidly—designing, prototyping, and testing, new and capable facilities for research on this field, and establishing an educated cadre of young hypersonic professionals who will be able to develop these tools further in the years ahead.[27] If these nations succeed in the race to field this technology, the US risks falling behind in our ability to solve the A2/AD problem, and thus in our ability to prevail in a future confrontation.

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25 Ibid.

26 Stew Magnuson, "Hypersonic Weapons Can Defeat the Tyranny of Time, Distance," *National Defense Magazine*, November 2014; Maj Gen Thomas Masiello, (Commander, Air Force Research Laboratory, Wright-Patterson AFB, Ohio), author phone conversation, Alexandria, Virginia, November 3, 2015. Masiello noted the next flight would be around 2019 to 2020.

27 Bradley Perrett and Guy Morris, "China's Scramjet Claim Puzzles US Researchers," *Aviation Week & Space Technology*, Nov 9, 2015, http://aviationweek.com/technology/china-s-scramjet-claim-puzzles-us-hypersonic-researchers (accessed Novermber 17, 2015)

The Path Forward: Recommendations

To make real progress, the time has come for decision-makers to lay out a consistent and disciplined technology path to close the remaining gaps; and foster the conditions for a concept of operations to develop; and allow the test and deployment of hypersonic weapons that could give America's air, sea, and land forces an assymetric advantage.

A satisfactory path forward is more achievable than some may believe. This study makes recommendations in **five key focus areas**.

First, the US Congress and defense leaders must **understand the state and near term potential of hypersonics**, and commit to a steady path to practical weapons capabilities.

Second, the Department of Defense (DOD) must establish a **realistic acquisition strategy** and guide a **practical requirements assessment and development process** for concepts of operation, science and technology, research and development, testing, and life cycle management activities.

Third, DOD and aerospace industry must **conduct the remaining technology maturation efforts** to bring required subsystems to sufficient readiness to begin actual weapon development with high confidence.

Fourth, DOD and industry must ensure the **construction and refurbishment of proper test facilities and range infrastructure** and provide resources to support this effort.

Finally, we must **create and sustain an educated, motivated cadre of hypersonics professionals** to keep our nation on the leading edge of this field.

Understanding and Commitment to Hypersonics

By recognizing the United States is losing its technological edge, we will be able to invigorate deliberate efforts to maintain its position at or ahead of rising competitors. This technological edge has real world implications, as it will ensure success in future confrontations with adversaries who have realized improvements in systems such as air defense, command and control, and combat aircraft. These weapons will give a new asymmetric advantage to US forces in future conflicts, by enhancing the ability to prosecute time sensitive targets and penetrate A2/AD capabilities utilizing the high speed of hypersonic weapons.

Hypersonics are not only an important aerospace technology, but also an inevitable step in the development of military aerospace technology, and the United States is not the only country that understands this trend. This fact must be tempered with the knowledge that potential competitors realize the advantage hypersonics pose as well, and are advancing rapidly with their own design, prototyping, and testing efforts to mature hypersonic capabilities, by investing in new facilities, as well as human capital in their respective scientific and research communities.[28] This raises the urgency for the US to commit to a disciplined program to develop and deploy hypersonic technology, and the need to communicate effectively with potential supporters and decision-makers about the benefits of this path, and the risks to not taking it.

A Hypersonics Acquisition Strategy

To ensure success, Congress, DOD, and decision-makers must develop appropriate policy guidance and a **concept of operations (CONOPS)** for moving forward, based on maturing incremental, realistic and achievable technologies leading to practical hypersonic weapons. They must also avoid overly aggressive projects that try to "solve it all at once." Equally important, each increment should tie to the primary goal, and each project should be followed up with a technology transition to useful capability.

This study proposes an approach that would first develop an **air-launched medium range hypersonic strike weapon in the 2020s**; a more-capable **strike/ISR weapon in the 2030s**; and an eventual goal of a **persistent, reusable hypersonic strike/ISR aircraft in the 2040s**.

Requirements development should be accelerated now, and be a multi-service effort. This should include an assessment of the A2/AD environment and the CONOPS for using hypersonic weapons in a variety of realistic scenarios ranging from isolated time-critical targets to integrated theater engagements. These should be tested via aggressive joint modeling, simulation, and wargaming.

While the relationships between NASA, DARPA and the military services have been successful and should be continued, the time has arrived for the Air Force to take the lead in developing and transitioning the technologies required for weaponization. USAF, more than any other service, serves as the home of the majority of the US military's collective knowledge, lessons learned, and human capital related to the research and development of hypersonics, and is the best situated to realize concrete results if appropriate support and direction is applied. The Navy also has great benefit to gain from operational hypersonics, as theater ballistic missile defense is a vital concern to the future viability of carrier groups. Operator involvement, from the Air Force, Navy, and across the joint force, is key to developing practical operational hypersonic capabilities and must better direct future investment.

The Air Force Research Laboratory has identified hypersonics as a game-changing technology, and the Air Force's most recent strategy document supports the contention that this technology will have enormous effects across mission areas over the coming decades.[29] Project efforts must show commitment to pushing the edge forward, towards this vision.

28 "China, India and Russia Have Supersonic Cruise Missiles and are Nearing Hypersonic Cruise Missiles," *Missile Threat.com*, March 23, 2015, http://missilethreat.com/china-india-and-russia-have-supersonic-cruise-missiles-and-are-nearing-hypersonic-cruise-missiles/; "Focus on Hypersonic Reusable Cruise Missile, Says Scientist," *The New Indian Express*, August 9, 2015, http://www.newindianexpress.com/states/andhra_pradesh/Focus-on-Hypersonic-Reusable-Cruise-Missile-Says-Scientist/2015/08/09/article2965112.ece. (accessed November 17, 2015)

29 Department of the Air Force, *Air Force Future Operating Concept: A View of the Air Force in 2035*, Washington, D.C., September, 2015, 30.

A tangible way to ensure this is to establish a **program office reporting to the assistant secretary of the Air Force for acquisition**. Second, the service must establish a **competitive hypersonic weapons development philosophy,** to fund at least two teams through preliminary design review. This will ensure the United States establishes a viable hypersonic technology industry with emphasis on varied design approaches. Downsizing these efforts too early would limit technology maturation efforts, and increase future costs if there is no incentive for competition.

Technology Maturation

A proper approach to near-term hypersonic weapons development requires focusing on a finite number of interrelated technology efforts. We support the approach advocated by the US Air Force Scientific Advisory Board in their 2014 study, *Technology Readiness for Hypersonic Vehicles*. Specifically worth noting, the board argues the Air Force should:

1. Make the investments needed to close the remaining technical gaps for hypersonic tactical strike weapons to ensure all critical sub-systems reach TRL 6 no later than 2020 with a focus on seeker/seeker integration, terminal guidance and maneuverability, and aero-shell materials for hypersonic boost glide concepts.

Also, the board states, the Air Force should:

3. Explore enhanced target lethality munitions concepts that leverage the high-terminal velocity of hypersonic strike weapons.

Long term, the technology maturation plan should also address technologies required for follow-on capabilities that will sustain our strategic edge. A list of hypersonic study areas, sought for a 2015 aeronautics conference, includes topics worthy of focus and investment. These include design and capability of vehicles and their missions, internal cooling and thermal management, sensor operations, options for propulsion systems such as ramjets and scramjets, control (surfaces, flight control algorithms, navigation, and guidance), power, materials and structures (metals and composites, signatures, flexibility, and heat resistance), as well as test and evaluation requirements, modeling, instrumentation, and test operations.[30] Additional areas of study to ensure successful weapons programs include sensors, communications, terminal guidance technologies, and hypersonic warhead design and integration.

Test Facilities and Range Infrastructure

Congress and DOD must also adequately support continued operation and upgrading of the national hypersonic technology infrastructure, particularly unique test tools and research facilities for undertaking both ground-based and full-flight testing and research.

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30 AIAA, "20th American Institute of Aeronautics and Astronautics International Space Planes and Hypersonic Systems and Technologies Conference, Call for Papers." https://www.aiaa.org/Hypersonics2015CFP/?terms=%22international%20space%20planes%20and%20hypersonic%20systems%20and%20technologies%20conference%22 (accessed November 16, 2015).

Congress and DOD must also adequately support continued operation and upgrading of the national hypersonic technology infrastructure ...

Critical hypersonic test facilities include the Hypervelocity Wind Tunnel Nine at White Oak, Maryland, operated by the Air Force; the NASA Eight-Foot High Temperature Tunnel (8FT HTT) at Langley Research Center, Virginia, operated by NASA, and the assortment of wind tunnels and ground testing facilities located at Arnold Engineering Development Complex (AEDC), at Arnold AFB, Tennessee. These national assets are periodically endangered by shortsighted policies which measure facility worth based on hourly usage rates rather than provision of critical test and development knowledge. This approach requires facilities to be paid for by the programs using them, thus driving the program costs up sharply, driving program customers away, and increasing the cost per remaining customer, resulting in a budgetary "death spiral." The nation must commit to maintaining these facilities and funding the research programs that require these assets.

Critical range infrastructure includes both overland ranges (such as the Edwards Air Force Base/China Lake R-2508 complex in California, the Utah Test & Training Range, and the White Sands Missile Range in New Mexico) and the overwater ranges necessary for long-range hypersonic testing (these include the Western Test Range in the Pacific Ocean, the Eastern Test Range off the US Atlantic Coast, and the Eglin Air Force Base Gulf Test Range in the Gulf of Mexico). Issues that must be addressed include establishing airspace procedures for hypersonic testing (clearing shipping from test zones, for example) and maintaining the control transmitters, tracking radars, infrared and photographic sensors, and data acquisition receivers necessary for flight-test activities. Our nation's test range infrastructure has been neglected for several decades. Though this trend has recently begun to reverse, we need to ensure that the test range infrastructure necessary for hypersonic testing is ready when needed.

Cadre of Educated, Motivated Hypersonic Professionals

There are a number of ways to support the field of hypersonics as an area of study for America's scientists and engineers. These include current efforts at developing Science, Technology, Engineering and Mathematics (STEM) programs as early as elementary school, establishing and funding hypersonics-related courses in aeronautical, mechanical, and chemical engineering departments at universities, offering scholarships to our brightest students, and funding our current hypersonics experts to serve as adjunct professors.

However, there is one obstacle to developing a cadre of hypersonics professionals for this country that, until eliminated, will risk failure. The US government and industry must establish a steady, viable, continuous hypersonics research and development program, with specific goals to produce a range of hypersonic capabilities for the United States.

The US must stop smothering success by disbanding and dispersing hypersonics experts to other fields following project termination—a common theme through several of the aborted experimental programs of years past. By leveraging this talent, we will cultivate core expertise, build the motivation to join the field, and sustain the momentum to achieve self-sufficiency. Given the threat of failure, our nation requires no less.

Conclusion: Hypersonics—The Right Decision

Recognizing the impossibility of being able to defend the United States from attack by any means, our nation has relied on our ability to deter and defeat our adversaries by holding their own territories, militaries and critical infrastructure at risk. Our continued capability to do so in the future is strongly dependent on our ability to penetrate our enemies' air defense networks. Recent advances in A2/AD capabilities put our military strike forces at considerable risk, and will increasingly do so in the next decade.

Hypersonic weapons provide an asymmetric advantage for our military, bolstering deterrence and, if need be, fostering success if we are forced to take the fight to an enemy.

Hypersonic technologies are remarkably close to maturity. The US government and industry must commit to sustained, steady hypersonic Research, Development, Test and Evaluation (RDT&E) efforts leading to technology transition and programs designed to improve our combat capability. Those efforts must be driven by focused, achievable weapons programs providing our military steadily improving capabilities over the next few decades. It is time to break the old habits of overly aggressive, expensive failures which lack follow-ups to success. Government and military leaders with vision will need to work with the service laboratories, industry, and academia to achieve these goals.

Hypersonics technologies and weapons are both vitally important and inevitable. Congress, DOD, and the aerospace industry must ensure the United States secures the hypersonic technology advantage, and captures the associated military advantage to protect its interests for decades to come.

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