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STRATEGIC PRIMER: HYPERSONIC WEAPONS

CURRENT CAPABILITIES AND EMERGING THREATS

AMERICAN FOREIGN POLICY COUNCIL

HYPERSONIC WEAPONS AND AMERICAN SECURITY

The American Foreign Policy Council (AFPC) is dedicated to advancing the prosperity and security of the United States. AFPC's Defense Technology Program launched its *Strategic Primer* initiative to educate Congressional staffers and the general public about technologies that affect U.S. national security. The *Primers* depict balanced representations of the potential benefits and limitations of a particular technology, its history and uses, and potential threats posed by adversarial use.

While the United States continues to face a growing threat from ballistic missiles and weapons of mass destruction, the current lack of a plan to address hypersonic weapons is truly problematic. As China and Russia continue their research and development of hypersonic weapons, it is imperative that U.S. policymakers and the defense community fully grasp the threat, as well as how this technology fits within the strategic calculus of adversary nations. This publication provides a brief overview of the challenge posed by hypersonic weapons, a discussion of how adversarial nations plan to incorporate hypersonic weapons into their military arsenals, an outline the U.S. offensive and defense capabilities, and policy recommendations to better address the threat.

An X-51A WaveRider hypersonic flight test vehicle is uploaded to an Air Force Flight Test Center B-52 for fit testing at Edwards Air Force Base on July 17, 2009. Four scramjet-powered Waveriders were built for the Air Force. The Air Force Research Laboratory, DARPA, Pratt & Whitney Rocketdyne, and Boeing are partners on the X-51A technology demonstrator program. (U.S. Air Force photo/Chad Bellay)

Cover Photo: MOSCOW, RUSSIA - May 04, 2018 Mikoyan MiG-31 (NATO: Foxhound) - supersonic interceptor aircraft with Kh-47M2 Kinzhal - hypersonic air-launched ballistic missile at Rehearsal of 2018 Victory Day Parade

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WHAT ARE HYPERSONIC WEAPONS?

Hypersonic weapons are a new class of offensive missiles that are both very fast and highly maneuverable. These advanced missiles can travel at over five times the speed of sound (Mach 5, > 3836 mph) across long distances and launch from a multitude of platforms (air, sea, or land). Traditional missile threats, such as ballistic and cruise missiles, have inherent vulnerabilities—for instance, ballistic missiles travel at extremely high speeds but have very limited maneuverability until the terminal phase of their flight, while cruise missiles travel at comparably low speeds but with high maneuverability. Hypersonic weapons, by contrast, boast the best characteristics of each, and only minimal vulnerabilities. This presents a significant strategic challenge for current U.S. defenses.

WHY IS THE U.S. AT RISK?

Russia and China are at the forefront of hypersonic weapons technology, with each country successfully manufacturing and testing these weapon systems. U.S. missile defenses are not capable of tracking hypersonic weapons from launch, monitoring them through flight, and then intercepting an incoming missile.

ADDRESSING THE THREAT

It is critical that policymakers commit funding to the development of necessary offensive and defensive capabilities that capitalize on the advantages presented by hypersonic weapons and which are capable of countering the evolving hypersonic weapons threat to the U.S. and its interests abroad.

OVERVIEW OF HYPERSONIC WEAPONS

TYPES OF HYPERSONIC WEAPONS

There are two main types of hypersonic weapons: Hypersonic Glide Vehicles (HGV) and Hypersonic Cruise Missiles (HCM). These weapons are able to carry out either conventional or nuclear strikes and are extremely difficult to track and defend against, since current U.S. sensor systems would lose track of them after launch. Though not considered hypersonic weapons, there are also some short-range ballistic missiles whose reentry vehicles are aeroballistic, or highly maneuverable in the atmosphere, and reach hypersonic speed. In addition to hypersonic weapons, hypersonic platforms could be used for reconnaissance. As a 2016 Air Force Association report noted, "A hypersonic intelligence, surveillance, and reconnaissance (ISR) system could one day reach an area of interest faster than a satellite could be repositioned, and [while] overflying contested airspace with a great degree of survivability."[1]

1 HYPERSONIC GLIDE VEHICLES (HGV)

Hypersonic glide vehicles, or boost-glide vehicles, use a rocket to accelerate to hypersonic speed, then discard the rocket and coast away.[2] They typically reach altitudes of between 25 mi. to more than 62 mi., and then "glide" along the upper atmosphere.[3] As the HGV spends very little time in ballistic mode, the unpredictable flight path can hold a large area at risk of attack.[4] Current ballistic missile defense systems cannot track such weapons during the bulk of their gliding phase, and terminal air and missile defense systems cannot cope with their combination of high speed and maneuverability, making HGVs extremely challenging to defend against.[5]

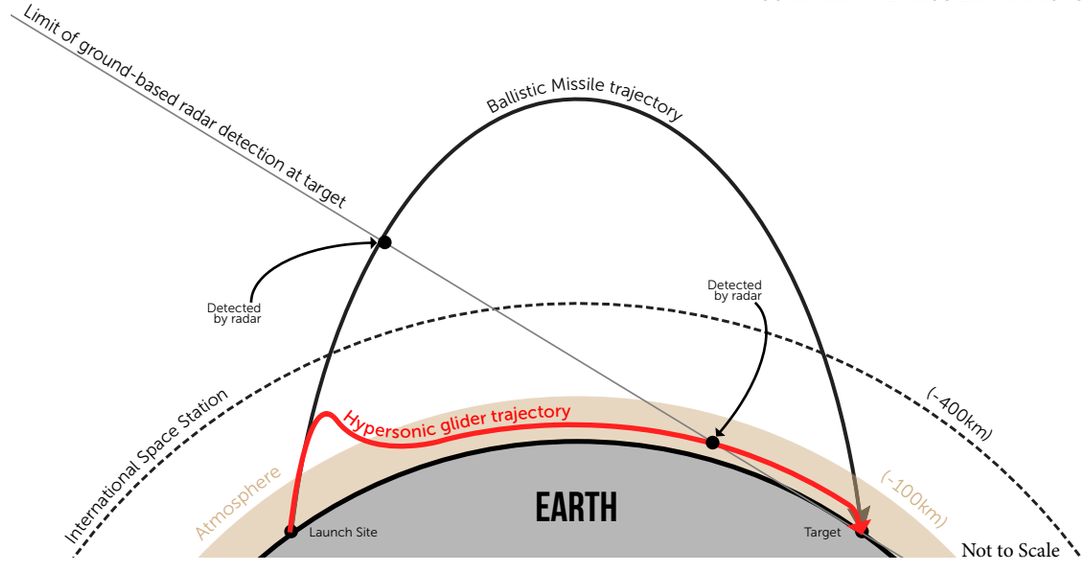
2 HYPERSONIC CRUISE MISSILES (HCM)

Hypersonic cruise missiles, or boost-cruise vehicles, are propelled by a jet or rocket in order to reach hypersonic speeds.[6] They then switch to a Supersonic Combustion Ramjet Engine (scramjet) and fly using their own power.[7] HCMs can be launched by ground systems, by aircraft, or by ships, and cruise at altitudes from 12 mi. to 19 mi.[8] Although they are within the altitude range of modern air defenses and surface-to-air missiles, their speed and maneuverability make them elusive.

UNDERSTANDING DEVELOPMENT AND USE

There are important questions surrounding the need to develop hypersonic weapons: what is the intended mission, do they affect the strategic balance and alter the concept of deterrence? One advantage of hypersonic weapons is their ability to evade the advanced integrated air defense systems of adversaries. Because hypersonic weapons have advanced maneuverability and high speed, another purpose for them would be to attack time-sensitive and/or mobile targets (though this remains challenging because it presupposes intelligence, surveillance, and reconnaissance (ISR) capabilities that are able to provide timely and accurate target coordinates). There are alternative methods to evade enemy air and missile defenses, including using decoys, stealth technology, saturating the target, or electronic warfare, but they all have various drawbacks.[12] Hypersonic weapons provide a potentially attractive and effective method for penetrating sophisticated modern air and missile defenses. Thus, the rationale for developing hypersonic weapons centers on defeating adversary air defenses and destroying time sensitive and/or mobile targets.

COMPARATIVE MISSILE TRAJECTORIES[9]



Source: The Economist

FLIGHT TRAJECTORY AND SPEED

Hypersonic weapons do not follow the parabolic trajectories that would normally allow for predictable interception.[10] They travel at low altitude, as compared to ballistic missiles, and at a minimum speed of Mach 5 (range is 3,836-15,500 mph), thereby greatly decreasing the likelihood of timely detection. According to a recent RAND Corporation report, "a radar operating from the surface of a smooth Earth would detect a 3,000-km-range (1,860-mi-range) [ballistic reentry vehicle] (RV) about 12 minutes before impact, but would not detect an HGV until about 6 minutes before impact."[11]

The logic of deterrence remains unchanged by the advent of hypersonic technologies. As Under Secretary of Defense Mike Griffin, the Pentagon's R&D chief, has noted, "through what we've called, for generations now, Mutually Assured Destruction, we are hostage to Russian [intercontinental ballistic missiles] ICBMs and they are hostage to ours...Maybe I'm missing something — that's always possible… but I do not see what a hypersonic nuclear missile brings to the strategic missile posture that earlier systems don't."[13] However, possession of offensive hypersonic weapons would broaden U.S. attack options, possibly enabling a disarming conventional first-strike to destroy an adversary's strategic arsenal without crossing the nuclear threshold.[14] This has led to some concern that hypersonic weapons could be destabilizing in a crisis, provoking a potential adversary to escalate to nuclear use prematurely for fear of losing its nuclear weapons to a U.S. attack with conventionally-armed hypersonic weapons.[15]

IMPLICATIONS OF THE THREAT

DECREASED DECISION TIME

Ballistic missiles travel at higher speeds than do hypersonic weapons, so they can reach a given target faster. However, the predictable trajectory of a ballistic missile can be determined comparatively early in its flight. By contrast, a hypersonic glide vehicle (HGV) boosted by the same rocket used for ballistic missiles would be detected at launch by overhead infrared systems, but would not be acquired by ground-based radar until late in its flight. Therefore, even after an HGV can be seen and tracked by ground-based radar, its ultimate target and path to its intended target would remain unknown. This combination of unpredictable flight path and very late detection by radar would leave U.S. decisionmakers with greatly reduced reaction and response times in the event of a crisis involving an HGV. Hypersonic cruise missiles, particularly those capable of intermediate or intercontinental range, could pose an even greater challenge because it would be harder to detect the initial launch of such weapons.

HIGH VALUE TARGET VULNERABILITY

The unpredictable flight trajectory and high speed of hypersonic weapons present serious threats to forward-deployed warfighters and mobile assets (including aircraft carriers or missile launchers).[16]

REDUCED MILITARY ADVANTAGE

U.S. adversaries possessing hypersonic weapons could dramatically decrease the existing "capability gap" with the U.S. military and enhance their ability to hold high-value U.S. targets at risk.[17]

MILITARY ESCALATION

Hypersonic weapons could lead to unintended escalation. For example, in a conflict with China, the U.S. military might launch hypersonic weapons tipped with conventional warheads with the intention of targeting Chinese air defense systems. However, due to the maneuverability and unpredictable flight path of these weapons, the Chinese could become fearful that the United States was targeting Chinese nuclear weapon systems and respond by launching a nuclear strike against U.S. targets.

DEGRADED MISSILE DEFENSES

Unlike ordinary ballistic missiles, the high maneuverability of hypersonic missiles ensures target ambiguity, making interception exceedingly complicated. Missile defenses will require advanced detection and tracking systems and improved interceptors in order to defend against such attacks.

"China and Russia are pursuing hypersonic weapons because their speed, altitude, and maneuverability may defeat most missile defense systems, and they may be used to improve long-range conventional and nuclear strike capabilities. There are no existing countermeasures."[19]

- U.S. Government Accountability Office

CHINESE PROGRAMS[20]

The People's Liberation Army (PLA) believes that "hypersonic technology is the commanding height of aerospace technology."[21] In 1995 and 1996, in an effort to influence the presidential election in Taiwan, the PLA launched "a major psychological warfare operation that, at the same time, was a display of military force and a warning to Taiwan not to go too far in moves toward democracy and independence."[22] The PLA conducted a series of military exercises that simulated an invasion of Taiwan and also announced missile impact zones at sea, and closed areas for air traffic, in the vicinity of the Taiwan Strait. The closure areas for the missile tests, which bracketed Taiwan, "had the effect of a temporary blockade or embargo of shipping and air travel to Taiwan."[23]

1 XINGKONG-2 (STARRY SKY 2)

In August 2018, the Washington Free Beacon reported that China had conducted a flight test of a new hypersonic missile that is nuclear-capable. The Xingkong-2 or Starry Sky-2 missile is multi-stage and capable of maneuvers at speeds of Mach 5.5, with a top speed of Mach 6 (4,500 mph).[25]

2 DF-ZF (WU-14)

In November 2017, the *Free Beacon* carried an article reporting the testing of a hypersonic Glide Vehicle (HGV), the DF-ZF, previously designated the WU-14, which travels on the DH-17 medium-range ballistic missile.[26] This missile warhead glides near its target in near space and can maneuver during reentry, confounding any U.S. defenses. The WU-14 is capable of maneuvering at speeds of between Mach 5 and Mach 10, or between 3,800 and 7,600 miles per hour.

3 DONGFENG-26 (DF-26)

On January 27, 2019, the PLA tested its Dongfeng-26 (known as the "Guam Killer") ballistic missile, which not only brings Guam into range but also is capable of targeting enemy naval formations at greater distances from China's shores than the DF-21D.[27] Publicity surrounding the test in one of China's Communist party-controlled newspapers revealed that this was the test of a nuclear or conventional strike/anti-ship missile using a hypersonic gliding warhead.[28] The article also claims this is the world's first supersonic mid-range and long-range missile with boost-gliding technology.

In response to China's missile exercises and actions, which began on March 8, 1996, President Bill Clinton announced that two U.S. aircraft carrier battle groups would be dispatched into the area. Ultimately, the carrier battle groups stayed out of the Taiwan Strait, but were deployed within striking distance of China and Taiwan. The carriers stayed in the area throughout the PLA exercises, which ended after Taiwan's presidential election on March 25, 1996.[24] Evidence suggests strongly that these events led to the development of new missile systems in China that were designed to attack U.S. carriers at sea, and which were the precursor of China's contemporary focus on hypersonic glide vehicles.

4 CM-401

At the 2018 Zhuhai Air Show, the PRC showed off a model of the CM-401 anti-ship cruise missile (ASCM), manufactured by China Aerospace Science and Industry Corporation (CASIC).[29] The CASIC brochure, according to media coverage from India, described the CM-401 as world's first "ultrafast ASBM." The brochure's claim may not be truthful, however; Russia developed a hypersonic ASCM much earlier. Despite the fact that the CM-401 may not be the first hypersonic ASCM, however, its development represents a major achievement for China and a significant threat to U.S. warships.[30]

THE THREAT

China has tested the DF-ZF hypersonic glide vehicle "at least nine times since 2014,"[31] and may therefore be closer to fielding such systems than is the United States. Moreover, China's anti-ship cruise missile, the CM-401, is already in production. This means that deployed U.S. forces at sea and engaged in the defense of island chains already face threats from hypersonic weapons. Despite what may be a current U.S. lead in research and testing, China already possesses hypersonic anti-ship cruise missiles.[32]

RUSSIAN PROGRAMS[33]

Russia believes that U.S. anti-ballistic missile (ABM) technology is progressing inexorably along a path that will one day neutralize Russia's strategic nuclear deterrent forces. Thus, Moscow's pursuit of hypersonic weapons, particularly ones with intercontinental range, is intended to defeat American ABM systems and preserve Russia's strategic nuclear deterrent. In his February 2019 State of the Nation address to the Duma, Russian President Vladimir Putin promoted the Tsirkon (Zircon) missile, hinting that it would be used to launch surprise strikes against the U.S. national command authority.[34] Within days, a retired Russian Admiral said that the Tsirkon would be capable of hitting command posts in the U.S. within five minutes from Russian submarines, and "Russia's Vesti Nedeli state TV station published a list of American targets it said the Kremlin could strike with hypersonic nuclear missiles within five minutes if war breaks out."[35] In a March 2019 speech, the Chief of the Russian General Staff, General Valery Gerasimov, said Russia was forced to "plan future delivery of strikes against decision making centers…"[36] Such pronouncements are probably intended to strengthen Moscow's strategic deterrence of potential U.S. aggression and, perhaps more importantly, to simultaneously reassure and distract domestic Russian audiences.

1 KINZHAL HYPERSONIC MISSILE (KH-47M2)

The Kinzhal is one of the five nuclear "superweapons" which President Putin unveiled in his March 1, 2018 State of the Nation address. It is an "aeroballistic missile" with hypersonic speed, according to the head of the Russian Aerospace Force (the new name for the Russian Air Force).[37] The Russian Defense Ministry has characterized the missile as stealthy and highly maneuverable[38] (which means it has to operate in the atmosphere for a substantial period of time rather than flying a ballistic trajectory).[39] The range of the Kinzhal (>1,240 mi.) makes it virtually impossible to create a barrier defense against the bombers that carry the missile.[40]

2 TSIRKON (ZIRCON) HYPERSONIC CRUISE MISSILE

The Tsirkon is a scramjet-powered hypersonic missile with multiple basing modes. It will likely be the cheapest (and, hence, most widely deployed) of the current Russian programs to develop and deploy hypersonic missiles. According to President Putin, the missile will be capable of traveling at a speed of Mach 9 with a range of 620 mi.[41] The Tsirkon will very likely be nuclear capable,[42] with an anti-ship and land-attack mission.[43] Since it is much smaller than the Avangard, it will also be harder to detect.

MOSCOW TAKES THE LEAD

Russia appears set to achieve a monopoly on operational hypersonic missiles, and is likely to retain a monopoly on intercontinental-range nuclear hypersonic weapons for the foreseeable future. Russia's theater range hypersonic missiles will be a very serious warfighting threat to NATO as well as to U.S. forces in the Far East and Japan.

3 AVANGARD HYPERSONIC BOOST GLIDE VEHICLE

The Avangard intercontinental-range hypersonic boost glide vehicle is in serial production and will reportedly be operational by 2020, although Russian President Vladimir Putin claimed it would be deployed in 2019. The Avangard's main mission is to preserve Russia's strategic nuclear deterrent capability in the face of ever-improving U.S. anti-ballistic missile systems.[44] Recent reporting by CNBC and *The Diplomat* quotes an unnamed U.S. source as saying that "It's expected they will make no more than 60 of these hypersonic weapons because it's just proving to be too expensive to develop."[45] Initial plans call for the deployment of Avangard on SS-19 rockets, of which Russia is reported to possess 30.[46]

U.S. PROGRAMS

America's development of hypersonic weapons has been defined and driven by the Prompt Global Strike (PGS) mission, which aims to guarantee that the United States has the ability to hit any target anywhere on earth in under an hour. In this context, U.S. military planners envision offensive hypersonic weapons as the way to defeat the kinds of advanced multi-layered air and missile defenses recently developed by China, Russia, and other adversaries, which undermine the previously held U.S. advantages of precision and stealth.[47] By adopting long-range, precise hypersonic technologies, the United States can continue to project power, ensuring that it "can attack high-value or transient targets at the beginning of or during a conflict"[48] despite the Anti Access/Area Denial (A2D2) capabilities of potential adversaries.[49] In contrast to China and Russia, both of which consider possible delivery of nuclear weapons as a goal of their hypersonic programs,[50] the United States is primarily seeking the new tactical advantages that would be brought to bear by conventionally-armed hypersonic weapons in regional theaters of conflict. These include allowing the U.S. military to expand its response options while remaining below the threshold of nuclear use. General John E. Hyten, Commander of U.S. Strategic Command, has confirmed that DoD is pursuing at least 16 different lines of effort in the development of American hypersonic capabilities.[51] The following are the most high-profile U.S. hypersonic programs. However, none of them are yet acquisition programs of record or as mature as those of Russia or China.[52]

1 ALTERNATE RE-ENTRY SYSTEM

Formerly known as the Advanced Hypersonic Weapon (AHW), the Army's Alternate Re-Entry System is a conically-shaped, precision-guided glide vehicle with a range of 3,730-4,970 mi.[53] Its first successful test took place in November 2011, followed by subsequent tests in August 2014[54] and October 2017.[55] At first, the AHW was envisioned as a backup to the Air Force's Hypersonic Technology Vehicle 2 (HTV-2) vehicle, which had a planned range of 10,560 mi. However, after the HTV-2 failed testing in April 2010 and August 2011,[56] AHW remained the lone front-runner for a U.S. hypersonic boost-glide vehicle.[57] Given the program's success to date, DoD has announced that all three services will use the Alternate Re-entry System as a common glide body, with fielding planned by the early 2020s.[58]

2 HYPERSONIC CONVENTIONAL STRIKE WEAPON (HCSW):

Pronounced "Hacksaw," the HCSW is a planned Air Force hypersonic missile being developed under rapid prototyping authorities. Unlike the "envelope-pushing" ARRW, HCSW will be an air-launched cruise missile that integrates already mature technologies in its design, which has prompted the Department of Defense to refer to HSCW as its "lower risk hypersonic option."[59]

3 CONVENTIONAL PROMPT STRIKE (CPS)

Owned by the Navy's Strategic Systems Programs office, this weapon would also be a boost-glide vehicle with an intermediate range, resembling the Alternate Re-entry System but providing a sea-based option for launch. Reportedly, the Navy is seeking to create a distinct launch profile and flight trajectory for CPS in order to prevent an adversary from misidentifying it as a nuclear launch.[60] The Navy is still determining whether this weapon would ultimately be launched from a submarine or a surface vessel,[61] although a first flight test in 2017 was conducted from an *Ohio*-class submarine. Another test is planned for 2020.[62]

4 HYPERSONIC AIR-BREATHING WEAPON CONCEPT (HAWC)

This program, a joint Air Force-Defense Advanced Research Project Agency (DARPA) initiative dating to 2014, encompasses a broad array of technologies that would enable air-launched, jet-propelled hypersonic cruise missiles.[63] Built on the successful X-51 Waverider Program,[64] the "air-breathing" concept refers to the fact that the vehicle's engine will get its oxygen from the air around it, funneling air inside the engine to achieve hypersonic-speed propulsion, instead of carrying separate oxygen tanks.[65] Known as "scramjet" (supersonic combustion ramjet) engines, this technology would enable the delivery vehicle to be lighter and faster than current options, and it would fly under its own power.[66]

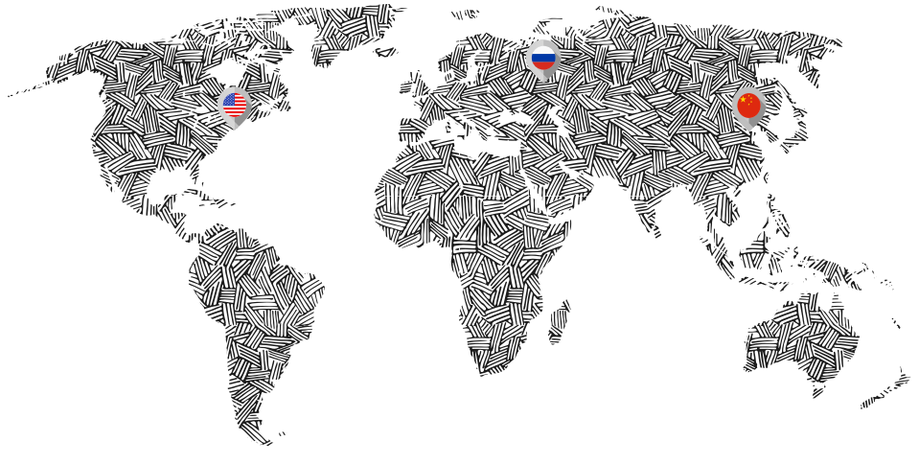
5 AIR-LAUNCHED RAPID-RESPONSE WEAPON (ARRW)

The AGM-183A ARRW ("Arrow") is the Air Force's planned air-launched hypersonic glider. This program calls for a more advanced design that will "push the envelope" on hypersonics;[67] reportedly, the missile would have a speed of Mach 20 during the glide phase—four times faster than similar Russian and Chinese hypersonic weapons.[68] The Air Force wants the flying prototype to be operational by 2021, and a first "captive carry" ARRW flight test was conducted in June 2019, with the missile carried by a B-52.[69]

6 TACTICAL BOOST GLIDE (TBG)

Initiated in 2014, this program represents a joint effort between the Air Force and DARPA to develop and improve the technologies necessary for future air-launched boost glide systems.[70] The program derives many of its foundational requirements from the early FALCON HTV-2 program,[71] including an ability to reach Mach 5, launch in under two hours, strike targets in under one hour, and maintain a maneuverable flight path after it detaches from the booster rocket.[72] The air-launched TBG vehicle would be distinct from other hypersonic programs because it is designed for tactical offensive use in theater rather than for the mission of global strike.[73]

HYPERSONIC WEAPONS COMPARISON



Weapon System	Type	Range	Payload
Xingkong-2 (Starry Sky-2)	HGV	Unknown	Nuclear or Conventional
DF-ZF (WU-14)	HGV	MR	Unknown
Dongfeng-26 (DF-26)	HGV	IR	Nuclear or Conventional
CM-401	HCM	Unknown	Unknown

Weapon System	Type	Range	Payload
Kinzhal (KH-47M2)	HGV	MR	Unknown
Tsirkon (Zircon)	HCM	SR	Nuclear or Conventional
Avanguard	HGV	IC	Nuclear

Weapon System	Type	Range	Payload
Alternate Re-Entry System	HGV	IC	Conventional
HCSW	HCM	Unknown	Conventional
CPS	HGV	IR	Conventional
HAWC	HCM	Unknown	Conventional
AARW	HGV	Unknown	Conventional
TBG	HGV	Unknown	Conventional

Range (mi.)	Weapon Range Classification	
< 620	SR	Short-Range
620 - 1860	MR	Medium-Range
1860 - 3420	IR	Intermediate-Range
> 3420	IC	Intercontinental-Range

"We don't have any defense that could deny the employment of such a weapon against us, so our response would be our deterrent force, which would be the triad and the nuclear capabilities that we have to respond to such a threat" [74]

- Gen. John Hyten, commander of U.S. Strategic Command

COUNTERING HYPERSONIC WEAPONS

1 THE DIFFICULTY OF TRACKING AND INTERCEPTION

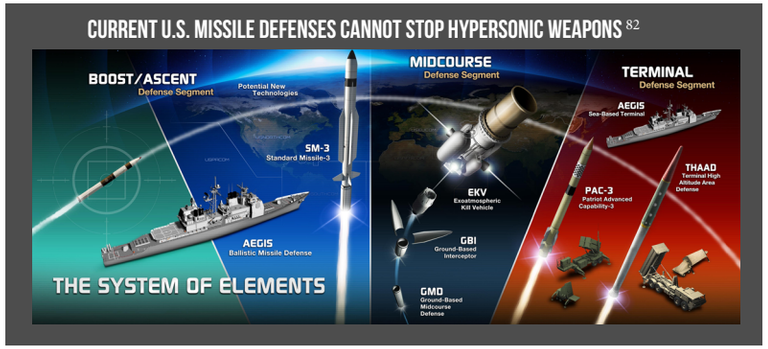
At present, U.S. countermeasures to the hypersonic threat are woefully inadequate. Despite ongoing R&D, major challenges persist with the tracking of, defending against, and executing successful command and control (C2) against such weapons. Even after detection, existing U.S. missile defense architecture is incapable of reliably defending against an incoming hypersonic missile. The current ground-based midcourse defense systems in Alaska and California are designed to target an incoming intercontinental ballistic missile during the stable and highly predictable mid-course phase of flight. Hypersonic vehicles avoid this regime, operating at much lower altitudes and along unpredictable flight paths. Terminal air and missile defense systems, such as the Army's Patriot and Terminal High-Altitude Air Defense (THAAD) and the Navy's Standard Missile-3 (SM-3) and Standard Missile-6 (SM-6) might have some limited capability against hypersonic weapons, but these would need to be deployed close to an intended target even to have a chance to intercept an incoming hypersonic weapon—and intercept is unlikely due to the hypersonic weapon's combination of high velocity and maneuverability. Finally, current Command, Control, and Communication and Intelligence (C3I) information systems for battle management are not technologically advanced enough to cope with the speed and unpredictable flight trajectories of hypersonic weapons.[75] Faster processing speeds and response times are needed if U.S. countermeasures are to be effective.

2 ESTABLISHING A SPACE-BASED SENSOR LAYER

A consensus exists that deploying a Space-based Sensor Layer (SSL) would be required to mitigate the tracking challenges posed by low-flying hypersonic missiles. The most recent Missile Defense Review conducted by the Office of the Secretary of Defense identified SSL as a top priority.[76] However, the most recent defense budget request's line for the SSL has been criticized as inadequate, while the decision to transfer the SSL's sensor development to the yet-to-be formed Space Development Agency "is an invitation to lack of focus, further delay, and requirements creep."[77]

3 DEVELOPING CAPABLE INTERCEPTORS

Space-based interceptors have been considered as an option to defeat hypersonic weapons, but Dr. Michael Griffin, Undersecretary of Defense for Research and Engineering, doesn't "see a space-based interceptor as a workable technical solution… [the space-based interceptor] concept is most useful against strategic missile boosters and post-boost vehicles."[78] It is also worth noting that the deployment of a space-based interceptors would be a major policy shift by deploying weapons in space[79] that would likely trigger negative international responses. DARPA is reportedly currently working an advanced and maneuverable hypersonic interceptor called Glide Breaker, which will undergo testing in 2020,[80] but few other details about the program are publicly available. Meanwhile, non-kinetic defenses, including electronic warfare and directed energy/laser targeting systems, are also being considered to mitigate the threat posed by hypersonic weapons. However, the technology for these systems remains immature and would not currently be efficient or effective enough to properly degrade an adversary's hypersonic weapons.[81]



HYPERSONIC WEAPONS FUNDING

DOD HYPERSONIC FUNDING INITIATIVES AND PRIORITIES

Overall, U.S. funding for hypersonic weapons has been on an upward trajectory for nearly two decades, with intermittent congressional speedbumps (primarily due to fears that adversaries might mistake a conventional hypersonic launch for a nuclear one, as well as the failures and consolidations of earlier programs.[83] Between FY 2011 and FY2017, the Pentagon spent approximately $1.5 billion in unclassified contract obligations on hypersonics.[84] By FY 2019, funding accelerated, with Congress increasing funding by an additional $150 million over the Administration's requested $263 million.[85] Last year, hypersonic R&D alone was funded at $257 million—a 136 percent increase from the previous year.[86] The increased flow of hypersonic-marked dollars has been a major boon for large contractors vying for the lucrative new contracts: Lockheed Martin won big in 2018 with a $928 million award for the HCSW and a separate $258 million for ARRW.[87]

HYPERSONIC WEAPONS DEFENSE FUNDING SHORTFALL

The latest DoD budget request continues this upward trend, notably prioritizing offensive hypersonic systems over defensive countermeasures. However, the absence of funds is a pressing problem; in the most recent defense budget request, the Missile Defense Agency (MDA), which has primary responsibility for developing countermeasures, only received $157 million to accomplish this mission—a mere 1/16 of the funding requested by the Pentagon for offensive hypersonic programs.[88] MDA had previously listed hypersonic defense work as one of its top unfunded priorities, to the tune of $720 million.[89] The lack of funding for defensive measures is stark when compared with the full $2.6 billion that was requested for offensive systems (a marked increase above the $1.9 billion that was allocated for FY2019).[90] Some efforts are underway to address these challenges. The 2020 defense budget request does plan for upgrades to the Command and Control, Battle Management, and Communication (C2BMC) network in order to better integrate the systems of different services to respond to and neutralize an incoming hypersonic threat. The Senate passed its version of the bill on June 27, 2019;[91] the House's version passed on July 12, 2019.[92]

CHALLENGES

While the United States continues to face a growing threat from ballistic missiles and weapons of mass destruction, the lack of a plan to contend with hypersonic weapons is truly problematic. After reaching full maturity, hypersonic missiles will be capable of delivering conventional or nuclear warheads anywhere on the globe with a flight time of less than an hour. Unlike more predictable ballistic trajectories, the exceptional maneuverability of these high-speed vehicles presents a major strategic challenge to which the U.S. does not currently have a solution.

RESPONDING TO RUSSIA'S RAPID DEVELOPMENT

The Russian Federation may have a strategic advantage over the United States and NATO in a regional conflict due to its major investments in hypersonic weapons technology. The Kremlin's development of hypersonic weapons systems – including the Kinzhal, Tsirkon (Zircon), and Avangard – has been going on for many, many years. President Vladimir Putin has said that Russia already has one operational hypersonic missile with a range of over 1,240-mi., and that a second with intercontinental range will be operational this year. Russian officials have been extremely vocal about their new hypersonic weaponry being capable of rapidly targeting and destroying the U.S. National Command Authority. This is because such systems have the ability to evade detection by U.S. early warning radars and interception by missile defense systems. Moreover, not only is Russia outperforming the United States in terms of developing hypersonic weapons, it may also be ahead in countering them—Russia claims that its new and soon to be operational S-500 missile/air defense system will itself be capable of intercepting hypersonic missiles.

COUNTERING CHINESE ADVANCEMENTS

The Chinese government believes it already has enough intercontinental ballistic missiles to effectively deter the United States. China's leadership assumes that if the country were to engage in a war with Taiwan or Japan, the United States would likely intervene, as outlined in the U.S. Treaty with Japan and the more ambiguous commitment of the Taiwan Relations Act. Fearing this potential intervention, China has developed hypersonic weapons (the Dong Feng 17 and Xingkong, or Starry Sky 2) capable of reaching U.S. naval bases. In the event of a future conflict, China's newly developed hypersonic missiles could potentially penetrate U.S. ballistic missile defenses and possibly target and destroy early warning radar, air, naval and logistical bases, and/or aircraft carriers. Chinese military doctrine supposes that the PLA will send a swarm of missiles at once, so U.S. defense planners will have to develop interceptor systems that are capable of multiple simultaneous intercepts in response. Similar to Russia, China is also taking defensive measures to guard against hypersonic weapons with the creation of an "Underground Great Wall" as a last line of defense.

PREVENTING PROLIFERATION

Russia and China may be incentivized to proliferate hypersonic weapons to regimes that are hostile to the United States, including Iran and North Korea, as they have with previous weapon systems.

RECOMMENDATIONS

PRIORITIZE FUNDING FOR HYPERSONIC WEAPONS AND DEFENSE

Investment in both hypersonic offensive and defensive systems is a top priority. As of last year, China had twice the hypersonic weapons infrastructure of the United States.[93] DoD's most recent budget request contained just $157 million for hypersonic missile defense,[94] leaving a number of MDA's priorities underfunded (among them the development and deployment of space sensors). Countering the hypersonic weapons threat will involve developing a globally distributed, continuously monitoring detection system that can track and cue interceptors to destroy adversary threats. Additionally, a new swift processing command and control architecture, along with new kinetic and non-kinetic interceptors, will also need to be developed.

SPACE BASED SENSOR LAYER

As outlined in the 2019 Missile Defense Review, "Space-based sensors… enjoy a measure of flexibility of movement that is unimpeded by the constraints that geographic limitations impose on terrestrial sensors, and can provide 'birth to death' tracking that is extremely advantageous."[95] Congress has rightly commissioned the DoD to create a space sensor layer to help track the hypersonic weapons at launch and as they transit the upper atmosphere to overcome ground-based radar limitations.[96] However, it will be important to ensure bureaucratic battles between the newly minted Space Development Agency and Missile Defense Agency do not stall progress.

LEVERAGE THE PRIVATE SECTOR

The cost to launch a satellite has decreased over time. However, it remains expensive to launch a massive constellation dispersed around the globe. DoD should consider partnering with U.S. companies in the commercial telecommunications industry that already plan to distribute thousands of satellites capable of transferring high-speed data.[97] Secure and fast data transfer is necessary "to share with all nodes and components everything that is known and learned about the weapon, from detection to destruction."[98] By leasing the secure laser communication technology platforms onboard these new constellations, DoD will save the significant cost of deploying its own.

DIRECTED ENERGY DEFENSE

Kinetic interception of hypersonic weapons will be exceedingly difficult, so it is imperative that alternate and supplementary non-kinetic systems are developed. Although most are still in their developmental phases, directed energy weapons (including particle beam weapons, lasers, and high-powered microwave weapons) should be considered for deployment to counter hypersonic weapons on air, land, and sea systems.[99] They can be used to target a hypersonic weapon's guidance system and onboard electronics.

REFERENCES

1. Dr. Richard P. Hallion, Maj. Gen Curtis M. Bedke, and Marc V. Schanz, Hypersonic Weapons and US National Security, Mitchell Institute for Aerospace Studies, p. 13, http://docs.wixstatic.com/ugd/a2dd91_b7016a5428ff42c8a21898ab9d0ec349.pdf
2. Freedberg, Sydney J., Jr. "DoD Boosts Hypersonics 136 % In 2019: DARPA." *Breaking Defense*, March 1, 2018. Accessed April 30, 2019. https://breakingdefense.com/2018/03/dod-boosts-hypersonics-136-in-2019-darpa/.
3. Speier, Richard H., George Nacouzi, Carrie Lee, and Richard M. Moore. "Hypersonic Missile Nonproliferation: Hindering the Spread of a New Type of Weapon." *Rand Corporation*, 2017, 8. Accessed April 29, 2019. https://www.rand.org/pubs/research_reports/RR2137.html.
4. Ibid.
5. Ibid., 10.
6. Richard M. Harrison, "Welcome to the Hypersonic Arms Race." *The National Interest*, January 19, 2019, https://nationalinterest.org/blog/buzz/welcome-hypersonic-arms-race-42002.
7. Bruce Dorminey, "Hypersonic Scramjets Still Key To Future Of Aerospace." *Forbes*, August 22, 2014, https://www.forbes.com/sites/brucedorminey/2014/08/22/hypersonic-scramjets-still-key-to-future-of-aerospace/#50b6fc8814ac.
8. Speier et al., *Hypersonic Missile Nonproliferation: Hindering the Spread of a New Type of Weapon*, 12.
9. Graphic adapted from an image in "Gliding missiles that fly faster than Mach 5 are coming," *The Economist*, April 6, 2019, https://www.economist.com/science-and-technology/2019/04/06/gliding-missiles-that-fly-faster-than-mach-5-are-coming
10. Harrison, "Welcome to the Hypersonic Arms Race."
11. Speier et al., *Hypersonic Missile Nonproliferation: Hindering the Spread of a New Type of Weapon*, 8.
12. Remarks by Dean Wilkening at "Hypersonic Missiles: Assessing the Benefits and Risks," Carnegie Endowment for International Peace, Washington, DC, June 9, 2019, https://carnegieendowment.org/2019/07/09/hypersonic-missiles-assessing-benefits-and-risks-event-7151
13. Sydney J. Freedburg, "Space-Based Missile Defense Can Be Done: DoD R&D Chief Griffin," *Breaking Defense*, August 8, 2018, https://breakingdefense.com/2018/08/space-based-missile-defense-is-doable-dod-rd-chief-griffin/.
14. Mary Kate Aylward, "Hypersonics: Revolutionary or just new?" *Army AL&T Magazine*, October-December 2018, https://www.army.mil/article/209949/hypersonic_weapons_revolutionary_or_just_new.
15. Amy Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues." *Congressional Research Service*, January 8, 2019, 47, https://fas.org/sgp/crs/nuke/R41464.pdf.
16. Adam Muspratt, "Hypersonic missiles: What are they and can they be stopped?" *DefenseIQ*, August 28, 2018, https://www.defenceiq.com/defence-technology/news/hypersonic-missiles-what-are-they-and-can-they-be-stopped
17. Kyle Mizokami, "China Conducts New Hypersonic Weapon Test," *Popular Mechanics*, August 7, 2018, https://www.popularmechanics.com/military/weapons/a22665761/china-conducts-new-hypersonic-weapon-test/
18. Speier et al., *Hypersonic Missile Nonproliferation: Hindering the Spread of a New Type of Weapon*, xi-8.
19. U.S. Government Accountability Office, "Report to Congress: NATIONAL SECURITY: Long-Range Emerging Threats Facing the United States As Identified by Federal Agencies," December 2018, 4, https://www.gao.gov/assets/700/695981.pdf
20. Text adapted from Larry Wortzel, "Hypersonic Weapons in China's Military Strategies," American Foreign Policy Council *Defense Technology Program Brief* no. 18, May 2019, https://www.afpc.org/uploads/documents/Defense_Technology_Briefing_-_Issue_18.pdf
21. Lee Jun, "Hypersonic Weapons Allow War to Enter the 'Countdown' Era (高超声速武器让战争进入“读秒”时代)," *People's Liberation Army Daily*, May 5, 2017, 11 (hereafter cited as PLA Daily).
22. Larry M. Wortzel, *The Dragon Extends its Reach: China's Military Power Goes Global* (Washington, DC: Potomac Books, 2013), 155-156.
23. Wortzel, *The Dragon Extends its Reach*, 156.
24. Barton Gellman, "U.S. and China Nearly Came to Blows in '96," *Washington Post*, June 21, 1998, https://www.washingtonpost.com/archive/politics/1998/06/21/us-and-china-nearly-came-to-blows-in-96/926d105f-1fd8-404c-9995-90984f86a613/?utm_term=.74c7d9f39a2f; Robert S. Ross, "The 1995-96 Taiwan Strait Confrontation: Coercion, Credibility, and the Use of Force." *International Security* 25, no. 2 (2000), 87-123, http://www.jstor.org/stable/2626754.
25. Bill Gertz, "China Reveals Test of New Hypersonic Missile: Starry Sky-2' wave rider designed to carry nuclear warheads through missile defenses," *Washington Free Beacon*, August 10, 2018, https://freebeacon.com/national-security/chinas-reveals-test-new-hypersonic-missile/
26. Ibid.; See also Joseph Trevithick, "China Shows Off Hypersonic Glide Vehicle Test Model after US Navy Weapons Test," *The War Zone*, November 7, 2017, https://www.thedrive.com/the-war-zone/15828/china-shows-off-hypersonic-vehicle-test-model-after-us-navy-weapon-test.
27. 环球网东风26已配备多锥体高超音速滑翔弹头 http://mil.huanqiu.com/world/2019-01/14197658.html?agt=15422
28. 环球网东风26已配备多锥体高超音速滑翔弹头 http://mil.huanqiu.com/world/2019-01/14197658.html?agt=15422
29. Ajai Shukla, "China's New 'Aircraft Carrier Killer" Missile Could Add Teeth to Pakistan Navy," personal blog, December 2018, http://ajaishukla.blogspot.com/2018/12/chinas-new-aircraft-carrier-killer.html
30. "Gliding Missiles that Fly Faster than Mach 5 are Coming: They combine the speed of intercontinental ballistic missiles with the accuracy of cruise missiles," *The Economist*, April 6, 2019, https://www.economist.com/science-and-technology/2019/04/06/gliding-missiles-that-fly-faster-than-mach-5-are-coming
31. Ibid.
32. International Institute of Strategic Studies, *The Military Balance 2019* (London: Routledge 2019), 235, 256-257.
33. Text adapted from Mark Schneidner, "Moscow's Development of Hypersonic Missiles and What it Means," American Foreign Policy Council *Defense Technology Program Brief* no. 18, May 2019, https://www.afpc.org/uploads/documents/Defense_Technology_Briefing_-_Issue_18.pdf
34. Office of the President of Russia, "Presidential Address to Federal Assembly," February 20, 2019, http://en.kremlin.ru/events/president/news/59863.
35. "Russia's hypersonic missiles may reach US command centers in 5 minutes, says expert," TASS, February 21, 2019, http://tass.com/defense/1045757; "Putin's US nuclear hit list revealed: Russian state TV names American locations the Kremlin would target with 'unstoppable' hypersonic nukes which can strike in just five minutes," Reuters, February 25, 2019, https://www.dailymail.co.uk/news/article-6742481/After-Putins-warning-Russian-TV-lists-nuclear-targets-US.html.
36. "Vectors of Development of Military Strategy," *Krasnaya Zvezda* (Moscow), March 4, 2019, http://redstar.ru/vektory-razvitiya-voennoj-strategii/ws/4-03-2019vektory-razvitijavoennoj-strategii. (In Russian. Translation by Dr. Veronika Kyrylenko).
37. "Russian commander comment on Putin's weapons announcement," BBC Monitoring of the Former Soviet Union, May 5, 2018, https://dialog.proquest.com/professional/docview/2010308306?accountid=155509.
38. Dave Majumdar, "Russia Places 10 Deadly MiG-31s on 'Experimental Combat Duty' to Carry 'Hypersonic' Missile," *The National Interest*, May 10, 2018, https://nationalinterest.org/blog/the-buzz/russia-places-10-deadly-mig-31s-experimental-combat-duty-25765.
39. Ibid.
40. Mark B. Schneider, "The Renewed Backfire Bomber Threat to the U.S. Navy," *Proceedings* 145, iss. 1, January 2019, 391, https://www.usni.org/magazines/proceedings/2019-01/renewed-backfire-bomber-threat-us-navy.
41. Jeremy Chin, "Russia Confirms Development of Tsirkon Hypersonic Cruise Missile," *Missile Threat*, Center for Strategic and International Studies, February 22, 2019, last modified April 8, 2019, https://missilethreat.csis.org/russia-confirms-development-of-tsirkon-hypersonic-cruise-missile/.
42. Katarzyna Zysk, "Nonstrategic nuclear weapons in Russia's evolving military doctrine," *Bulletin of the Atomic Scientists*, August 22, 2017, https://www.tandfonline.com/doi/full/10.1080/00963402.2017.1362908.
43. "Russia's hypersonic missiles may reach US command centers in 5 minutes, says expert," TASS, February 21, 2019, http://tass.com/defense/1045757; U.S. Defense Intelligence Agency, *Russia Military Power: Building a Military to Support Great Power Aspirations* (Washington, DC; Defense Intelligence Agency, 2017), 79.
44. Franz-Stefan Gady, "Report: Russia to Produce 60 Avangard Hypersonic Boost-Glide Warheads." *The Diplomat*, July 04, 2019, https://thediplomat.com/2019/07/report-russia-to-produce-60-avangard-hypersonic-boost-glide-warheads/
45. Amanda Macias, "Russia will only make a few units of a hypersonic weapon Putin bragged about, US intelligence says." *CNBC News*, July 1, 2019, https://www.cnbc.com/2019/07/01/russia-will-make-few-units-of-hypersonic-weapon-putin-bragged-about.html; Gady, "Report: Russia to Produce 60 Avangard Hypersonic Boost-Glide Warheads."
46. Gady, "Report: Russia to Produce 60 Avangard Hypersonic Boost-Glide Warheads."
47. Sydney J. Freedburg, "Army Warhead is Key to Joint Hypersonics." *Breaking Defense*. August 22, 2018, https://breakingdefense.com/2018/08/army-warhead-is-key-to-joint-hypersonics/.
48. "Advanced Hypersonic Weapon," *Army Technology*, n.d., https://www.army-technology.com/projects/advanced-hypersonic-weapon-ahw/.
49. Benjamin Knudsen, "An Examination of U.S. Hypersonic Weapon Systems," technical report, June 2017, https://www.researchgate.net/publication/317388988_An_Examination_of_US_Hypersonic_Weapon_Systems
50. James M. Acton, "Hypersonic Boost-Glide Weapons." *Science and Global Security* no. 23, 2015, 192, http://scienceandglobalsecurity.org/archive/sgs23acton.pdf.
51. John E. Hyten, Statement before the U.S. Senate Committee on Armed Services, March 20, 2018, https://www.armed-services.senate.gov/imo/media/doc/Hyten_03-20-18.pdf
52. Sydney J. Freedburg, Jr., "Hypersonics Won't Repeat Mistakes of F-35," *Breaking Defense*, March 13, 2019, https://breakingdefense.com/2019/03/hypersonics-wont-repeat-mistakes-of-f-35/
53. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
54. Acton, "Hypersonic Boost-Glide Weapons.".
55. Sydney J. Freedburg, Jr., "Army Warhead is Key to Joint Hypersonics." *Breaking Defense*, August 22, 2018, https://breakingdefense.com/2018/08/army-warhead-is-key-to-joint-hypersonics/.
56. Acton, "Hypersonic Boost-Glide Weapons."
57. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
58. Ibid.
59. Vivienne Machi, "Air Force Two Years Away from Initial Hypersonics Capability, Official Says." *Defense Daily*, February 8, 2019, https://www.defensedaily.com/air-force-two-years-away-initial-hypersonics-capability-official-says/air-force/.
60. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
61. Meghan Eckstein, "Navy Developing Prompt Global Strike Weapon that Could Launch from Sub or Surface Ship," *USNI News*, November 21, 2018, https://news.usni.org/2018/11/21/navy-developing-prompt-global-strike-weapon-launch-sub-surface-ship.

62. Freedburg, "Hypersonics Won't Repeat Mistakes of F-35."
63. Andrew Knoedler, "Hypersonic Air-breathing Weapon Concept." Defense Advanced Research Projects Agency, n.d., https://www.darpa.mil/program/hypersonic-air-breathing-weapon-concept.
64. Knudsen, "An Examination of U.S. Hypersonic Weapon Systems."
65. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
66. Sydney J. Freedburg, Jr., "DoD Boosts Hypersonics 136% in 2019: DARPA," *Breaking Defense*, March 1, 2018, https://breakingdefense.com/2018/03/dod-boosts-hypersonics-136-in-2019-darpa/.
67. Machi, "Air Force Two Years Away from Initial Hypersonics Capability, Official Says."
68. Kyle Mizokami, "The First U.S. Hypersonic Weapons: Arrow and Hacksaw," *Popular Mechanics*, August 21, 2018, https://www.popularmechanics.com/military/weapons/a22791042/the-first-us-hypersonic-weapons-arrow-and-hacksaw/
69. Hemanth Kumar and Talal Husseini, "USAF performs first flight test of ARRW hypersonic weapon," *Air Force Technology*, June 20, 2019, https://www.airforce-technology.com/news/usaf-arrw-hypersonic-weapon/.
70. Peter Erbland, "Tactical Boost Glide." Defense Advanced Research Projects Agency, n.d., https://www.darpa.mil/program/tactical-boost-glide.
71. Ibid.
72. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
73. Knudsen, "An Examination of U.S. Hypersonic Weapon Systems."
74. Rebecca Kheel, "Russia, China eclipse US in hypersonic missiles, prompting fears," *The Hill*, March 27, 2018, https://thehill.com/policy/defense/380364-china-russia-eclipse-us-in-hypersonic-missiles-prompting-fears
75. John L. Dolan, Richard K. Gallagher, and David L. Mann, "Hypersonic Weapons Are Literally Unstoppable (As In America Can't Stop Them)." *The National Interest*, May 15, 2019, https://nationalinterest.org/blog/buzz/hypersonic-weapons-are-literally-unstoppable-america-cant-stop-them-57642.
76. Thomas Karako and Wes Rumbaugh, "Masterpiece Theater: Missed Opportunities for Missile Defense in the 2020 Budget," Center for Strategic and International Studies, March 2019, 2, https://csis-prod.s3.amazonaws.com/s3fs-public/publication/190329_Missile_Defense_2020.pdf
77. Ibid.
78. Michael Griffin, remarks at "Reenergizing the Missile Defense Enterprise," Center for Strategic & International Studies, Washington, DC, December 11, 2018. https://www.csis.org/analysis/reenergizing-missile-defense-enterprise
79. Freedburg, "Space-Based Missile Defense Can Be Done: DoD R&D Chief Griffin."
80. Michael Peck, "Meet DARPA's 'Glide Breaker': A Hypersonic Missile Killer?" *The National Interest*, January 20, 2019, https://nationalinterest.org/blog/buzz/meet-darpas-glide-breaker-hypersonic-missile-killer-42117.
81. Speier et al., *Hypersonic Missile Nonproliferation: Hindering the Spread of a New Type of Weapon*.14.
82. Department of Defense Graphic. Available at https://dod.defense.gov/Photos/Photo-Gallery/igphoto/2001515296/
83. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
84. "Space Platforms and Hypersonic Technologies Taxonomy," Govini, June 2019, 19, https://www.govini.com/wp-content/uploads/2019/06/Govini_Space_Hypersonic_Taxonomy.pdf.
85. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
86. Freedberg, "DoD Boosts Hypersonics 136 % In 2019: DARPA,"
87. Aaron Mehta, "Air Force Awards Nearly $1 billion Contract for a Hypersonic Cruise Missile," *Defense News*, April 18, 2018.
88. Freedburg, "Hypersonics Won't Repeat Mistakes of F-35."
89. Karako and Rumbaugh, "Masterpiece Theater: Missed Opportunities for Missile Defense in the 2020 Budget."
90. Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues."
91. *National Defense Authorization Act for Fiscal Year 2020*, S. 1790, 116th Congress (2019-2020), https://www.congress.gov/bill/116th-congress/senate-bill/1790
92. *National Defense Authorization Act for Fiscal Year 2020*, H.R. 2500, 116th Congress (2019-2020), https://www.congress.gov/bill/116th-congress/house-bill/2500
93. Freeberg, "DoD Boosts Hypersonics 136% in 2019: DARPA."
94. U.S. Department of Defense, "Department of Defense Press Briefing on the President's Fiscal Year 2020 Defense Budget for the Missile Defense Agency," March 12, 2019, https://dod.defense.gov/News/Transcripts/Transcript-View/Article/1784150/department-of-defense-press-briefing-on-the-presidents-fiscal-year-2020-defense/.
95. Office of the Secretary of Defense, *2019 Missile Defense Review*, January 2019, 36, https://media.defense.gov/2019/Jan/17/2002080666/-1/-1/1/2019-MISSILE-DEFENSE-REVIEW.PDF
96. James M. Acton, "Hypersonics Weapons Explainer," Carnegie Endowment for International Peace, April 2, 2018, https://carnegieendowment.org/2018/04/02/hypersonic-weapons-explainer-pub-75957.; Michael Griffin, remarks at "Reenergizing the Missile Defense Enterprise," Center for Strategic & International Studies, Washington, DC, December 11, 2018: https://www.csis.org/events/reenergizing-missile-defense-enterprise-0.
97. Howard Thompson, "The Advent of Hypersonic Weapons: Implications and Challenges for Congress, the Defense Department, and Industry," American Foreign Policy Council *Defense Dossier* iss. 24, June 2019, 23, https://www.afpc.org/publications/e-journals/planning-for-great-power-conflict
98. Ibid., 23.
99. Ibid.

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