The Interagency Challenges of Hypersonic Strike Weapons

by Richard C. Robbins

Years in the future, when historians reflect upon the early twenty-first century reemergence of great power competition, they will likely speak of hypersonic weapons as the novel technology that most transformed the nature of warfare and deterrence. Among the new technologies that are transforming warfare, including cyber warfare, engineered biological agents, laser weaponry, and robotics, hypersonic strike weapons (HSW) are the most coveted of emerging offensive capabilities and chief among challenges to U.S. strategic interests. While HSW technology development and prototype demonstrations have been ongoing for the better part of a decade, historians may remember 2018 as the year that great power ambitions to acquire and field HSW capabilities came into full public view. This article first describes the characteristics and features that distinguish HSW from modern, precision-guided strike weapons and then outlines the associated benefits, issues, and risks that HSW present to the U.S. and its allies. Summarizing the recent history and current status of U.S., Chinese, and Russian HSW programs, it then explores the strategic implications of this technology to missile defenses, projection of conventional military power, regional deterrence, future proliferation security, and the stability of nuclear deterrence. Throughout, this article contends that the introduction of HSW within an emerging world order that requires the U.S. to hold in check the revisionist ambitions of both China and Russia requires thoughtful planning, adjustments, and coordination across the interagency to preserve a coherent, national security strategy.

Until recently, analysts compared the emergence of HSW to that of stealth technology and precision-guided strike weaponry in the 1980s. While the contemporary maxim "speed is the new stealth"[1] remains appropriate in certain respects, analysts are now recognizing that the confluence of technologies that comprise HSW will yield capabilities holding far more significance. Indeed, HSW designs have abandoned many twentieth century approaches to airborne stealth[2] in

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exchange for tactical and strategic advantages afforded by operational deception, surprise, and higher probability of kill, benefits not entirely attributable to speed. Most distinctively, unlike the advances in stealth and precision in the 1980s, the performance thresholds crossed by emerging HSW in areas that include speed, maneuverability, and scalable effects have potential to destabilize the deterrence structures that have constrained great power behaviors for over seventy years.

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Employed as conventional weapons, precision-guided HSW can deliver destructive effects with smaller warheads, against hardened targets, and with reduced collateral damage. With foreseeable improvements in targeting precision, future HSW may replace explosive warheads and proximity fusing[3] with warheads that use only the energy imparted by hypersonic impact for destructive effect.[4] This more precise use of power with less potential for collateral damage will likely be attractive to states that may then substitute traditional conventional weapons for HSW, lowering the threshold at which states deem use of HSW acceptable. This would, in turn, force states threatened by HSW to a lower their thresholds for exercising pre-emptive options. This influence would be particularly acute in the near term, as states are forced to reevaluate and adjust their underlying doctrines for conventional and nuclear deterrence.

For those states that succeed in acquiring them, HSW will become the weapon-of-choice for high-priority, conventional, precision-guided strike missions against hardened, ephemeral, or otherwise well-defended targets. With Russia's unveiling of its HSW, the Avangard hypersonic glide vehicle,[5] HSW have already been employed as a tool of strategic influence, blurring lines that previously differentiated conventional deterrence from nuclear deterrence. In future multi-domain operations—from measures short of war to high-order conventional and nuclear conflict—the emergence of HSW will require changes—if not radical transformation—across the Services and Combatant Commands in areas of doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy.

The urgency facing the U.S. with respect to HSW is a result of the determination that China and Russia continue to demonstrate in pursuit of their own HSW systems. Over the past ten years, the rise of China's economic and military power and the resurrection of Russia's nationalist ambitions and military capabilities have created an unfamiliar multi-polar international system to which the U.S. is only beginning to adapt, having been distracted by its military commitments in the Middle East for nearly two decades. The emergence of HSW in the context of this new political reality will alter conventional and nuclear deterrence in ways that defense analysts have not yet adequately considered—at least not in open-source literature. The U.S. must consider its response to this challenge with all available instruments of national power in mind. Plans to leverage the capabilities and mitigate the threats presented by HSW should not be relegated to the Department of Defense alone. Rather, the implications of HSW to conventional and nuclear deterrence should be assessed across the interagency, in a cooperative approach to build a coherent national security strategy.

General Characteristics of Emerging Hypersonic Strike Weapons

The broad definition of "hypersonic" describes objects capable of traveling at airspeeds equal to or exceeding Mach 5 (approximately 3,836 mph at sea level). Though speed remains the primary distinguishing feature of emerging HSW, they are further distinguished from earlier maneuvering reentry vehicle (MaRV) systems by three additional features, enhanced maneuverability, unique lethality mechanisms, and advanced thermal management technologies enabling prolonged hypersonic flight. Rapid precision-controlled maneuvering within the hypersonic regime can significantly improve survivability, effectiveness, and mission flexibility of HSW over previous precision-guided strike weapons, particularly if data from onboard or off board sensors are used avoid countermeasures. Unlike ballistic weapons, HSW can conceal their intended targets by maneuvering along an offset or circuitous flight path. HSW also enable unique lethality mechanisms for conventional destructive effects that can be tailored to specific strike missions. Finally, HSW will be capable of surviving the extreme heat loads created by sustained atmospheric friction within the hypersonic regime. Thermal management remains a significant challenge for sustained atmospheric flight above Mach 10 and presents a difficult challenge for the design of reusable hypersonic platforms.[6]

The Benefits and Risks of HSW to U.S. National Security

The competition between the U.S., China, and Russia to develop, acquire, and deploy HSW is understandable given the advantages these weapons confer, which are numerous and significant. The advantages described below will confer obvious benefits to these three countries in on-going conflicts in the Indo-Pacific, Middle East, and Eastern Europe regions.

First, HSW provide the ability to project power against targets protected by increasingly sophisticated anti-access/area denial systems and doctrines, enabling decapitating surprise attacks against opposition command and control nodes and air defenses.

Second, with the use of high-confidence intelligence, HSW can be used in precision strikes against ephemeral, high-priority targets, including short meetings between terrorist leaders and transfers of weapons of mass destruction or weapons of mass destruction materials that cannot be seized or neutralized by other means.

Third, not only can HSW be used to defeat anti-access/area denial systems, they can also enable and enforce anti-access/area denial. Introduced in 2012, China's DF-21D Anti-Ship Ballistic Missile,[7] a weapon far less capable than HSW, has already demonstrated the powerful influence that HSW will have on U.S. warships operating in disputed territorial waters.

Fourth, when deployed in sufficient numbers, conventionally-armed HSW could be used to eliminate all fixed-site or otherwise geo-locatable nuclear missiles in a pre-emptive first-strike. Liquid-fueled, intercontinental ballistic missiles could be targeted and destroyed by HSW in less time than is required to prepare the intercontinental ballistic missiles for launch.

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Finally, HSW are likely to become powerful tools for deterrence, both in conventional and nuclear roles, as they threaten a credible, proportionate, and debilitating response to acts of aggression.

The U.S. drive to acquire these advantages from HSW began in earnest shortly after the events of September 11, 2001. Russia, which held the lead in many areas of hyper-sonics research before the fall of the Soviet Union, resurrected its hypersonic weapons program in 2009, developing what may become the first operationally-deployed HSW. China has made extensive investments in hyper-sonics research and infrastructure over the past decade and has successfully demonstrated its own prototype HSW marked for deployment in 2020. The U.S., which has successfully demonstrated several HSW prototypes, has recently accelerated its HSW development to acquire fieldable prototype HSW systems by the early to mid-2020s.

In addition to the disadvantage from possibly being third in line to operationally deploy HSW, the U.S. is facing even graver long-term challenges. First, both China and Russia are likely to continue to develop and field HSW in numbers that will deny the U.S. its current advantage in global power projection.

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Second, China and Russia will use HSW to further enhance regional and global influence and to enforce claims of sovereignty over disputed territories.

Third, the U.S. Ground-Based Midcourse Defense and AEGIS Ballistic Missile Defense systems, designed to engage ballistic missiles outside the atmosphere, are largely irrelevant when up against HSW, which have flight profiles predominantly within the atmosphere (below 100K feet).[8] While the U.S. Ground-Based Midcourse Defense and AEGIS Ballistic Missile Defense systems are not scaled to protect the U.S. from a full-scale, preemptive, ballistic missile attack from China (much less Russia), their ability to preserve U.S. second-strike capability will be diminished.

Fourth, Russian and Chinese investments in road- and rail-mobile launchers will gain significant advantage over U.S. fixed ICBM silos, which are more vulnerable to preemptive attack. Forward-basing of nuclear-capable bombers, a measure used to signal resolve during heightened nuclear tensions, will only place those assets at similar risk of preemptive attack by HSW.

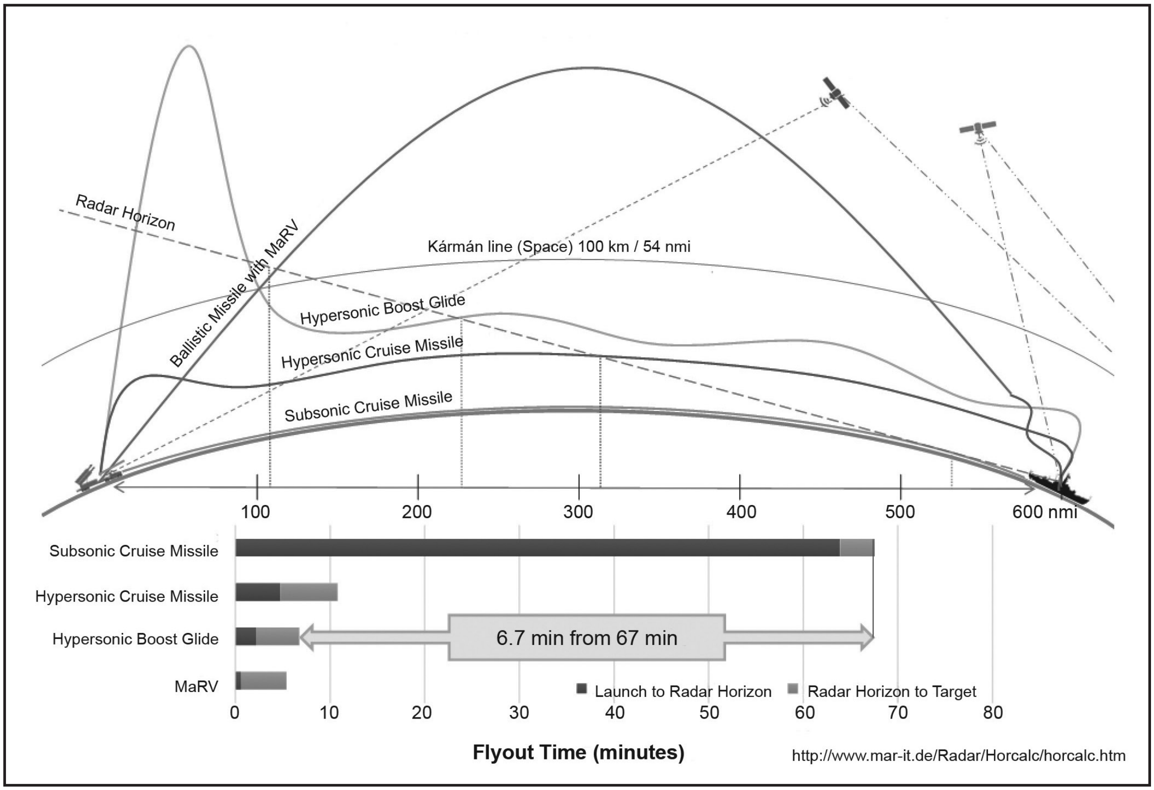
Fifth, HSW defenses ("counter-hypersonics") are seriously lagging behind HSW development and may never provide a level of protection similar to ballistic missile defenses. Current space-based sensors and ground-based missile radars cannot detect and track HSW in the manner necessary to support mid-course intercepts, and the U.S. has no missile capable of such intercepts in any stage of development. Counter-hypersonic systems capable of terminal phase intercepts present even greater technical challenges.

Finally, HSW will present a significant threat for proliferation among smaller nations, including Iran and North Korea. Much of the basic research on hyper-sonics-related technologies is open-source, and while the entry barriers to more advanced hypersonic technology development remain high, over a dozen other states besides the U.S., Russia, and China have active HSW programs.[9]

In future confrontations between the U.S. and China and/or Russia and with smaller states, these challenges will limit U.S. options, complicate crisis management, and raise the risk of inadvertent, rapid, and uncontrollable escalation in nuclear brinkmanship scenarios.

Comparison of Hypersonic Strike Weapons

Understanding the benefits, issues, and risks of HSW and how they may evolve requires a fundamental understanding of the features and capabilities of the current HSW lines of development. The full potential of HSW will not be realized with the first operational systems or in only one line of development. Separate approaches to HSW design will introduce different offensive capabilities for different missions. These separate lines of development



http://www.mar-it.de/Radar/Horcalc/horcalc.htm

Figure 1: Comparison of Hypersonic Strike Weapon Flight Profiles/Fly-out Times

will also complicate the development of counter-offensive capabilities, as the approach required to counter one system may be very different from the approach required to counter another.

Emerging HSW systems are divided into two primary categories—hypersonic boost-glide weapons and air-breathing hypersonic cruise missiles. MaRVs, deployed for over 40 years, are hypersonic (traveling at a rate of over five times the speed of sound) for smaller portions of their flight profile, but current convention applies the term “hypersonic” only to systems that remain endoatmospheric (within the atmosphere/below 100k feet) and aerodynamically maneuverable for greater than 50 percent of their flight profile. Long-range ballistic missiles typically spend most of their flight profile outside of the atmosphere where aerodynamic maneuvering is impossible. Russia’s air-launched Kh-47M2 Kinzhal “hypersonic” missile and other depressed trajectory ballistic missiles stretch this definition by offering very limited aerodynamic maneuverability.

Hypersonic Boost-Glide Weapons Programs: The United States vs. China and Russia

Hypersonic boost-glide weapons use rocket propulsion to achieve a boost-phase ballistic trajectory that is much steeper than typical ballistic missile trajectories, achieving an apogee well above the Kármán line (100k feet above sea level). During the hypersonic boost-glide weapon’s decent from apogee, it accelerates back into the Earth’s atmosphere, where it uses aerodynamic lift to level-out and ascend to a hypersonic glide profile below the Kármán line. From there, the hypersonic boost-glide weapon skips across the upper atmosphere en route to its target. By remaining aerodynamically maneuverable over most of their flight profiles, hypersonic boost-glide weapons can fly circuitous routes to their targets, perhaps to avoid a neutral country's airspace, to avoid a known threat, or to remain ambiguous concerning its intended target.

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The U.S. Air Force has funded two hypersonic boost-glide weapon prototype development efforts in the Department of Defense Fiscal Year 2019 budget—the Hypersonic Conventional Strike Weapon and the AGM-183 Air-Launched Rapid Response Weapon. According to an Air Force press release, the Hypersonic Conventional Strike Weapon and Air-Launched Rapid Response Weapon will each provide "unique capabilities for the warfighter, and each has different technical approaches."[10] The Air Force has thus far not offered details differentiating these two technical approaches but intends to advance one or both prototypes to operational capability in 2021. This pace of development is only made possible by rapid prototyping provisions in Section 804 of the FY16 National Defense Authorization Act[11] and similar provisions in the FY17 and FY18 National Defense Authorization Acts.[12]

Both China and Russia have hypersonic boost-glide weapon programs that match or exceed the U.S. in progress in certain technology areas. China's primary developmental hypersonic boost-glide weapon program, the DF-17, is anticipated to deliver a weapon that will eclipse the performance of its DF-21D to become the most significant anti-access/area denial threat to U.S. forward-deployed forces in the Indo-Pacific Theater. Flight tests, which have been ongoing since 2014, suggest that the DF-17 could match or exceed the technical maturity of U.S. hypersonic boost-glide weapon prototypes demonstrated to date. China has tested the DF-17 prototype from a variety of solid and liquid-fueled medium and intermediate-range missiles, suggesting that it may be used in both conventional and nuclear deterrence.[13]

Russia also continues to make active progress toward operationalization. In his annual state of the nation speech on March 1, 2018, Vladimir Putin unveiled the Russian Avangard hypersonic boost-glide weapon, along with a video animation depicting an Avangard-delivered nuclear strike against the U.S. Tested with apparent success on December 26, 2018, Russia claims that the Avangard will be operational in 2019. In an article published in the March 2018 edition of *The National Interest*, defense reporter Dave Majumdar cites a Russian source claiming that the Avangard will carry "a single massive thermonuclear warhead with a yield exceeding two megatons [to provide] an assured retaliatory second-strike capability designed to bypass missile defenses."[14] Interestingly, unlike China and the U.S., Russia has made strategic nuclear deterrence its initial priority for HSW employment. Both Russia and China justify their pursuit of HSW as necessary to restore the strategic balance upset by the increasingly capable U.S. ballistic missile defenses. The U.S., however, maintains that its Ground-Based Midcourse Defense and AEGIS Ballistic Missile Defense systems will be deployed only in numbers necessary to protect the itself and its allies against ballistic missile threats from Iran and North Korea.[15]

Hypersonic Cruise Missile Programs: The United States vs. China and Russia

Hypersonic cruise missiles use a rocket booster to initially accelerate to near-hypersonic speeds where supersonic combustion ramjets (scramjets), which can operate only in the hypersonic regime, then provide thrust for the balance of its flight profile. A scramjet engine uses atmospheric oxygen for combustion, achieving greater "thrust-to-weight" than a rocket that must carry both fuel and oxidizer. This continuous thrust at greater thrust-to-weight ratios provides the hypersonic cruise missile with greater mid-course maneuverability and potentially greater survivability against future counter-hypersonic defenses. Additionally, a hypersonic cruise missile with comparable range to a hypersonic boost-glide weapon could be sized smaller or carry a larger payload.

The intense heat created by atmospheric friction at lower altitudes is likely to restrict hypersonic cruise missiles to mid-course altitudes above 60,000 feet—lower than hypersonic boost-glide weapon but higher than manned aircraft. In 2014, the Air Force Science Advisory Board assessed hypersonic cruise missiles as having less developmental risk than the hypersonic boost-glide weapon, a surprising assessment considering that scramjet-powered flight with hydrocarbon fuels had been successfully demonstrated once and then only for 210 seconds. Today, the U.S. Air Force and Defense Advanced Research Projects Agency is pursuing a hypersonic cruise missile concept demonstration, the Hypersonic Air-Breathing Weapon Concept, with contracts awarded in 2016. Hypersonic Air-Breathing Weapon Concept is not funded to produce an operational prototype, such as the Hypersonic Conventional Strike Weapon and Air-Launched Rapid Response Weapon, leaving little doubt that a hypersonic boost-glide weapon will be the first U.S. HSW to reach operational capability. Both China and Russia also have hypersonic cruise missile programs in unknown stages of development.

Challenges to Missle Defense

The U.S. is currently ill-equipped to defend itself against HSW. Existing missile defense systems are not yet up to the task. HSW compress the time available for considering defensive or counter-offensive responses and will leverage improved airspeed, maneuverability, and abbreviated fly-out times and novel approaches to stealth to defeat or seriously compromise the effectiveness of current missile defenses. The challenges facing counter-hyper-sonics (compared to ballistic missile defenses) includes greater limitations on effective intercept geometries requiring additional interceptor placements to maintain the same area of protective coverage. Using only ground-based sensors for detection, the time available to deploy mid-course interceptors and other countermeasures is drastically reduced. Moreover, intercepting HSW in their terminal phase present a formidable challenge, according to Dr. Michael D. Griffin, the U.S. Under Secretary of Defense for Research and Engineering. The aerodynamic advantage of HSW in the lower atmosphere presents "a very hard intercept problem. . ." for closer-in existing missile defenses such as the Terminal High Altitude Area Defense and PATRIOT Advanced Capability-3 (PAC-3) systems.[16]

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Figure 1 (page 21), a Comparison of HSW Flight Profiles, depicts a scenario similar to a People's Liberation Army Rocket Force medium-range HSW launched from inland China against a U.S. carrier battle group 600 nautical miles (nm) away. From 600 nm, a hypersonic boost-glide weapon would take less than seven minutes to reach its target compared to 67 minutes for a subsonic cruise missile. A successful defense against HSW requires early detection, followed by rapid analysis, decision, and response. Even with satellite detection at launch, the compressed timeline for considering a tactical response could drive states threatened by HSW to adopt automated or preemptive responses that include launch-on-warning. For states with access to space-based intelligence, these automated responses will drive a requirement for tactical exploitation of raw intelligence data.[17] These capabilities, which are necessarily provided by space and cyber assets and capabilities, will require similarly capable defenses within the space and cyber warfighting domains.

Air Force General John Hyten, U.S. Strategic Command, openly admits that the U. S. is not prepared to defeat its adversaries' hypersonic missile technologies, referring on multiple occasions to difficulties with satellite detection and tracking.[18] The Missile Defense Agency understands these capability gaps and has proposed an enhanced system architecture to address these shortfalls. On March 6, 2018, Lieutenant General Samuel Greaves, director of the Missile Defense Agency, argued that the U.S. must act "to move the [enhanced] sensor architecture to space and use that advantage of space in coordination with our ground assets to relieve the gaps." Greaves further argued that the necessary leaps in technology are available and must be fielded in the next six to seven years.[19]

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The Political Context of U.S. HSW Development

U.S. engagement with the challenges and threats posed by HSW has been unsteady, largely driven by fear of escalation and shifting priorities. The impetus behind the current U.S. HSW development effort originated with the George W. Bush Administration's 2001 Nuclear Posture Review. The 2001 Nuclear Posture Review first proposed using long-range, non-nuclear weapons systems as part of a "New Triad," combining precision conventional weapons with strategic nuclear forces under a new category of "offensive strike" weapons.[20] The intent was to reduce the role of nuclear weapons in U.S. security strategy, as afforded by the perceived dissolution of the Cold War nuclear stand-off with Russia, while preparing to answer the new and greater threat of nuclear terrorism by nonstate actors. In 2003, the Department of Defense established a new mission, conventional prompt global strike, to answer this objective. As proposed, conventional prompt global strike would use intercontinental ballistic missiles and submarine-launched ballistic missiles as "high-precision conventional weapons capable of striking a target anywhere in the world within one hour."[21] By 2008, however, Congress had cut-off funding for the Conventional Trident Modification, a submarine-launched ballistic missile instantiation of conventional prompt global strike, over concerns with nuclear ambiguity, i.e., the possibility that conventionally-armed ballistic missiles could be mistaken for nuclear missiles resulting in inadvertent nuclear escalation. At that point, HSW, previously only seen as an emerging solution for countering increasingly sophisticated anti-access/area denial systems, became linked to U.S. efforts to reduce the number and general dependence on nuclear weapons.[22] By 2012, the conventional prompt global strike technology focus had shifted from hypersonic weapons launched on intercontinental ballistic missiles to smaller, regionally-deployed, air- and submarine-launched HSW. HSW research accelerated during the Obama administration as the U.S. began to recognize the full extent of the emerging threat posed by China's and Russia's HSW programs to U.S. national security interests.

President Trump's 2018 Nuclear Posture Review marked a shift from that of the two previous administrations by re-establishing nuclear deterrence as first among U.S. nuclear posture priorities. The Trump administration deemed this reprioritization of nuclear deterrence as necessary to answer "the rapid deterioration of the threat environment since the 2010 [Nuclear Posture Review]" due to deteriorating great power relationships.[23] To this end, the 2018 Nuclear Posture Review proposes two new nuclear weapons programs: a submarine-launched ballistic missile with a single low-yield nuclear payload, to be fielded near-term and a nuclear sea-launched cruise missile for the longer-term. Critics decried both proposed systems for showing insufficient concern for the dangers posed by nuclear ambiguity,[24] the same objection that constrained conventional prompt global-strike development over the previous two presidential administrations.

General Hyten attempted to respond to these ambiguity concerns in a Nuclear Posture Review Policy Seminar held at National Defense University on February 16, 2018, explaining that the low-yield, nuclear, submarine-launched ballistic missile is proposed primarily to deter use of similar low-yield nuclear weapons on the battlefield. Their employment, he explained, would only occur after nuclear deterrence has failed, i.e., when the opponent had chosen to breach the nuclear threshold with a low-yield tactical nuclear weapon. At that point, the only ambiguity facing the opponent would be whether the U.S. has launched a submarine-launched, ballistic missile carrying a single, low-yield nuclear weapon or a submarine-launched ballistic missile carrying a full multiple independently targetable reentry vehicle (MIRV) payload of standard nuclear warheads.

In this comment, General Hyten highlighted a fundamental tension between requirements for deterrence and concerns with warhead ambiguity: for deterrence to function, the threat of the consequences that will follow the undesired act or behavior must be sufficiently credible and severe to convince the opponent not to act. A U.S. threat to launch a full-scale nuclear response against Russia's or China's limited use of precision, low-yield, and electromagnetic pulse nuclear weapons is not as credible as a threat of a proportionate U.S. response with similarly devastating counter-force weapons. Should the opponent choose to accept the risk of limited nuclear escalation and the U.S. responds as threatened, the ambiguity facing the opponent concerns whether the U.S. submarine-launched, ballistic missile response is indeed proportionate (the first salvo of a preemptive strike against all targetable nuclear weapons) or the first salvo of a full-scale nuclear war. If the opponent believes the U.S. remains a rational actor and is confident in its own ability to respond with a devastating nuclear counterstrike, its own rational choice is to either preserve its option to continuing along a path of controlled escalation, revert to conventional warfare, or capitulate and retreat with limited losses.

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The ambiguity-risks inherent to HSW use in conventional strike missions pose a greater challenge than those from HSW use in a nuclear one. Unlike the low-yield, nuclear-submarine-launched ballistic missile and future, low-yield, nuclear sea-launched cruise missile, the U. S. will be less constrained in using conventional HSW weapons. These weapons could be used to preempt an opponent's decision to employ nuclear missiles if positioned such that fly-out times are less than the time required to prepare a ballistic missile for launch (and where this rapid response is advantageous). Conventional HSW, employed in sufficient numbers to counter an opponent's nuclear weapons, pose a very credible preemptive threat. HSW pose a powerful deterrent against states with less confidence in their ability to preserve a second-strike capability, but this is accompanied by greater instability due to ambiguity-risk in actual HSW employment. On first indication of an HSW launch, an opponent possessing nuclear missiles may believe that it is facing a use-or-lose decision and choose to use their HSW rather than risk being struck. From the beginning of the conventional prompt global strike initiative, the U.S. has resolved to find ways to reduce or eliminate these ambiguities. China, on the other hand, purposefully shrouds its plans for HSW employment in nuclear ambiguity. In political standoffs involving deterrence and brinkmanship, this willingness to impose ambiguity-risks that the U.S. is unwilling to similarly impose confers an initial advantage.

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The Department of Defense should not, by itself, be required to mitigate ambiguity-risks inherent to HSW when dealing with adversaries that are willing to accept such risks. The interagency must remain dedicated to accurately discerning the doctrines, beliefs, and intent of U.S. adversaries concerning HSW and to promote and maintain clear and open communications with all states that are capable of misinterpreting U.S. intent with potentially disastrous consequences.

Toward a Balanced Perspective

To date, few assessments of the future of hyper-sonics have attempted to provide a comprehensive and balanced perspective of the threats and opportunities that HSW pose for the U.S. and other nations. In a recent *Foreign Affairs* article, "The Eroding Balance of Terror: The Decline of Deterrence," Andrew Krepinevich sounds an alarm from a broader perspective, describing the technological and geopolitical challenges that threaten the ability of the U.S. to deter rising aggression from both China and Russia. While addressing this broad array of issues, Krepinevich touches upon the challenges to deterrence presented by new technologies across multiple warfare domains. While offering few recommendations, he argues that policymakers must rethink their deterrence strategies to account for how China and Russia assess their strategic balance against U.S. capabilities and how they might formulate a cost-benefit models for weighing potential acts of aggression.[25]

While Krepinevich's is a helpful recommendation, it does not speak directly to the full array of tactical tradeoffs in the use of HSW. Beyond the effects of HSW on the deterrence dynamics between the U.S., China, and Russia, there are few assessments of strategic challenges when HSW begin to proliferate among the major powers. A forward-looking study by RAND titled "Hypersonic Missile Nonproliferation" released in September 2017[26] may be the only notable exception.

Conclusion

Given the extraordinary strategic advantages conferred by HSW, any failure by the U.S. to match or exceed the emerging HSW capabilities of China and Russia would risk effectively ending U.S. advantage in regional power projection and capitulate to China and Russia's revisionist ambitions. The introduction of counter-hyper-sonics capabilities lags behind the introduction of HSW by many years and is likely to remain behind. Moreover, incremental improvements to HSW capabilities could render counter-hyper-sonics impractical or unaffordable for the foreseeable future. The shift in the offense-defense balance brought about by the emergence of HSW highlights the critical importance of effective deterrence at a time when U.S. ability to deter its great power rivals appears to be in jeopardy. The battle to restore U.S. deterrence must be fought across all warfighting domains using all instruments of national power within a coherent national security strategy implemented across the interagency. This strategy must efficiently apply resources to create a deterrent-threat that is tailored to the adversary's belief system and decision process, particularly those beliefs and decisions that could escalate to nuclear confrontation. ***IAJ***

The views expressed in this article are those of the authors and are not an official policy or position of the National Defense University, the Department of Defense or the U.S. government.

NOTES

1 "Hypersonic Missiles: Speed is the New Stealth," *The Economist*, June 1, 2013, https://www.economist.com/technology-quarterly/2013/06/01/speed-is-the-new-stealth, accessed on February 7, 2019.

2 These include aerodynamic designs to suppress infrared signatures and structures and materials to suppress radar returns, which are often incompatible with requirements for operating in the hypersonic regime. The first HSW will likely have large and recognizable IR signatures in all phases of flight. Plasma fields surrounding HSW will likely amplify radar returns in lower frequencies but may be used to attenuate returns in higher frequencies, which are common to targeting radars. Russia has been pursuing plasma as an active stealth technology for over 20 years. Larkins Dsouza, "Plasma Stealth," *Defence Aviation*, March 1, 2008, https://www.defenceaviation.com/2008/03/plasma-stealth.html, accessed on February 7, 2019.

3 A proximity fuse is an electronic detonator that causes the warhead to explode within a preset distance of its target.

4 Daniel C. Sproull, "Kinetic Energy Weapons: The Beginning of an Interagency Challenge," *InterAgency Journal,* Vol. 8, No. 2, 2017, pp. 62–68.

5 Vladimir Putin, "Presidential Address to the Federal Assembly," Kremlin, March 1, 2018, http://en.kremlin.ru/events/president/news/by-date/01.03.2018, accessed on March 2, 2018.

6 Ian Boyd and Robert D. Braun, "United States Air Force Scientific Advisory Board Report on Technology Readiness for Hypersonic Vehicles SAB-TR-14-01," Technology Readiness Assessment, 2014, United States Air Force Science Advisory Board, Washington, D.C., p. 56.

7 Andrew S. Erickson, "Chinese Anti-Ship Ballistic Missile (ASBM) Development: Drivers, Trajectories and Strategic Implications," The Jamestown Foundation, Washington, D.C., May 2013, http://www.andrewerickson.com/wp-content/uploads/2018/03/Chinese-Anti-Ship-Ballistic-Missile-Development_Book_Jamestown_2013.pdf, accessed on January 18, 2019.

8 A new approach is required to achieve a midcourse intercept of HSW. The Defense Advanced Research Program Agency began soliciting proposals for Glide Breaker, a prototype demonstrator for intercepting hypersonic glide vehicles, on November 6, 2018.

9 Russia is developing a hypersonic cruise missile, the BrahMos II, in cooperation with India. The United States and Australia are cooperatively developing a hypersonic glide vehicle under the Hypersonic International Flight Research Experimentation (HiFIRE) program.

10 Secretary of the Air Force Public Affairs, "Air Force Awards Hypersonic Weapon Contract," U.S. Air Force, August 13, 2018, https://www.af.mil/News/Article-Display/Article/1600963 /air-force-awards-hypersonic-weapon-contract, accessed on February 7, 2019.

11 Act of Nov. 25, 2015, Pub. L. No. 114-92, 129 Stat. 726, "National Defense Authorization Act for Fiscal Year 2016," https://www.congress.gov/114/plaws/publ92/PLAW-114publ92.pdf, accessed on February 7, 2019.

12 Act of Dec. 23, 2016, Pub. L. No. 114-328, 130 Stat. 2000, "National Defense Authorization Act for Fiscal Year 2017," https://www.congress.gov/114/plaws/publ328/PLAW-114publ328.pdf, accessed on February 7, 2019; Act of Dec. 12, 2017, Pub. L. No. 115-91, 131 Stat. 1283, "National Defense Authorization Act for Fiscal Year 2018," Congress.gov, https://www.congress.gov/bill/115th-congress/house-bill/2018, accessed on February 7, 2019.

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