Weaponized and Overhyped: Hypersonic Technology

Cruise missiles and boost gliders that can travel faster than five times the speed of sound without revealing their target until the very last moment have become a reality. While hypersonic weapon systems are on their way to change the strategic stability parameters by the middle of this decade, the magnitude of their disruptive effect remains a known unknown.

By Dominika Kunertova

Military vehicles carrying hypersonic missiles drive past Tiananmen Square during a military parade in Beijing, October 1, 2019. *Thomas Peter / Reuters*

Hypersonic weapon systems appear to be a game-changer in a not-so-distant future. They may become a transformative strategic capability introducing a qualitatively new way of overcoming air and missile defenses, bringing an element of surprise and uncertainty, and compressing the response time within the Observe-Orient-Decide-Act (OODA) loop. Thanks to their speed, conventional or nuclear capability, and target ambiguity, hypersonic weapons have the potential to undermine nuclear deterrence postures and create cracks in strategic stability.

Strategic stability in its Cold War heydays meant stability of deterrence: opponents could strike back because the other side was not able to take all nuclear capabilities out in a successful first strike. The concept has never simply been a matter of quantity and quality of weapons, but also the complex political reality of nuclear relationships, such as ideological, geopolitical, and historical factors, which have influenced the strategic stability-instability continuum. It rests upon the twin dynamics of crisis stability (disincentivize leaders to launch a nuclear first strike in a conflict) and arms race stability (the absence of perceived or actual incentives to augment their nuclear weapons).

Today, strategic stability goes beyond the bilateral nuclear dynamics and reflects the changes in military strategy, doctrines, and multiple asymmetric nuclear relationships. Advanced conventional capabilities with a disruptive potential, including hypersonic weapons, can alter the perceived stability of mutual vulnerability and increase both the anxiety of losing the retaliatory ability and the likelihood of a pre-emptive strike.

The technological arms race is already happening: the US, Russia, and China are engaged in an intense competition for military supremacy in the 21st-century warfare. These three nuclear-armed states have the most advanced hypersonic research and development programs. The tail of countries developing hypersonic weapons includes France, Germany, India, Japan, and Australia. The United Kingdom, Norway, Iran, Israel, and South Korea are investing into research on hypersonic propulsion systems.

Although the US has the most experience with hypersonics, China and Russia appear to have made substantial progress in the weaponization of their hypersonic technology. Russia reportedly deployed its first hypersonic weapons in December 2019 and

China in 2020, while the US is not likely to have its hypersonic weapons in service before 2023. This is because both China and Russia believe in having an urgent reason for the military application of hypersonic technology: both fear that their second-strike capabilities are undermined by the existing American missile defense systems and thus, as a matter of national security, emphasize developing new capabilities to overcome them.

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However, policymakers tend to overestimate the capabilities of these new weapons and overlook their possible disadvantages. Recent research warns that the craze around hypersonic weapon systems does not seem to be technically justified. Worse still, great powers may not care; as they got caught in their fear of losing the technological edge and ultimately national prestige, the damage to the perceived strategic stability equilibrium has already been done.

The Hypersonic Nitty-Gritty

Missile technology distinguishes between two main categories: ballistic and cruise missiles. Ballistic missiles are fast but less accurate and their flight can be calculated based on the trajectory and velocity. Standard cruise missiles can navigate to the target more accurately, but they fly relatively slow. Most missiles travel at supersonic speeds between Mach 1 (the speed of sound) and Mach 5. Technically, all intercontinental ballistic missiles (ICBM) are hypersonic since they can fly faster than Mach 5.

The new generation of hypersonic weapons combines the main advantages of both cruise and ballistic missiles: extreme speed, and superior precision and accuracy. As their name indicates, hypersonic weapons travel at a sustained speed of greater than Mach 5 (6,125 kilometers per hour). The extreme speed is not the only standout feature of these new systems. In contrast to ICBMs that travel along a predictable trajectory, hypersonic weapons bring an element of surprise as they can maneuver and change altitude in the atmosphere. Thus, maneuverability and flight altitude are two other main differences from conventional missile technology.

Hypersonic weapons come in two main types: hypersonic cruise missiles (HCM) and hypersonic glide vehicles (HGV). Some institutions, such as the NATO Science and Technology Organization, also include a hypersonic "post-stealth" strike and reconnaissance aircraft, expected by the 2030s. HCMs are a faster version of existing cruise missiles, flying at altitudes of 20-30 kilometers. They are propelled by air-breathing jet engines called supersonic combustion ramjet engines. These "scramjets" compress the incoming air in a short funnel before the combustion phase, allowing the engine to operate extremely efficient at high speeds. Because they get the necessary oxygen directly from the atmosphere, scramjet missiles are smaller and more maneuverable. In contrast, HGVs are unpropelled and rely on rocket-boost glide technology to be lifted into the upper atmosphere. After being released at altitudes between 40-100 kilometers, they travel unpowered down at hypersonic speeds to strike targets. Their ability to maneuver and be released at different altitudes makes their trajectory unpredictable and difficult to calculate.

Hypersonic weapon systems introduce new dangers that can be detrimental to strategic stability. First, the most obvious one is their speed: the higher the speed, the less time for decision-making. In the case of incoming hypersonic weapons, the defender's OODA loop can shorten to only as little as a few minutes to react, decide on the target, identify the type of warhead, and assess potential damage of the chosen course of action. These conditions create an excellent breeding ground for human error.

Second, their ability to maneuver can deceive the defender as to which target the missile will strike. Together with unusual flight altitudes and unpredictable trajectories, it is extremely difficult for existing terrestrial and space-based sensors to detect and track hypersonic missiles and gliders. Their speed and target ambiguity drastically reduces the time between detection and interception and creates an OODA loop beyond human abilities. Future missile defense systems will require AI-enhanced performance to process data effectively and respond quickly enough to the incoming hypersonic threat.

Third, although hypersonic weapons can rely only on their high speed and accuracy to destroy the target with the kinetic energy impact alone, they can carry supplemental conventional or nuclear warheads. Dual-capable missiles are a significant source of uncertainty. Compounded by the defender's lack of clarity about the target, hypersonic weapons are becoming a new strategic stability nightmare.

Major Weaponizers

The US, Russia, and China are leaders in the military application of hypersonic systems (see Table). Countries naturally prefer to keep these programs secret to preserve their intended strategic advantage. Although the technological race in weaponizing hypersonics has become a reality, only relatively little reliable data on the development of these systems is available to the public. The actual performance of these new weapon systems has been difficult to corroborate. For instance, Russian and Chinese political propaganda tends to exaggerate the system's operational status. It may nevertheless come as a surprise when the Pentagon's director of defense research and engineering admitted last year that China was moving ahead of the US "by almost any metric that I can construct". Moreover, the US, unlike China and Russia, has publicly ruled out acquiring nuclear-capable hypersonic weapons. This means that the US hypersonic weapons will have to be more accurate in order to be effective, since nuclear-tipped missiles can afford to lack precision thanks to their blast effect.

The US has been researching hypersonic technology for decades. However, only recently has the development of hypersonic weapons and the hypersonic industrial base become a top priority for both the Pentagon and Congress, mainly to catch up with Russia and China. The US has accelerated its hypersonic programs since 2018 after Russian President Vladimir Putin announced the Russian new hypersonic "wonder" weapons in his state-of-the-nation address. The US has increased its spending on hypersonics from 800 million USD in 2017 to 3.2 billion USD in 2021 (projected). As the Assistant Director for Hypersonics pointed out, the US was developing prototypes for future evaluation of the weapon system concept with the objective of having these weapons operational in 2023.

Russia has been eyeing nuclear-capable hypersonic weapons to strengthen its nuclear deterrent, which, as Moscow believes, was undermined when the US withdrew from the Anti-Ballistic Missile Treaty (limiting active defenses against strategic ballistic missiles) in 2002. By means of investing in the new classes of weapons (hypersonic, nuclear-powered nuclear weapons), Russia tries to come up with a qualitatively different way of overcoming American air defenses. Moscow also uses its hypersonic weapon programs to showcase its great power status both at home and abroad.

In contrast, China has been developing hypersonic weapons to further project its power in the South China Sea and over Taiwan while circumventing the US missile defenses in the Asia-Pacific region. It reflects the Chinese fear of the US preemptive strike that would disable China's nuclear arsenal and deprive China of its ability to retaliate. Both Russia and China are motivated to acquire hypersonic weapon capability not only to have more long-range missiles and better nuclear deterrence, but also for their tactical use in a naval contest, especially anti-ship missiles that can sink aircraft carriers.

While today there are no countermeasures against the hypersonic threat, this may change by the mid-2020s. The US Missile Defense Agency (MDA) has been developing missile defense systems against hypersonic threats together with the Space Development Agency as part of the National Defense Space Architecture. This layered space architecture of 550 satellites is expected to be fielded by 2025 in order to provide full global coverage. It will enable the US to track and target advanced hypersonic threats at both high and low altitudes. The MDA is also looking into new boost-phase defenses using directed energy.

Overhyped

Hypersonic weapon systems are believed to enhance the deterrence posture. In addition to this strategic role, they can have a tactical application, such as enabling a rapid strike against time-sensitive targets over longer distances. They may prove valuable in permeating contested areas that are protected by advanced Anti-Access/Area Denial capabilities. On the flip side, their extreme speed and maneuverability make it very challenging for most current air defenses to counter HCMs and HGVs.

Experts disagree about the technical feasibility and the utility of hypersonic weapons.

Hypersonic weapons seem frightening, unstoppable, and indeed a game-changer. However, this new generation of hypersonic systems may simply be evolutionary. Experts disagree about their technical feasibility, utility, and consequently their impact on strategic stability. The trade-off between speed, altitude, maneuverability, and accuracy deserves more research.

First, experts argue that Russia and China already have the means to reach US soil with their ICBMs. In this respect, hypersonic weapons are an unnecessary waste of money as they do not present a new strategic advantage. Flying faster, striking the target harder, and from bigger distance are evolutionary, rather than revolutionary characteristics of missile technology. The speed and range of advanced hypersonic systems, even nuclear-capable, are comparable to ICBMs.

Second, it takes time and resources to master hypersonic capability. Scramjets and glide vehicles operating under extreme conditions pose significant engineering and technical challenges in terms of aerothermodynamics and resistant materials. The wide use of hypersonic weapons is unlikely as their technical requirements remain complex and costly.

Third, recent scientific studies based on computational modeling of hypersonic gliders have warned against overstating the facts as the supposedly advantageous capabilities of HGVs still await a sober and rigorous technical assessment. Especially physical limitations imposed by low-altitude atmospheric flight put their novelty, such as speed and invisibility, into question. HGVs lose energy and speed as they glide and maneuver down to their target, so the actual speed of impact is lower than that of a ballistic missile with a similar range. This means that the US Patriot and the Terminal High-Altitude Area Defense may already be able to detect and track hypersonic weapons during the glide or terminal phases, although they can cover only small areas.

The highly praised alleged advantage of hypersonic weapons – maneuverability – is not as reliable as usually thought. The externally navigated weapons can be spoofed or jammed. Essentially, as the airspeed and

Major National Hypersonic Weapon Programs

	Weapon System	Status
UNITED STATES		
Navy	Conventional Prompt Strike (intermediate-range HGV)	Initial Operating Capability (IOC) in 2028
Army	Long-Range Hypersonic Weapon (long-range HGV)	Flight testing through 2023
Air Force	AGM-183 Air-Launched Rapid Response Weapon (HGV compatible with B-52s and F-15s)	Flight testing through 2022
DARPA	Tactical Boost Glide (air-launched HGV with a tactical range)	Flight testing through 2021 (at least)
	Operational Fires (ground-launched tactical hypersonic system)	Flight testing through 2021 (at least)
	Hypersonic Air-breathing Weapon Concept (a basis for HCM)	Flight tests completed in 2020
RUSSIA		
	Avangard (nuclear-capable HGV)	IOC in 2019*; IOC of its Sarmat ICBM component in 2022
	3M22 Tsirkon (ship-launched HCM)	IOC in 2023
	Kh-47M2 Kinzhal (maneuvering air-launched ballistic missile)	Flight tests until 2018; IOC now*
CHINA		
	DF-17 (medium-range ballistic missile designed to launch HGVs)	Entering service (IOC in 2019*)
	DF-41 (dual-capable, long-range ICBM)	Entering service (IOC in 2019*)
	DF-ZF HGV	Flight testing since 2014, entering service (IOC in 2020*)
	Starry Sky-2 / Xing-King 2 (nuclear-capable hypersonic vehicle prototype)	IOC in 2025

* Information not confirmed

Sources: Congressional Research Service, IISS

Further Reading

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friction heat the surface of hypersonic vehicle to levels exceeding 2000° Celsius, the resulting plasma can disrupt the navigating signal. HGVs would need to be traveling slowly enough to preclude plasma formation during the terminal phase to allow for GPS-guidance and radio communication. This has led scientists to question the hypersonic weapons' "invisibility." The high-temperature surfaces produce a line of ionized gas that is more visible on radars and space-based sensors than the vehicle itself. Hypersonic weapons seem to be betrayed by their heat.

In sum, hypersonic weapon systems may not be faster or stealthier than the good old ICBMs. For now, their advantages seem to be apocryphal. From a military-technological perspective, hypersonic systems should remain a niche capability, not a must-have weapon. And even though hypersonic weapons currently may seem unstoppable, there will eventually be a counter weapon for every weapon.

Time to Halt the Arms Race

Despite these known unknowns, hypersonic weapons bear the potential to upset strategic stability. The ongoing arms race for technological edge itself is destabilizing the security environment by polluting it with more uncertainty and mistrust, which can lead to (unintended) armed confrontation. Regardless of the actual military performance and expected advantages of these weapons, weaponized hypersonic technology has already changed the governments' perception of vulnerability and national prestige. For instance, the 2018 US National Defense Strategy identifies hypersonic weapons as one of the key technologies for the US in order to ensure military supremacy to win future wars.

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Hypersonic weapons should be included in future arms control agreements to limit their proliferation. However, great powers are less likely to negotiate new multilateral treaties at a time when they are widely engaged in an arms race to build and perfect those very weapons. As a consequence, the crisis stability seems to be in danger due to the offense-defense dynamic: Russia and China fielding offensive hypersonic capability to overcome American air and missile defenses has led the US to invest in ways to build new defense systems to counter this new hypersonic threat.

The New Strategic Arms Reduction Treaty (New START) provides some stability. For instance, the Russian Avangard system is counted within the limits of this treaty. At the same time, New START does not cover weapons that fly on a ballistic trajectory for less than 50 per cent of their flight, as do most HGVs and HCMs, and is only temporary since it is due to expire in 2026.

Yet, arms control treaties alone cannot restore strategic stability. Conflict prevention mechanisms and confidence-building measures can temper the fears and minimize the first-use incentives by improving transparency, consultation, and dialogue. Furthermore, alliances and military relations with non-nuclear countries play an increasingly crucial role. More informal measures could do the job (see CSS Policy Perspective 9/3 "Arms Control Without Treaties"). Mutual reciprocity of unilateral gestures, such as reducing national investments into hypersonic weapon programs, staying open to data exchanges, conducting joint technical studies, or providing advanced notices, can ease the bitter competitive ambiance. Still, it is reasonable to expect some more sonic booms.

For more on perspectives on Military Doctrine and Arms Procurement, see CSS core theme page.

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