Hypersonic missiles: Evolution or revolution for missile non-proliferation and arms control instruments?

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The development of new weapons combining high speed and manoeuvring ability, referred to as 'hypersonic weapons', has become a priority in many countries that tend to see these systems as game-changers. On the other hand, it is sometimes assessed that hypersonic missiles are more an evolution than a revolution and may not deeply modify the strategic balance between states.

After listing major programmes and key drivers beyond the acquisition of these technologies, this paper considers their development under the prism of arms control, and analyses whether current mechanisms (non-proliferation arrangements, bilateral arms control treaties and confidence-building measures) dealing with missiles are adapted to these weapons.

It notes that export control mechanisms are largely taking into account hypersonic cruise gliders and hypersonic gliders, while confidence-building measures such as the HCoC may require adaptations to fully cover these delivery vehicles. Most fundamentally, the ways these systems are regulated will continue to depend mostly on whether they are designed to carry WMDs. The global missile arms control architecture may remain ill-equipped to limit the spread of conventional hypersonic weapons, raising questions on what is perceived as strategic weapons.

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Introduction and definition

Hypersonic missiles are defined as devices that spend most of their trajectory in the atmosphere at speeds above Mach 5, i.e., more than 1.5 km/s, and which are able to manoeuvre. 'Hypersonic missiles' are thus distinguished from purely ballistic missiles, which spend most of their flight outside the atmosphere, at speeds systematically greater than 1.5 km/s for missiles with a range of over 300 km. The notion of hypersonic has so far covered technological developments in propulsion and trajectory, leading to a distinction between two major classes of so-called 'hypersonic' systems: hypersonic cruise missiles and hypersonic gliders.

Hypersonic cruise missiles

Generally speaking, cruise missiles are missiles that are propelled throughout their trajectory. They are said to be hypersonic when their maximum speed exceeds 1.5 km/s. The best way to achieve this level of performance currently is to use a type of propulsion called 'scramjet' (supersonic combustion ramjet). Current programmes aiming at using this technology seek to reach speeds of between 1.5 and 2.6 km/s, or Mach 5 to Mach 8. They are achievable at altitudes of between 20 and 35 km, which allows the vehicle to manoeuvre over the entire trajectory.

The super-ramjet (or scramjet) is a type of aerobic propulsion – in other words, these engines use oxygen from the atmosphere as an oxidiser and only carry fuel to achieve combustion (solid or liquid propellant is composed of a fuel and an oxidiser). Moreover, in a ramjet or a scramjet, the compression of the air is obtained by the speed of the airflow in the inlet, enabling smaller and lighter engines with no mobile part (compressor, turbine). Nonetheless, this reaction has to be initiated at over Mach 5, which means that the scramjet has to be propelled with a booster to get the minimal speed. Nowadays, the main focus of development is to combine a ramjet and a scramjet in order to lower the initial speed needed for igniting the combustion.

At over 1.5 km/s, the air flows to the combustion chamber at supersonic speed, which generates specific constraints around the nose of the engine (shock wave), in the compression of the air in front of the air inlet and inside it, in the air flow to the combustion chamber, and in the combustion itself. One of the greatest difficulties in the operation of the scramjet is to achieve the combustion of the fuel and the oxidiser (the air) at supersonic speeds and to manage the resulting thermal stresses in the combustion chamber. The structural integrity of the latter can only be maintained over a relatively short period of time – nowadays, around a few minutes, but likely to be extended thanks to the development of adapted materials. Compared to subsonic cruise missiles, scramjets are propelled for a rather short time, but, due to the very high speeds they are able to attain for several minutes, they can fly hundreds of kilometres and probably more than a thousand in the years to come. The load of propellant needed to reach these speeds is far lower than in any other type of propulsion, which is attractive for military propulsion but also for commercial projects.

The numerous difficulties linked to the development of an operational scramjet explain why missiles propelled by scramjets are still largely in the development phase. To date, the closest to operational deployment is the Tsirkon/Zircon missile, developed by Russia. The ranges of these systems are currently estimated at around 500 to 1,000 km and should gradually increase.

Hypersonic gliders

The second major family of hypersonic missiles is that of hypersonic gliders, which are, schematically, manoeuvring re-entry vehicles reentering into the atmosphere at an altitude of approximately 100 to 120 km after a launch by either a booster derived from a space launcher or a ballistic missile. The trajectory of the launch means that the re-entry vehicle rapidly falls back into the atmosphere, at a speed and an angle of attack that allows it to 'glide' within it and also to bounce on its dense layers. Although the bounces cause a deceleration, as most of the trajectory is in the upper atmosphere, the gliders keep a good part of the energy obtained upon injection, which allows them to maintain very high speeds over a large portion of their flight.

The speed and range of the glider are directly dependent on the launcher. Thus, a glider launched by an intercontinental ballistic missile (ICBM), such as the Russian Avangard deployed on the SS-19 intercontinental ballistic missile, could have an injection speed of more than 7 km/s, a range of more than 10,000 km, and, at the end of its trajectory, would still have a significant residual speed. Gliders designed to operate over ranges of the order of 1,000 to 2,000 km associated with medium range ballistic missiles (MRBM) type launchers, such as the Chinese DF-17, are beginning to be deployed, while the United States is developing vehicles flying over ranges of between 1,500 and 3,000 km.

When it reaches the denser layers of the atmosphere, the aerodynamic support of the glider is sufficient to allow it to bounce and then, as the altitude decreases, to manoeuvre by modifying its trajectory and/or direction. This ability to manoeuvre, performed at high altitudes and high speeds, greatly complicates any interception attempt. Manoeuvring also makes it more difficult to predict the potential target.

Gliders currently represent the less challenging technology, in particular because this technology derives from work carried out for many years on manoeuvring warheads. However, their development remains complex, because of the aerothermal effects generated at very high speeds and the constraints of navigation and guidance.[1]

Besides the two major technological families, aero-ballistic missiles such as the Russian Kinzhal or quasi-ballistic missiles such as the North Korean KN-23 can be defined as hybrid systems, responding to the criteria of a hypersonic weapon (speed, flight in the atmosphere at over 1.5 km/s, manoeuvrability, ability to bounce) but using traditional chemical propulsion. They can be categorised as a kind of tactical

1. Stéphane Delory and Christian Maire, 'Missiles hypersoniques: le cas du Kh-47M2 Kinjal,' *Note de la FRS n°17/2022*, 6 April 2022, https://www.frstrategie.org/publications/notes/missiles-hypersoniques-cas-kh-47m2-kinjal-2022.

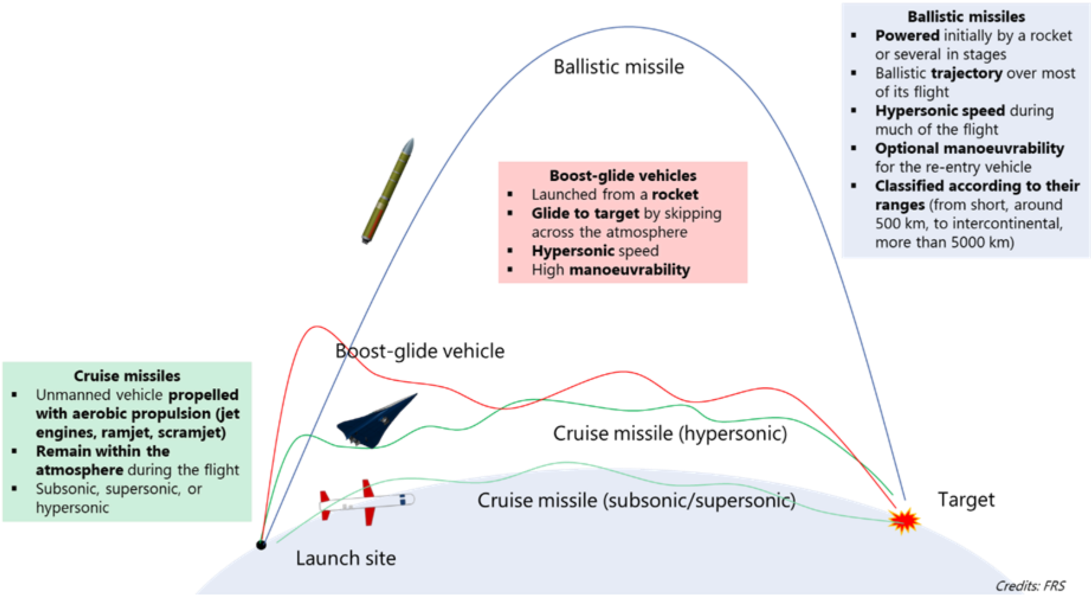

Figure 1: Flight trajectories and characteristics of ballistic missiles, cruise missiles, and hypersonic gliders

glider and are very likely to proliferate in the near term. Their main advantage is that they derive from well-known technologies and can be relatively easily designed, even by emerging ballistic powers such as Iran or North Korea. Their main drawback is the mass of propellant needed to achieve long-range flight and their inability to maintain a high speed throughout their trajectory.

Current programmes, drivers, and perspectives

Current developments and deployments

United States

The various US agencies have been interested for decades in hypersonic technologies. Following up on programmes and efforts is not always easy, as R&D programmes on hypersonic technologies have been multi-pronged (scramjet/glider) and have tended to evolve into new programmes once a technology demonstrator has been completed or several flight tests have been conducted. A summary table of the main efforts in this field shows the main developments currently ongoing.

The programme that has made the most progress and on which emphasis is now most regularly placed is that surrounding the Common-Hypersonic Glide Body (C-HGB), which entrusts the Navy to develop a common glider for its main hypersonic programme, the Conventional Prompt Strike, which will also be adapted for use by the US Army, in the framework of the LRHW programme (Long-Range Hypersonic Weapon). The two systems will be launched by specific boosters. This C-HGB builds on the development of an earlier prototype, the Alternate Re-Entry System, which was part of the AHW programme (Advanced

	Programme launch	Agency in charge	Characteristics	Tests	Funding in FY-2022 (USD)	Expected funding for FY-2023 (USD)
Conventional Prompt Strike (CPS)	2018	US Navy	Use of the common glider, based on the Alternate Re-Entry System, prototype tested in 2011 and 2017, coupled with a booster Also usable by other services	20 March 2020 27 May 2021 (success) 25 August 2021 (success) 28 October 2021 (success)	1,325 million	1,205 million
Hypersonic Air-Launched OASuW (HALO)	2022	US Navy	Probably air-launched	-	0	92 million
Long-Range Hypersonic Weapon (LRHW)/ Dark Eagle	2018	US Army	Use of the common glide vehicle developed by the Navy in the CPS programme Land-based, truck-launched Possible range of around 2,800 km	20 October 2021 (3 successes, 1 failure) 29 June 2022 (failure)	426 million	806 million
Tactical Boost-Glide (TBG)	2015	DARPA	Technology demonstrator with Mach 7 speed	2021	50 million	30 million
OpFires	2020	DARPA	Ground-launched system using TBG technologies Possible range of about 1,600 km.	July 2022 (success)	45 million	0
AGM-183 - Air-Launched Rapid Response Weapon (ARRW)	2018	Air Force	Use of TBG to develop an air-launched prototype with a 1,600 km range and Mach 6–8 speed Developed by Lockheed Martin	5 April 2021 (failure) 28 July 2021 (failure) 15 December 2021 (failure) 14 May 2022 (success) 12 December 2022 (success)	319 million	115 million
Hypersonic Air-breathing Weapon Concept / HAWC/ MoHAWC	2014	DARPA/ Air Force	Scramjet technology demonstrator built by Boeing Programme completed	September 2021 March 2022 (success) January 2023 (success)	10 million	30 million
Hypersonic Attack Cruise Missile (HACM)	2020	Air Force	Air-launched, from fighter or bomber (F-15) Air-breathing cruise missile	-	190 million	462 million

Figure 2. Current US hypersonic programmes

B-52 carrying a ARRW (AGM-183A) missile for its first flight over Edwards Air Force Base. Edwards Air Force Base, 12 June 2019. Credit: US Air Force

Hypersonic Weapon), developed by the US Army in the late 2000s. The weapons currently being developed reportedly have intermediate ranges and are designed to be launched from land-based systems and submarines, the air-launched version having been cancelled by the Air Force. These programmes illustrate the fact that, in the face of difficulties in building intercontinental-range systems, new attention has been given to theatre weapons with ranges of around 2,000 to 3,000 km. This shift does not mean an abandonment of global strike ambitions, which are still considered necessary to provide more flexibility to the US deterrent.[2]

Russia

While a lot of emphasis has been placed in recent years on Russian progress in hypersonic technologies, the work on these weapons started, as in the United States, with R&D carried out from the 1960s to the 1980s, before being interrupted by the collapse of the USSR.[3] The strategic programmes were reinitialised after the abrogation of the ABM Treaty, while Russia pursued Soviet research on scramjets and aero-ballistic missiles and remained at the forefront of hypersonic propulsion. In this respect, President Putin's address to the Federal Assembly on 1 March 2018 marked a culmination with the mention of several hypersonic systems – the Kinzhal air-breathing missile and the Avangard glider.[4] Since then, Russian officials have regularly insisted on Russia's ability to be the first country to develop and field such systems and have touted their superiority over the United States on the matter.

Thus, a few months after the Russian president announced the start of serial production of the Avangard system (February 2019), the Russian army announced the entry into operational service of its first Avangard hypersonic missile regiment (Dombarovsky division, Orenburg region) in December 2019. Defence Minister Sergei Shoigu said that MiG-31s equipped with the Kinzhal hypersonic missile, which is said to have been successfully tested against targets more than 1,000 km away, had carried out

2. 'Admiral Cecil Haney, 'Department of Defense Authorization for Appropriations for Fiscal Year 2016 and the Future Years Defense Program,' Hearings before the Committee on Armed Services, Senate, Washington, DC, 19 March 2015, https://www.armed-services.senate.gov/hearings/15-03-19-us-strategic-command-us-transportation-command-and-us-cyber-command.

3. Michael Kofman, 'Beyond the Hype of Russia's Hypersonic Weapons,' *The Moscow Times*, 16 January 2020, https://www.themoscowtimes.com/2020/01/15/russias-hypersonic-weapons-a68907.

4. 'Presidential Address to the Federal Assembly,' Kremlin, 1 March 2018, http://en.kremlin.ru/events/president/news/56957.

more than 380 air patrols over the Black Sea and Caspian Sea.[5] In January 2020, the Russian military tested the Tsirkon/Zircon hypersonic cruise missile for the first time from the frigate Admiral Gorshkov in the Barents Sea against a target in the Northern Urals. At least eleven launches have been conducted since then.[6]

While Russia's ability to field these systems and to conduct successful tests signifies strong political will, investment, and technological know-how, several points can be noted in comparison to US endeavours. First, there is a complete lack of information on the technical characteristics of the Avangard and in particular on the range over which the weapon is able to glide after its injection into the atmosphere. This ability is important to assess in order to ascertain whether the system is able to escape attempts at interception over the majority of its trajectory or whether the glider behaves like an 'extended' manoeuvrable re-entry vehicle. The navigation and guidance system of the glider also remains mysterious, but Russian press statements specify that the system might be coupled with a high-yield nuclear weapon, leading to the conclusion that its accuracy is likely to be poor.

Second, the Tsirkon/Zircon probably uses a scramjet engine, which may allow it to reach hypersonic speeds (Mach 8 according to Russian sources) over shorter distances (600 to 800 km according to Russian sources). This ability to accelerate over a short distance might provide a tactical edge in order to avoid interception in the final phase. Due to its probable short propulsion phase, it might not represent a radical improvement on highly supersonic missiles such as the Kh-32.[7] It nevertheless opens the way to a new category of faster and lighter weapon systems that can be launched from smaller platforms than those currently used by the Russian army. Hence, a small scramjet missile is currently being developed for the Su-57 stealth fighter, and Tsirkon is currently being tested from a frigate, whereas older highly supersonic missiles had to be launched from heavy bombers or cruisers.

Launch of a Tsirkon hypersonic missile from the frigate Admiral Gorshkov in the White Sea, 6 October 2020, Credit: Press Service of the Russian Ministry of Defence

5. 'MiG-31 Aircraft Armed with Kinzhal Hypersonic Missiles Regularly Patrol Airspace over Black, Caspian Seas – Shoigu,' *Interfax*, 20 February 2019; 'Tests Confirm Kinzhal is Capable of Hitting Both Ground and Sea Targets – Russian Defense Ministry,' *Interfax*, 20 February 2019.

6. Alexander Marrow, 'Russia Conducts First Ship-based Hypersonic Missile Test: TASS,' *Reuters*, 27 February 2020, https://www.reuters.com/article/us-russia-military-missiles-idUSKCN20L2CL.

7. Philippe Gros, Nicole Vilboux, Frédéric Coste, and Stéphane Delory, 'La compétition dans les technologies de rupture entre les États-Unis, la Chine et la Russie,' Rapport n°2, *Observatoire de la politique de défense américaine*, FRS, June 2019, https://www.frstrategie.org/sites/default/files/documents/programmes/observatoire-de-la-defense-americaine/publications/2019/2019-02.pdf.

	Programme launch	Manufacturer	Characteristics	Reported tests
Avangard	2004	NPO Mashinostroyeniya	Coupled with RS-18A/SS-19 Stiletto, plan to couple it with RS-28/SS-X-30 Sarmat Declared operational in 2019, 6 units delivered to 621st Missile Regiment in Dombarovsky Range of at least 10,000 km	February 2015 June 2016 October 2016 26 December 2018
Tsirkon/Zircon		NPO Mashinostroyeniya	Described as a hypersonic cruise missile despite questions about design Operational in 2022 Range estimated at 1,000 km, speed of Mach 8 Anti-ship missile with development ongoing of a land platform	2015–2016 (unconfirmed), 2017, 2018, 2020 6 October 2020 26 November 2020 11 December 2020 19 July 2021 4 October 2021 18 November 2021 29 November 2021 16 December 2021 24 December 2021 19 February 2022 28 May 2022
Ostrota	2021	MKB Raduga	Scramjet hypersonic cruise missile Short range	-
Gremlin	2018	Tactical Missiles Corporation	Scramjet hypersonic cruise missile Long range	-

Figure 3. Current Russian hypersonic programmes

Additional programmes might be in the development phase, but very little information is available about them, and no tests have been reported at this stage.[8]

China

China is also an advanced country regarding the development and production of hypersonic weapons. The most ambitious programme appears to be the DF-ZF/WU-14, which was tested seven times between 2014 and 2016. Chinese sources indicate that five of these tests were successful, enabling the glider to reach speeds of between Mach 5 and Mach 10, with ranges of between 1,250 and 2,100 km.[9]

Since 2017, Western reports have associated this glider prototype with a version of the DF-16 intermediate-range ballistic missiles.[10] The new weapon named DF-17 may be operational. The DF-ZF glider

8. Kolja Brockmann and Dmitry Stefanovich, 'Hypersonic Boost-glide Systems and Hypersonic Cruise Missiles: Challenges for the Missile Technology Control Regime,' *SIPRI*, April 2022, https://www.sipri.org/publications/2022/other-publications/hypersonic-boost-glide-systems-and-hypersonic-cruise-missiles-challenges-missile-technology-control.

9. James M. Acton, 'China's Advanced Weapons,' Carnegie Endowment for International Peace, Testimony before the U.S.-China Economic and Security Review Commission, 23 February 2017, https://carnegieendowment.org/files/Acton_Testimony_2_23_17.pdf.

10. Philippe Gros, Nicole Vilboux, Frédéric Coste, and Stéphane Delory, op. cit.

	Programme launch	Manufacturer	Characteristics	Reported tests
DF-ZF/WU-14/ DF-17			HGV coupled with medium-range ballistic missile or fractional orbital bombardment system (FOBS) Based on DF-ZF/WU-14	2014 (3 tests), 2015 (3 tests), 2016, 2017 July 2021 (FOBS) August 2021 (FOBS)
Xingkong-2/ Starry Sky-2	-	China Academy of Aerospace Aerodynamics	Air-breathing engine, probably scramjet	3 August 2018
Jiageng-1 (XTER/TBCC)	-	Xiamen University/Space Transportation NORINCO	Prototype of air-breathing engine Turbine ejector-ramjet combined cycle	24 April 2019

Figure 2. Current Chinese hypersonic programmes

is a demonstration of Chinese know-how. Although the range of the system is rather short, China chose a wedge-shaped glider, which is much more difficult to develop but more efficient than a biconical glider, such as the C-HGB. This demonstration is not a surprise, since China has invested heavily in wind tunnels for more than two decades, possesses some of the most powerful supercomputers in the world, and is now able to achieve significant scientific breakthroughs, in particular on materials. It is rather likely that the DF-ZF will be upgraded to be coupled with a more powerful launcher than the DF-16.

Most recently, the US media reported that China had conducted in July and August 2021 two tests of a fractional orbital bombardment system (FOBS) whose delivery vehicle could have been a hypersonic glider.[11] Without official confirmation, little is known about these vehicles.

China also seems interested in scramjet cruise missiles. In June 2018, images of the Lingyun-1 prototype were shared with the media. The technology of the scramjet was slightly outdated and probably does not represent the state of the art. The same year, the Chinese People's Liberation Army proceeded to the launch of the Xingkong-2. According to Chinese data, the device flew for 400 seconds over a distance of 700 km and reached a speed of Mach 6.[12] It cannot be excluded that the scramjet was not ignited and that the system only performed a free flight. It seems that China is still encountering numerous difficulties in the development of scramjet technology, but it seeks to innovate, notably through combined propulsion systems, coupling rocket motors, ramjet, and scramjet for reusable platforms.

11. Emmanuelle Maitre, 'Système de bombardement orbital fractionné (FOBS): une nouvelle capacité chinoise?,' *Bulletin n°91*, Observatoire de la dissuasion, FRS, November 2021, https://www.frstrategie.org/programmes/observatoire-de-la-dissuasion/systeme-bombardement-orbital-fractionne-fobs-une-nouvelle-capacite-chi-noise-2021.

12. Henri Kenhmann, 'Mach 6, 400 secondes… Essai réussi d'un Waverider hypersonique chinois,' East *Pendulum*, 6 August 2018, http://www.eastpendulum.com/mach-6-400-secondes-essai-reussi-dun-waverider-hypersonique-chinois.

Others

While these three countries have taken a noticeable step forward in the development of hypersonic systems, other nations are also investing to acquire these technologies. Thus, France is working on both hypersonic cruise missiles and gliders. The first technology will be mobilised in the design of the ASN4G. This scramjet-powered weapon is set to replace the current supersonic ASMPA, as a nuclear-capable system strictly dedicated to the deterrence mission.[13] On the glider side, the VMAX (Véhicule Manœuvrant Expérimental) was officially announced by former defence minister Florence Parly in 2019.[14] No information is available on the mission for such a weapon, or its characteristics and technical requirements, the VMAX being above all a demonstrator. In the long term, a future system may be associated with a submarine-launched intercontinental missile and a nuclear warhead in line with the nuclear deterrence mission.[15]

Other European countries have shown some interest in hypersonic flight, without

State	Programme	Programme launch	Manufacturer	Characteristics	Reported tests
France	VMAX	2019	Ariane Group	Hypersonic glider	-
	ASN4G	2013	MBDA	Hypersonic cruise missile – nuclear warhead	-
North Korea	Hwasong-8	?	Korean People's Army	Boost-glide, ground-launched, road-mobile	27 September 2021
India	HSTDV	2001	DRDO	Air-breathing technology demonstrator	12 June 2019 7 September 2020
Japan	HCM	2020 (announced)	Acquisition, Technology and Logistics Agency	Hypersonic cruise missile	-
	HVGP	2020 (announced)	Acquisition, Technology and Logistics Agency	Hypersonic glide vehicle	-
South Korea	Hycore	2019	Agency for Defense Development	Hypersonic cruise missile prototype coupled with short-range ballistic missiles	-
Australia	SCIFiRE	2020	United States Department of Defense and Australian Department of Defence	Air-launched strike and anti-ship air-breathing cruise missile	-
	Delta-Velos	2019	Hypersonix	Demonstrator using scramjet technology	-

Figure 3. Other military hypersonic programmes in development

13. Timothy Wright, 'Hypersonic Missile Proliferation: An Emerging European Problem?,' *Non-Proliferation and Disarmament Papers n°80*, EUNPDC, May 2022, https://www.nonproliferation.eu/wp-content/uploads/2022/05/EUNPDC_no-80.pdf.

14. French Republic, 'Déclaration de Mme Florence Parly, ministre des armées, sur la politique de défense, à Paris, le 21 janvier 2019,' French Ministry of the Armed Forces, 21 January 2019, https://www.vie-publique.fr/discours/269178-florence-parly-21012019-politique-de-la-defense.

15. Timothy Wright, op. cit.

committing to a clear weapons programme at this stage. The United Kingdom is probably the most determined to develop and acquire this category of weapon and has, for some years, studied concepts of air-breathing engines, in partnership with Australia. At the beginning of 2022, the Chief of the Defence Staff declared that the United Kingdom should have hypersonic weapons, and a small R&D programme has subsequently been launched, but the kind of technology considered has not been specified.[16] Potential cooperation within the AUKUS framework has been mentioned.[17] It seems likely that the United Kingdom will favour conventional systems at this stage. Germany has also conducted studies in the field, but they concern at this stage scientific experiments for civilian applications.[18]

In the Indo-Pacific, Australia continues to show its interest in scramjet technologies with the SCIFiRE project, under development since 2021 in cooperation with the United States. Japan and South Korea are both investing in air-breathing engines.[19] Japan is also working on a ground-launched boost-glide system under the acronym HVGP.[20] India also plans to develop an air-breathing delivery vehicle that could be coupled with an Agni-1 booster. A demonstrator was tested in June 2019 and September 2020.[21] India also has the technological know-how to develop a glider.

Finally, North Korea has also declared its interest in hypersonic technology, with the announcement in September 2021 and January 2022 of the flight tests of hypersonic gliders. Questions have been raised as to whether these weapons fully fit the criteria of a hypersonic glider, with some experts pointing out that the second one may be a more traditional ballistic

Launch of the Hwasong-8, Korean Central News Agency, 27 September 2021

16. Larisa Brown and Catherine Philp, 'Admiral Sir Tony Radakin Warns of Russian Threat at Sea,' *The Times*, 7 January 2022, https://www.thetimes.co.uk/article/admiral-sir-tony-radakin-warns-of-russian-threat-at-sea-kx7vf5sxv.

17. Phil Clare, '"High Time for Hypersonic Missiles" – The Challenges of Fielding Hypersonic Weapons for UK Defence,' *Wavell Room*, 20 September 2022, https://wavellroom.com/2022/09/20/high-time-for-hypersonic-missiles-the-challenges-of-fielding-hypersonic-weapons-for-uk-defence/.

18. Timothy Wright, op. cit.

19. 'South Korea Unveils Hypersonic Cruise Missile Prototype Concept,' *Aviation Week*, 6 December 2021, https://aviationweek.com/defense-space/missile-defense-weapons/south-korea-unveils-hypersonic-cruise-missile-prototype.

20. Mike Yeo, 'Japan Unveils Its Hypersonic Weapons Plans,' *Defense News*, 13 March 2020, https://www.defensenews.com/industry/techwatch/2020/03/13/japan-unveils-its-hypersonic-weapons-plans/.

21. 'DRDO Successfully Flight Tests Hypersonic Technology Demonstrator Vehicle,' Press Information Bureau, Government of India, Ministry of Defence, 7 September 2020, https://pib.gov.in/Pressreleaseshare.aspx?PRID=1651956.

missile coupled with a manoeuvrable warhead.[22]

Drivers for the acquisition of gliders

United States

The development of hypersonic weapons in the United States is based on a twofold logic. On the one hand, the progress made in the precision and velocity of delivery vehicles has made it possible to envisage precision conventional strikes in very distant theatres. On the other hand, the emergence of certain types of threats in the 1990s, linked in particular to the proliferation of weapons of mass destruction (WMDs) and anti-access weapons, led certain military and political leaders to suggest the acquisition of conventional strike systems combining high precision, very long range, and speed.

Thus, the 2001 Quadrennial Defense Review emphasised the need to develop new long-range precision weapons.[23] In the same year, the Nuclear Posture Review gave theoretical scope to the notion within the framework of the 'New Triad' concept.[24] The text mentions in particular the need to be able to hit 'mobile and relocatable' targets as well as 'hardened and deeply buried' targets. These two requirements led to two separate approaches: the development of scramjet prototypes for tactical strikes against mobile targets around projects led by the Air Force or the Navy, and most visibly the assessment of a long-range capability able to strike any target around the world in less than an hour to eliminate WMD assets or time-sensitive targets.

The Air Force and its representatives repeatedly specified their needs under the Bush administration, but budgetary constraints, repeated failures in the programmes, and changing priorities resulting from the enduring conflicts in Iraq and Afghanistan gradually eroded the military's interest in these systems. By contrast, the development of a strategic capability enjoyed broad political support, as the existing delivery system, conventional or nuclear, was unfit to deal with the rather vague and ill-defined targets envisaged by the administration. The 2006 Quadrennial Defense Review formalised the notion of 'prompt global strike' (PGS), still focused on 'fixed, hard and deeply buried, mobile and re-locatable targets'.[25] In doing so, it emphasised the value of speed and precision.

When defining the future PGS, the Bush administration had initially considered capacity around a dedicated nuclear

22. Vann van Diepen, 'Another North Korean "Hypersonic" Missile?,' *38th North*, 7 January 2022, https://www.38north.org/2022/01/another-north-korean-hypersonic-missile/#_ftn3.

23. *Quadrennial Defense Review Report, Department of Defense*, 30 September 2001, https://history.defense.gov/Portals/70/Documents/quadrennial/QDR2001.pdf?ver=AFts7axkH2zWUHncRd8yUg%3d%3d.

24. *Nuclear Posture Review*, Department of Defense, Submitted to Congress on 31 December 2001, https://uploads.fas.org/media/Excerpts-of-Classified-Nuclear-Posture-Review.pdf.

25. *Quadrennial Defense Review Report, Department of Defense*, 6 February 2006, https://history.defense.gov/Portals/70/Documents/quadrennial/QDR2006.pdf?ver=2014-06-25-111017-150.

weapon, designed to destroy WMD assets with limited damage (Robust Nuclear Earth Penetrator – RNEP), and a conventional option, around a conventionalised submarine-launched ballistic missile (SLBM) (Conventional Trident Modification – CTM). Both initiatives were rejected by Congress, both being deemed too destabilizing, as their use could be misinterpreted by other nuclear powers and lead to a nuclear conflict. In transforming the PGS into Conventional PGS (CPGS), the Obama administration decided to denuclearise the programme but also to renounce the use of traditional ballistic systems in favour of a new technology, in order to avoid any confusion between the delivery systems dedicated to strategic nuclear deterrence and the new systems dedicated to the enhancement of global deterrence. Hypersonic systems, whose trajectory cannot be mistaken for any ballistic trajectory but which allow for deep strikes at a strategic range, were then an obvious choice.

Several official documents and statements confirmed the Obama administration's interest in the CPGS mission, in particular the White House report on the ratification of the New START Treaty, which states that the CPGS 'could offer a number of benefits, including reinforcing deterrence of States like North Korea and Iran.'[26]

In summary, documents and statements published between 2000 and 2016 cited a number of justifications for the development of long-range, high-precision conventional weapons, including :

- The need for high-precision weapons that can hit moving targets (e.g., a terrorist group, WMD shipment, etc.)[27] and strike hardened or buried targets very quickly (e.g. WMD including the nuclear capabilities of proliferating states such as Iran or North Korea, ballistic missiles very quickly at intercontinental range);[28]
- The need to reduce the role of nuclear deterrence in the American posture by replacing it as far as possible with conventional deterrence: from 2010 onwards, conventional deterrence appears to be a useful complement to nuclear deterrence that gives credibility to the American posture in cases where the use of nuclear weapons appears to be implausible. This capability is however described as a niche capability that is not a substitute for nuclear weapons;[29]

26. White House, 'Report on Conventional Prompt Global Strike in Response to Condition 6 of the Resolution of Advice and Consent to Ratification of the New START Treaty,' 2 February 2011, quoted in James M. Acton, *Silver Bullet? Asking the Right Questions About Conventional Prompt Global Strike*, Washington, DC: Carnegie Endowment for International Peace, September 2013.

27. National Research Council, 'Conventional Prompt Global Strike Capability: Letter Report,' Washington, DC: The National Academies Press, 2007, https://doi.org/10.17226/11951.

28. Peter Flory, 'Department of Defense Authorization for Appropriations for Fiscal Year 2007,' Hearing before the Committee on Armed Services, Senate, Washington, DC, 29 March 2006, https://www.govinfo.gov/content/pkg/CHRG-109shrg30353/pdf/CHRG-109shrg30353.pdf.

29. Elaine M. Grossman, 'Conventional Arms No Substitute for Nuclear: Strategic Command Offi

- The need for very long-range weapons that can strike targets far from US deployment bases;[30]
- The need for weapons that can operate in a contested defensive environment;[31]
- The need to be able to strike critical targets via conventional weapons to limit the risks of conflict escalation (e.g., anti-satellite weapons, mobile missile launchers, command and control [C2] networks).[32]

Though the US administration reduced its ambitions and cancelled its strategic programmes in favour of more limited ones, these elements are still deemed pertinent today and explain why STRATCOM has reiterated its interest in the deployment of conventional hypersonic weapons under the Biden administration.[33] However, since 2016, hypersonic weapons are increasingly justified by some US officials in terms of their ability to provide a tactical advantage in a conflict, especially against a major competitor. Indeed, all programmes are now clearly described as 'focused on tactical and theatre-level operations'.[34]

The main asset of these systems is their ability to strike time-sensitive, high-value targets, in an environment characterised by the deployment of anti-access and area denial (A2/AD) capacities, on the battlefield and in the depth of military theatres. Although they are part of the integrated deterrence strategy – contributing to potentially alleviating the role played by nuclear weapons[35] – they are no longer conceived as a direct contributor to strategic deterrence.[36]

cial,' *Global Security Newswire*, 29 February 2012.

30. Michael Vickers, 'Department of Defense Authorization for Appropriations for Fiscal Year 2009,' Hearings before the Committee on Armed Services, Senate, Washington, DC, 12 March 2008, https://www.armed-services.senate.gov/hearings/strategic-forces-programs.

31. *2010 Quadrennial Defense Review*, Department of Defense, February 2010, https://history.defense.gov/Portals/70/Documents/quadrennial/QDR2010.pdf?ver=vVJYRVwNdnGb_00ixF0UfQ%3d%3d; Michael Schiffer, 'Long-term Readiness Challenges in the Pacific,' Hearing before the Subcommittee on Readiness of the Committee on Armed Services, House of Representatives, Washington, DC, 15 March 2011, https://www.govinfo.gov/content/pkg/CHRG-112hhrg65588/html/CHRG-112hhrg65588.htm

32. General James Cartwright, 'National Defense Authorization Act for Fiscal Year 2008,' Hearings before the Committee on Armed Services, House of Representatives, Washington, DC, 21 March 2007, https://www.govinfo.gov/content/pkg/CHRG-110hhrg37320/pdf/CHRG-110hhrg37320.pdf.

33. Charles A. Richard, Statement, House Armed Services Committee on Strategic Forces, 1 March 2022, https://www.stratcom.mil/Portals/8/Documents/2022%20USSTRATCOM%20Posture%20Statement.pdf?ver=CUIoOCLyos9xe9C9I0XjMQ%3D%3D.

34. John A. Tirpak, 'Walker: Hypersonic HAWC and TBG Neck-And-Neck to Fly by End of Year,' *Air & Space Forces Magazine*, 1 May 2019, https://www.airforcemag.com/walker-hypersonic-hawc-and-tbg-neck-and-neck-to-fly-by-end-of-year/.

35.Others emphasise speed, which increases the survivability of engaged systems and multiplies force by ensuring that 'fewer [weapons] are required to defeat difficult targets and fewer platforms are required from greater standoff distances' – David E. Walker, 'Department of Defense Appropriations for Fiscal Year 2015,' Subcommittee of the Committee on Appropriations, Senate, Washington, DC, 14 May 2014, https://www.govinfo.gov/content/pkg/CHRG-113shrg49104598/pdf/CHRG-113shrg49104598.pdf.

36. Ash Carter, 'Department of Defense Authorization for Appropriations for Fiscal Year 2017 and the

While the theatre capability is therefore increasingly assumed and claimed, it should be noted that the CPGS mission is still sought in a complementary manner, to diversify the possible responses to an attack below the nuclear threshold.[37]

Finally, while military missions have been assigned to hypersonic weapons even before they emerged as potentially functional capabilities, their acquisition of has since 2016 also often been politically motivated. One such consideration is to maintain a technological edge over any potential competitor. In 2018, the National Defense Strategy also emphasised this need to keep up with technology, citing hypersonic as a particularly important field of competition.[38] The progress made by China and Russia is very regularly cited in this context to justify the increased funding of US programmes. For example, the Under Secretary of Defense for Research and Engineering recently stated that hypersonic was a priority for all DoD services 'because China and Russia have devoted enormous resources to mastering hypersonic technology.'[39] For his part, John Hyten, former STRATCOM commander, argued in 2018 that as Russia and China 'continue to move fast in this area, [the US] must retake the initiative and commit the necessary resources to develop and field hypersonic conventional weapons.'[40] Most recently, officials including Secretary of Defense Austin Lloyd have noted the importance of recovering a leading position in the technological race to field hypersonic weapons, while members of the Biden administration have also noted that it is unnecessary to 'mirror-imag[e] the potential threats'.[41]

It should be underlined that even if, from a US perspective, but also from a Russian or Chinese one, hypersonic technology is now perceived in an arms race logic, partially disconnected from any military rationale, this rationale remains strong. The reactivation of the US 56th Artillery Command in Germany is rather telling. This unit, which was in charge of the Pershing II at the end of the Cold War, is to supervise the use of LRHW Dark Eagle, deployed in

Future Years Defense Program,' Hearings before the Committee on Armed Services, Senate, Washington, DC, 17 March 2016, https://www.armed-services.senate.gov/hearings/16-03-17-department-of-defense-budget-posture.

37. John E. Hyten, 'National Defense Authorization Act for Fiscal Year 2019,' Hearing before the House Committee on Armed Services, 7 March 2018, https://armedservices.house.gov/hearings?ID=5627421E-6922-4E3C-937E-DEE54F84C759.

38. *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge*, 2018, https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

39. Aaron Metha, 'Hypersonics 'highest technical priority' for Pentagon R&D head,' *DefenseNews*, 6 March 2018, https://www.defensenews.com/pentagon/2018/03/06/hypersonics-highest-technical-priority-for-pentagon-rd-head/.

40. John E. Hyten, 'National Defense Authorization Act for Fiscal Year 2019,' Hearings before the Committee on Armed Services, Senate, Washington, DC, 20 March 2018, https://www.armed-services.senate.gov/imo/media/doc/Hyten_03-20-18.pdf.

41. Paul McLeary and Lee Hudson, 'Austin Pushes to Fast-Track Hypersonic Missiles as China, Russia Make Gains,' *Politico*, 26 January 2022, https://www.politico.com/news/2022/01/26/austin-fast-tracks-hypersonic-missiles-as-china-russia-make-gains-00002584.

the 17th Field Artillery Brigade. The reactivation of the Command is a clear indication that hypersonic weapons could be used rapidly in the case of conflict against targets located deep into Russian territory. Functionally, the LRHW is operated as an artillery system and will directly support US Army and US Air Force operations. For the United States, this category of weapon is not perceived as strategic, although the selection of potential targets will take into account the risk of escalation and will be strictly scrutinised. The same logic is to be expected for the AGM-183A, knowing that air-launched weapons can more easily be used for strategic goals.

Russia

An important motivation for the development of hypersonic technologies in Russia is to respond to the threat posed to its nuclear deterrence by US policies, notably in terms of missile defence. Nuclear deterrence remains a fundamental pillar of Russian defence policy and is considered the ultimate guarantee of the country's sovereignty in the face of what is seen as very strong external pressure. The development of strategic hypersonic means (Avangard) is thus presented as part of Russia's response to the US challenge to strategic stability in the Russian sense.

As Vladimir Putin explicitly stated in his 'speech of 1 March 2018',[42] the hypersonic investment is first and foremost a response to US plans in the field of missile defences, which Moscow rejected from the outset (when Ronald Reagan announced the Strategic Defense Initiative in 1983) as calling into question the logic of mutually assured destruction, which underpins the strategic balance between the two countries. It was in this context that the Avangard hypersonic glider project was launched in the 1980s (Albatross project). It was part of the logic of 'asymmetric response' conceived by Soviet strategists at the time to dissuade the United States from pursuing the development of a global anti-missile system by creating armaments likely to bypass it even before it was created.[43]

Regardless of the current state of US missile defences, which are objectively unlikely to challenge the credibility of the Russian deterrent, whose capabilities have been considerably modernised over the past fifteen years, the Russian authorities take seriously the possibility of US technological breakthroughs in this area in the long term, especially as the US has continued to invest in this area. In this context, the priority of the Russian authorities is to preserve the national capacity to carry out a second strike, and the Avangard hypersonic glider should contribute to this.

Russian concerns about the effects of the US's global missile defences have been heightened by the emergence of the CPGS

42. Isabelle Facon, 'Le "discours du 1er mars" de Vladimir Poutine: quels messages?,' *Note de la FRS, n°04/2018,* FRS, 12 March 2018, https://www.frstrategie.org/publications/notes/discours-1er-mars-vladimir-poutine-quels-messages-2018.

43. S. K. Oznobishchev, V. Ia. Potapov, and V. V. Skokov, *Kak gotovilsia 'asimmetritchnyï otvet' na 'strateguitheskouïou oboronnouïou initsiativou'* R. Reïgana: Velikhov, Kokochine, i drouguie [How the 'asymmetric response' to R. Reagan's 'strategic defense initiative' was conceived: Velikhov, Kokochine, et al.], Moscow/USSR, 2008.

mission in the United States in the 2000s. Russian strategists believe that the CPGS project could give the United States the ability to neutralise a large part of Russia's nuclear deterrent with conventional strike, thus remaining under the nuclear threshold, while missile defences would reduce the ability of the remaining Russian forces to carry out a second strike.[44] Russia would then be in a catch-22 situation, the conventional nature of the strike making it hard to attempt a nuclear reprisal, which, in any case, would provoke utter destruction in Russia. Moreover, the supposed ability of the United States to erode the Russian strategic component through conventional strike and to nearly erase it by a decapitating nuclear first strike would nullify the deterrence function of the arsenal, depriving Russia of its main security tool.

From this perspective, the choice to accelerate the development of strategic hypersonic systems would have a twofold logic for Russian strategists: on the one hand, to reinforce Russia's capacity to carry out a second strike in an unfavourable operational environment; and on the other hand, not to let the United States gain a new advantage in the military field and to develop a symmetrical response through the development of similar Russian means.[45]

Secondly, the development of hypersonic weapons can be interpreted as a willingness to acquire additional conventional capacities. For several years, Russia has been working to reduce its reliance on nuclear weapons in its defence policy and to beef up its conventional strike capacities. A system like the Iskander (SS-26), developed as a nuclear system but also as a conventional precision strike system, illustrates this effort. Missiles such as the aero-ballistic missile Kinzhal and the hypersonic cruise missile Tsirkon/Zircon can also be seen as following the same objective, even if the dual capacity of the Kinzhal also enhances Russia's tactical nuclear capability.

As conventional systems, these two missiles allow for advanced strike capability with superior survivability against missile defences. As such, they expand the range of

A Kinzhal being carried by a MiG-31K, Victory Day, 2018, Credit: Kremlin.ru.

operational options for the Russian military and correspond to its stated interest in rapid, precise strikes to neutralise high-value infrastructure (anti-missile sites, C4 elements, airbases, etc.), thereby disrupting the adversary's military infrastructure.

44. Austin Long, 'Red Glare: The Origin and Implications of Russia's "New" Nuclear Weapons,' *War on the Rocks*, 26 March 2018, https://warontherocks.com/2018/03/red-glare-the-origin-and-implications-of-russias-new-nuclear-weapons/.

45. '"Deterrence Not Arms Race": Russia Hints It May Develop Rival to US Prompt Global Strike,' *RT*, 11 September 2014.

Different roles are suggested for the Kinzhal, which is not strictly speaking a hypersonic missile, such as anti-ship strikes or long-range strikes against ground targets, with the Ministry of Defence indicating that tests have been conducted on both types of targets.[46] Use in combat during the war in Ukraine has not made it possible to test specifically the ability of the Kinzhal to penetrate heavily defended areas, but may have suggested that the weapon could be useful for hitting time-sensitive targets. Its political impact should also not be understated.[47] For its part, the Tsirkon/ Zircon brings a new capability, allowing Russian naval forces to target naval groups with few weapons at very long range, threatening the US sea lane of communication and eroding naval groups' ability to withstand further attacks. Weapons like the Tsirkon/Zircon could also reduce the dependency of Russian naval strategy on nuclear operations. More broadly, hypersonic weapons seem to fit with the informal evolution of Russian doctrine, which emphasises conventional strategic strikes as elements of conflict management.[48] From that perspective, Russia may find it useful to develop specific conventional strategic systems in parallel to nuclear ones, the supposed objective of these strategic strikes being to disrupt some critical part of an adversary's economy or of its political and societal infrastructure, but also to signal an escalation in the conflict.

Nonetheless, the nuclear option remains. Vladimir Putin, following his address to the Federal Assembly in February 2019, spoke of the possibilities of hypersonic missile-equipped naval platforms deployed in neutral waters, suggesting that if a strike was launched against Moscow, it would have an immediate and faster response capability from its Tsirkon/Zircon-equipped naval platforms, for example against decision-making centres.[49] The very limited military load of the missile suggests that, in this case, it may be coupled with a nuclear weapon.

Indeed, due to their range, very high speed, and superior survivability, hypersonic armaments are of great use in relation to the ambiguity that the military institution consciously cultivates regarding its operational options. Although the Russian military institution, as mentioned above, wishes to free itself from excessive dependence on nuclear weapons, it intends at the same time to suggest that it does not rule out any option in the escalation of a conflict when faced with an adversary in a

46. 'Tests Confirm Kinzhal is Capable of Hitting Both Ground and Sea Targets – Russian Defense Ministry,' op. cit.; see also: 'This Hypersonic Missile is Key to Russian Control of the Arctic: Kh-47M2's Massive Strike Range a Major Asset,' *Military Watch Magazine*, 1 December 2019, https://militarywatchmagazine.com/article/this-hypersonic-missile-is-key-to-russian-control-of-the-arctic-kh-47m2-s-massive-strike-range-a-major-asset.

47. Stéphane Delory and Christian Maire, op. cit.

48. Dave Johnson, 'Russia's Conventional Precision Strike Capabilities, Regional Crises, and Nuclear Thresholds,' *Livermore Papers on Global Security n° 3*, Center for Global Security Research, Lawrence Livermore National Laboratory, February 2018, https://cgsr.llnl.gov/content/assets/docs/Precision-Strike-Capabilities-report-v3-7.pdf.

49. 'New Russian Weapons' Characteristics Allow Their Carriers to Be Deployed in Neutral Waters – Putin,' *Interfax*, 20 February 2019. At the December 2019 Defense Ministry college meeting, the Russian president indicated that 22 ships for the remote sea zone were under construction and would be equipped with precision weapons, 'including Tsirkon hypersonic missiles' (http://kremlin.ru/events/president/news/62401).

superior situation.

Finally, and importantly, the development of hypersonic technologies in Russia shows an ambition to display technological superiority. This goal is very present in the posture of the Russian authorities on hypersonic. From this point of view, Vladimir Putin's words, evoking Russia's apparent successes in this domain and comparing the scope, in terms of security, of the creation of the Avangard to the launch of the first artificial satellite, are quite eloquent. Since 2018, the Russian president has regularly stated that Russia is a leader in hypersonic technologies and is well ahead of the United States in that field.[50]

China

Chinese officials have never stated officially the purposes and drivers of their hypersonic weapons programmes. Based on the analysis of non-official sources close to the military, but also on the observation of the technological choices that are being made, it can be inferred that the logic of the Chinese in developing hypersonic weapons is not entirely different from that of the Russians. The main driver of the country's investment in hypersonic systems thus appears to be to compensate for the country's military-technological shortcomings in the face of a more technologically advanced adversary equipped with missile defences.

China's interest in in-depth, high-tempo operations – i.e., operations exploiting the high velocity and range of any given delivery system – precedes the development of hypersonic technology. In conceptualizing the anti-ship ballistic missile DF-21 D and in developing a space architecture capable of identifying and targeting hostile vessels far in the Pacific Ocean, China has, since the end of the 1990s, built a complex of weapons coupled with long-range ISR and modernised command and control able to detect and engage a naval target located 1,000 to 1,500 km away in a matter of minutes. In parallel, the development of a large arsenal of ballistic missiles with manoeuvring vehicles deployed near Taiwan also aims at delivering massive precision strikes to disrupt the defences of Taipei and allow the Chinese forces to gain air and naval dominance and to seize the initiative in a conflict. China is probably one of the most advanced countries in terms of deep strike operations at hypersonic speed, even though it relies on ballistic systems.

Although China continues to rely on its ballistic forces, numerous official, semi-official, and unofficial sources indicate that there is a great deal of thought being given to the use of hypersonic systems and, as recalled below, manoeuvring systems as part of the country's military strategy and especially to achieve the armed forces' priority objectives in the event of a conflict. The development of hypersonic systems appears to be motivated by several complementary factors, including the perceived need to improve deterrence capabilities, particularly against US nuclear and conventional forces, and the need to increase China's precision strike capabilities,

50. 'Russia Leads the World in Hypersonic Missiles Tech, Putin Says,' *Reuters*, 12 December 2021, https://www.reuters.com/world/russia-leads-world-hypersonic-missiles-tech-putin-says-2021-12-12/.

particularly in its periphery, and more precisely on the key military infrastructures of Taiwan. This effort is also driven by the ambition to improve its A2/AD capabilities in order to limit or even prevent a US intervention, and finally by a will to align itself with US technological developments in a logic of techno-nationalism and international prestige.[51] As much of the Chinese research technologies focused on long range tend to show, future uses of coming hypersonic systems will probably be dual and will be coupled with conventional or nuclear munition, depending on the stakes of the conflict, the involvement of a nuclear power, and the evolution of the combat.[52]

The test flight of a hypersonic glide vehicle coupled with a FOBS last summer, a system that has the ability to circle the globe and penetrate from an unexpected angle at top speed, could illustrate the objective of assuring the credibility of the second strike at all costs.

Others

Other countries currently developing hypersonic technologies are mostly following the logic stated above. North Korea has shown its willingness to deploy extremely fast and manoeuvrable weapons to ensure that some nuclear weapons can reach their target in a region where the deployment of anti-missile systems is extremely dense and could potentially erode the efficiency of an attack conducted using basic ballistic missiles. Quasi-ballistic missiles appear to be a first answer to this challenge, but the tests of the KN-08 clearly illustrate that Pyongyang is in search of a longer-range system. The ability of North Korea to develop such systems domestically and the striking similarity between the North Korean glider and the Chinese DF-ZF raise questions about Chinese involvement in North Korean programmes.

France and the United Kingdom currently have different approaches, since France strictly conceives of hypersonic delivery systems as likely components of its future nuclear deterrence, whereas the United Kingdom has yet to define its policy on the matter. Both Paris and London currently lack the ISR capability to sustain ground operations with conventional hypersonic missiles, but naval warfare appears as a natural step to deploy these systems. Should the British decide to develop such a capacity, it is doubtful that France would choose to stay behind.

For the other programmes, the motivations are various and sometimes exploratory, as the goal is to invest in a technology perceived as likely to be crucial in the future and to make sure stakeholders are not latecomers in the field and have the technical background to develop a military weapons programme if necessary.

51. Antoine Bondaz, 'Critiquer et faire face: la Chine et la défense antimissile américaine,' *Recherches & Documents,* n°9/2021, FRS, April 2021, https://www.frstrategie.org/sites/default/files/documents/publications/recherches-et-documents/2021/092021.pdf.

52. Lora Saalman, 'Factoring Russia into the US-Chinese Equation on Hypersonic Glide Vehicles,' *SIPRI Insights on Peace and Security*, n°2017/1, January 2017, https://www.sipri.org/publications/2017/sipri-insights-peace-and-security/factoring-russia-us-chinese-equation-hypersonic-glide-vehicles.

Outlooks

On 16 May 2020, Donald Trump inaugurated the new flag of the US Space Force by boasting about the development of a 'super-duper' missile that is seventeen times faster than the systems currently deployed and three times faster than its competitors.[53] This widely reported statement illustrates the highly political nature of hypersonic technology, which a number of leaders exploit to praise their country's technological superiority. Conversely, the hypersonic gap may justify growing investments, as seen in the United States, but also, on a smaller scale, in India, or even in the United Kingdom.

However, beyond the political display aimed at having the most sophisticated weapons and not allowing potential adversaries to lead the field, different logics seem to be at work regarding the potential use of these systems in the three most advanced countries in terms of hypersonic technology. Numerous missions have been envisaged for these weapons, more or less directly and officially. The main focuses are on reinforcing deterrence, either nuclear or global, neutralizing A2/AD architectures to restore access to regional areas or theatres, extending deep strike capabilities, creating conventional capacities able to have major effects on the theatre or even to have a strategic impact, or to nullify missile defence architectures.

Beyond the mission allocated to them, which is bound to change as the technologies mature and their costs decrease, hypersonic weapons have to be considered more broadly. To take full advantage of their potential, notably in terms of speed and range, they need enablers, i.e., ISR resources that can locate targets accurately over huge distances but also guide the weapon all along its trajectory. Up to now, the designation of targets was mainly done either in line of sight, long distance targeting requiring airborne capacities, or by geographical coordinates, with the use of GNSS allowing high precision, including at very long range. Should hypersonic weapons be used in the same way as current systems, i.e., at short-to-medium range against mobile targets or targets of opportunity, and at long range against fixed targets, the existing ISR systems would prove sufficient to perform strikes. However, in Washington (as probably in Beijing), assessments about possible future missions seek to exploit fully the intrinsic characteristics of hypersonic weapons in order to destroy fixed or mobile targets at very long range in contested environments. This implies developing complex architectures capable not only of detecting the target but also of guiding the weapon very accurately during the last phase of its trajectory, before the on-board sensors can take over. Over long distances, only high-altitude or space assets can perform this task. However, against mobile targets, these assets must be able to identify, follow, and designate the target very accurately and to feed the weapons with data in real time. Due to the speed of

53. Donald Trump, 'Remarks by President Trump at Presentation of the United States Space Force Flag and Signing of an Armed Forces Day Proclamation,' Remarks, White House, 15 May 2020, https://trumpwhitehouse.archives.gov/briefings-statements/remarks-president-trump-presentation-united-states-space-force-flag-signing-armed-forces-day-proclamation/.

hypersonic missiles, this requires very short-latency data transfers and the deployment of low-orbit constellations of satellites able to communicate with the weapon. In parallel, the identification of the targets will also be highly dependent on space assets, since traditional airborne assets are not able to see deep into hostile territory.

The use of space for military operations is obviously omnipresent nowadays, but hypersonic weapons bring a new dimension, since the full exploitation of their potential is nearly unthinkable without a developed space component. If it is assumed that their military effect can be tremendous, notably when they are used as decapitation weapons against C2, radars, mobile missile launchers, etc., the development of complex space architectures, able to see nearly everything everywhere and to transmit data in near real time, is an imperative. Conversely, developing means to neutralise or destroy hostile critical space assets is also necessary. In order to limit this risk, the use of major constellations, military or commercial, and the miniaturisation of sensors and communication systems is also necessary, along with the use of AI to process the huge flow of data in space before dispatching the necessary information to the C2 and the weapons. Space assets are also crucial for hypersonic missile defence.

Clearly, the militarisation of space is not a result of the hypersonic arms race, but the latter certainly fosters the former. Space dependency will also compel medium powers, such as France or the United Kingdom, to organise the development of their hypersonic capacities with greater space powers, namely the United States, in particular if they intend to use them against mobile targets or targets of opportunity. In fact, hypersonic weapons are only a part of an evolving mode of warfare where protecting or neutralizing space assets is becoming the focus of all high-tempo military operations. Consequently, any initiative taken to frame their development or use should take space operations into account.

Integration of hypersonic weapons in the missile non-proliferation architecture

The significant media attention paid to hypersonic weapons, often described as cutting-edge technologies or revolutionary systems, has been perceived as exaggerated by some analysts, who focus on the fact that these weapons are more an evolution than a revolution in terms of military technology.[54] However, while claims of their revolutionary nature need to be nuanced, it ought to be recognised that they may pose some specific difficulties regarding arms control. The need to regulate somehow the development of some of these systems stems from the fact that some may have an impact on strategic stability or be perceived

54. See for instance, Elliott Negin, 'Ask a Scientist: Calling Out the Hype Over Hypersonic Weapons,' *The Equation*, Union of Concerned Scientists, 2 April 2021, https://blog.ucsusa.org/elliott-negin/calling-out-the-hype-over-hypersonic-weapons/; Ivan Oelrich, 'Cool Your Jets: Some Perspective on the Hyping of Hypersonic Weapons,' *Bulletin of the Atomic Scientists*, 1 January 2020, https://thebulletin.org/premium/2020-01/cool-your-jets-some-perspective-on-the-hyping-of-hypersonic-weapons/.

as such,[55] but also from the potential arms race dynamics that they may create, which may, if nothing else, lead to the waste of huge amounts of money given the high price tag of these systems.[56]

First, the development of additional technological practices and the use of some materials may create a need to reconsider the scope of export control regimes focusing on delivery vehicles. Second, the deployment of and increased reliance on non-nuclear strategic weapons may question the scope of existing arms control. Lastly, the reliance on a variety of new systems, which are in fact very different though they may share technological features, may necessitate increased transparency to avoid misunderstanding and worst-case assessment.

Integration in export control regimes

As far as the export control of these systems is concerned, the existing provisions, and in particular the Missile Technology Control Regime (MTCR), are largely sufficient to control most hypersonic delivery systems, which are included as such in the control lists, even if there is still some ambiguity as to their status (delivery vehicle or re-entry vehicle). [57]

Indeed, as explained by a recent study on the subject, the MTCR currently covers in particular the propulsion technologies that

MTCR Annex Handbook, Credit: MTCR

are used by hypersonic gliders and cruise missiles, i.e., boosters often of ballistic origin, as well as their engines, and propellants. The guidelines also take into account the specific ramjet, scramjet, and combined cycles engines used for hypersonic cruise missiles, their sub-components, and fuels. Gliders themselves are controlled in the annex as re-entry vehicles. As regards critical components for this type of technology, advanced guidance and navigation systems are already included in the lists, as are heat shields and materials, including ceramics, that can be used for objects that must withstand extreme heat. Test infrastructures, in particular hypersonic wind tunnels, are also covered by the annexes. Finally, the implementation of the 'catch-all' clause largely allows for the control of exports of any system or component intended for a system designed

55. Dean Wilkening, 'Hypersonic Weapons and Strategic Stability,' *Survival*, vol. 61, n°5, October-November 2019.

56. Tim Thies, 'Hyperschallwaffen in Europa: Wie die Rüstungskontrolle Schritt halten kann,' *Research Report #009*, Institut für Friedensforshung und Sicherheitspolitik, June 2022, https://ifsh.de/publikationen/research-report-009.

57. Kolja Brockmann and Dmitry Stefanovich, op. cit.

MTCR Plenary Session, Dublin, October 2017. Credit: MTCR Chair

to carry WMDs.

However, the regime remains limited, in particular by its criteria (300 km/500 kg). Consequently, some experts recommend considering the explicit inclusion of hypersonic gliders within 'complete rocket systems', allowing them to be included among Category I items without ambiguity.[58] Thus, it was proposed to MTCR partners to include explicitly HGVs under the definition of 'complete hypersonic gliders, complete hypersonic cruise missiles' and their warheads, or to explicitly include them in the definition of re-entry vehicles, in order to avoid any debate on interpretation. Although engines, fuels, thermal protection materials, sensors, navigation and communication elements, flight controls, and ground test facilities are generally controlled, proposals suggest that the adequacy of the current rules should be better examined. For example, the idea of specifically examining certain technologies that could be developed for gliders and ramjet missiles, particularly in the area of high-temperature resistant materials, has been suggested.[59] It should be noted that the Wassenaar Arrangement also has a rather broad checklist that would cover a number of critical components produced for hypersonic gliders or hypersonic cruise missiles, but it has not specifically updated its lists in this regard.

These expansions and clarifications would

58. Kolja Brockmann and Dmitry Stefanovich, op. cit.

59. Venkatasubbiah Siddhartha, 'Spaceplanes, Hypersonic Platforms and the Missile Technology Control Regime, Strategic and Security Studies Programme,' National Institute of Advanced Studies, 2017, http://isssp.in/spaceplanes-hypersonic-platforms-and-the-missile-technology-%201050%20Q11%20control-regime/.

not necessarily change the practices of the MTCR partners and those countries adhering to MTCR guidelines in any significant way, but they would strengthen the regime's role in the control of strategic systems.

Integration in export arms control agreements

Existing mechanisms

Some types of hypersonic weapons are already in the scope of existing arms control mechanisms. This is the case for gliders coupled with ICBMs, such as the combination between the RS-18A/SS-19 Stiletto (and later SS-X3-0/Sarmat) and the Avangard warhead. The Russian authorities have stated that they count these as part of their agreed number of deployed land-based strategic systems.[60] As such, the booster counts as a deployed ICBM, while the glider itself counts as one of the 1,550 authorised warheads.[61]

Concerning air-launched systems, their status depends on the bomber used to carry them. At this stage, only bombers with a strategic range are considered under the Treaty. If another bomber is carrying the weapon, even if it is clearly a delivery vehicle for a nuclear warhead, the New START restrictions do not apply.

Ground-launched intermediate-range systems were covered by the INF Treaty, but its termination in 2019 means that there are no more restrictions on the United States and Russia developing hypersonic systems with these kinds of ranges.

Possible frameworks

While the adaptation of arms control to new technologies is systematically mentioned as a priority in speeches and publications on the subject, concrete proposals for regulating the development of hypersonic systems remain modest to date. Thus, the most realistic proposals concern the adaptation of the US-Russian bilateral New START Treaty, which deals with strategic arms control.

Under New START, air-launched missiles are counted if they are deployed on long-range bombers. In order to control deployed strategic cruise missiles, air-launched ballistic missiles, and airborne gliders, it may be necessary to revise this classification and either count all deployed strategic missiles or restrict their deployment to heavy bombers counted by the Treaty. For the sea -launched component, submarine-launched nuclear gliders (currently non-existent) could be considered as more conventional SLBMs. For land-based systems, their inclusion in the New START framework is already possible insofar as they are strategic weapons.[62] If Russia and the United States

60. 'Foreign Ministry: Sarmat, Avangard Systems May Be Included in New START Treaty,' *TASS*, 1 November 2019, https://tass.com/defense/1086515.

61. Pranay Vaddi, 'Bringing Russia's New Nuclear Weapons into New START,' *Lawfare*, Carnegie Endowment for International Peace, 13 August 2019, https://carnegieendowment.org/2019/08/13/bringing-russia-s-new-nuclear-weapons-into-new-start-pub-79672.

62. James M. Acton and Pranay Vaddi, 'A ReSTART for U.S.-Russian Nuclear Arms Control: Enhancing

eventually contemplate the possibility of negotiating a follow-up to the New START Treaty, some clarifications may therefore be necessary to ensure that the Treaty covers all strategic systems. While on the Russian side, the coupling of gliders with nuclear warheads may make this integration rather logical, on the US side, it would require the understanding that non-nuclear strategic weapons can be added to the scope of the Treaty, which would modify radically the purpose of the instrument and face major political obstacles. In that context, asymmetric arrangements may be necessary to find equivalence between different weapon systems,[63] although they would be extremely difficult to negotiate and implement. The feasibility of such an approach would largely depend on the political environment and the aftermath of the war in Ukraine, as it is clear that it would have little chance of success in the present circumstances.

While there are currently no more bilateral restrictions applying on intermediate range, following the demise of the INF Treaty, propositions to reinstate some form of controls on the deployment of these weapons have occasionally integrated land-based hypersonic weapons. Technically, the important question to address would be to what extent agreements on intermediate range should focus solely on nuclear-capable systems or integrate all delivery vehicles on these ranges (500 to 5,500 km). Some renowned experts have suggested that the regime would be more efficient and militarily pertinent if it focused on nuclear systems, which would leave out most of the hypersonic systems considered to this day.[64] However, such an approach might necessitate a formal agreement enabling the verification of the type of warhead, which may be difficult to envisage in the current political context. If the objective is more limited to a moratorium on the deployment of systems, then limiting land-based hypersonic weapons would be more doable. Integrating weapons deployed on ships or air-launched might be pertinent from a military perspective but would require intrusive on-site inspections, which would be hard to put in place in the current context. Declaratory mechanisms may be a second-best but more realistic option in the short term.[65]

Beyond the question of feasibility, the problem of bilateral arms control is that it does not take into account the main actors that are also developing these systems, in particular China. While it has been argued that China could be convinced to join a light, voluntary transparency mechanism,[66] taking part in a legally binding follow-up to

Security Through Cooperation,' *Paper*, Carnegie Endowment for International Peace, 2 October 2020, https://carnegieendowment.org/2020/10/02/restart-for-u.s.-russian-nuclear-arms-control-enhancing-security-through-cooperation-pub-82705.

63. Heather Williams, 'Asymmetric Arms Control and Strategic Stability: Scenarios for Limiting Hypersonic Glide Vehicles,' *Journal of Strategic Studies*, vol. 42, n°6, 2019.

64. Rose Gottemoeller, 'Speech by NATO Deputy Secretary General Rose Gottemoeller at the Swedish Institute for International Affairs,' NATO, 10 September 2019, https://www.nato.int/cps/en/natohq/opinions_168662.htm.

65. Tim Thies, op. cit.

66. Tong Zhao, 'Practical Ways to Promote U.S.-China Arms Control Cooperation,' *Policy Outlook*, Carnegie Endowment for International Peace, 7 October 2020, https://carnegieendowment.org/2020/10/07/practical-ways-to-promote-u.s.-china-arms-control-

the New START Treaty or the INF Treaty seems out of the question under the current circumstances.

More generally, a report commissioned by the United Nations raised the possibility of a treaty banning these weapons, along with bilateral or confidence-building measures (CBMs) on hypersonic systems, but without considering the actual support that such a measure would receive.[67] Indeed, no state has made such proposals to this date.

By contrast, a few authors have supported the more modest goal of banning hypersonic glider testing in particular. These suggestions are in line with the logic of the Comprehensive Nuclear-Test-Ban Treaty and would be a measure to curb both the dissemination of systems and their qualitative development in countries that already have them. However, other experts have also stressed that such proposals are unrealistic today.[68] The main difficulty might be the lack of clear distinction between a glider coupled with a booster and a ballistic missile coupled with a manoeuvring warhead.[69]

While such measures may seem limited, the design of an unequal mechanism, involving a trilateral effort by the United States, Russia, and China to prevent other countries from accessing the technology, as proposed in a widely circulated RAND Corporation study in 2017, seems completely unrealistic for the foreseeable future due to a lack of political support.[70] Criticism of such a measure has already been published,[71] especially by countries such as India, and the three countries currently leading the game do not seem to be willing to restrict access to these technologies to their allies and partners, given that the potential applications of these systems go far beyond the delivery of WMDs.

In this context, the inclusion of these systems, insofar as they are conceived as strategic weapons, in existing and hypothetical arms control mechanisms would already be a step that may seem ambitious. Similarly, the implementation of adequate confidence-building measures to limit the risks posed by these weapons to strategic stability might be seen by many experts as useful but would require significant diplomatic efforts.

Integration in CBMs and in particular in the HCoC

As current geopolitical factors reduce the likelihood that legally binding instruments

cooperation-pub-82818.

67. John Borrie, Amy Dowler, and Pavel Podvig, 'Hypersonic Weapons: A Challenge and Opportunity for Strategic Arms Control. A Study Prepared on the Recommendation of the Secretary-General's Advisory Board on Disarmament Matters,' United Nations Office for Disarmament Affairs and United Nations Institute for Disarmament Research, New York, 2019, https://www.un.org/disarmament/wp-content/uploads/2019/02/hypersonic-weapons-study.pdf.

68. 'Test Ban for Hypersonic Missiles? Roundtable with Tong Zhao, Rajaram Nagappa, and Mark Gubrud,' *Bulletin of the Atomic Scientists*, 6 August 2015, https://thebulletin.org/roundtable/test-ban-forhypersonic-missiles/.

69. Ibid.

70. Richard H. Speier, George Nacouzi, Carrie Lee, and Richard M. Moore, *Hypersonic Missile Nonproliferation: Hindering the Spread of a New Class of Weapons*, Santa Monica, CA: RAND Corporation, 2017, https://www.rand.org/pubs/research_reports/RR2137.html/

71. Venkatasubbiah Siddhartha, op. cit.

Figure 5. Comparison between ballistic missile pre-launch notification mechanisms

may be adopted in the short term, promoting the adoption of confidence-building measures to limit the most destabilizing aspects of these technologies may be a realistic pathway.

The Hague Code of Conduct against Ballistic Missile Proliferation (HCoC) is an existing instrument that already calls for transparency on some hypersonic systems. Adopted in 2002, the Code requires its subscribing states to exercise caution in the transfer of systems and technologies that may be used to produce ballistic missiles capable of carrying WMDs. More specifically, it calls on them to provide each year an annual declaration on their ballistic missile policy and to send pre-launch notifications to all other subscribing states whenever they test-launch such systems.

Given its current scope, the HCoC cannot be used to cover any hypersonic weapon based on cruise missile technology. However, it can apply to systems that are launched by more classic ballistic boosters. This is especially the case of weapons such as the Russian Avangard. According to the Code, the tests of a system like the Avangard have to be pre-notified. A number of gliders used for strategic missions and especially to carry nuclear weapons should be concerned by this obligation. In all likelihood, these tests have been reported under the Code when conducted by subscribing states.

As the Code focuses explicitly on systems that are designed to carry WMDs, it logically restricts its scope of application for weapons that are currently seen in many cases as purely conventional weapons. However, the criteria generally used to assess that a missile is WMD-capable, technical criteria based on the MTCR, may not be so pertinent, as long-range precision systems are developed for conventional missions. It might therefore be useful for a regime such as the Code to rethink how it deals with conventional strategic weapons and whether to apply the same transparency mechanism to avoid misunderstandings and erroneous interpretations.[72]

Beyond the Code, states could attempt to share information on systems not covered by the HCoC and to share information about exercises. Propositions made to invite observers to exercises appear unrealistic in the current context.[73] However, sending information for all kinds of tests related to gliders and cruise missiles, not covered by the Code, or developing bilateral or specific mechanisms involving states that do not subscribe to the Code (especially China) would be a positive development.[74] A specific trilateral arrangement has recently been proposed in detail by experts.[75]

As it is, Russia and China, on the one hand, and India and Pakistan, on the other, both have a bilateral pre-notification mechanism. The Sino-Russian agreement only concerns ICBMs or SLBMs (as well as space launch vehicles). The India-Pakistan one is slightly different since it takes into account all sea and surface ballistic missiles. It might be possible to consider an extension of the scope of these mechanisms to allow for the inclusion of hypersonic cruise missile tests as well as glider tests.

More generally, states could decide at the unilateral or bilateral level to clarify their policies concerning intermediate-range or long-range gliders and cruise missiles. In particular, lifting the ambiguity about the warhead might avoid potential confusion about a strike and reduce the risk of escalation. However, it has been noted that the effectiveness of such a measure would largely depend on the political will to enforce it or to accept intrusive verification. The same is true of efforts to avoid co-locating conventional and nuclear-armed missiles on the same site.[76] Second, clarifying the context and mission for which each specific armament is designed could be useful in avoiding the systematic anxiety that is caused by any use of the term hypersonic. Finally, when used in regional theatres, providing information about intentions and scopes through established military-to-military communication channels could also limit escalation risks.[77] Unfortunately, discussions on the implications of various weapon systems for strategic stability in the framework of strategic dialogues appear difficult to resume, but they could be useful especially if they can take place beyond the bilateral level.

Perspectives and conclusions

72. Stéphane Delory, 'Ballistic Missiles and Conventional Strike Weapons: Adapting the HcoC to Address the Dissemination of Conventional Ballistic Missiles,' *HcoC Research Paper no. 6*, FRS, January 2020, https://www.nonproliferation.eu/hcoc/ballistic-missiles-and-conventional-strike-weapons-adapting-the-hcoc-to-address-the-dissemination-of-conventional-ballistic-missiles/.

73. James M. Acton, *Silver Bullet?*, op. cit.

74. John Borrie, Amy Dowler, and Pavel Podvig, op. cit.

75. James M. Acton, Thomas D. MacDonald, and Pranay Vaddi, 'Reimagining Nuclear Arms Control: A Comprehensive Approach,' Carnegie Endowment for International Peace, October 2021, https://carnegieendowment.org/files/Acton_et_al_ReImagining_Arms_Control_fnl_1.pdf.

76. Dean Wilkening, op. cit.

77. Tim Thies, op. cit.

Beyond their technological prestige, hypersonic weapons thus respond to a set of logics, which are likely to be multiplied as they are deployed and will be the subject of more precise concepts of use. Often equated in the press with nuclear deterrence systems, they are in fact moving further and further away from this objective and are increasingly considered from tactical angles, except in Russia, where the strategic aspect remains highly developed for the time being (a situation that could change with the development of new systems). In the United States, the missions have evolved in line with the changing political context (post-2001 marked by terrorism, then the increased risk of confrontation with a strategic competitor) but also because of the technical hazards encountered by the programmes. In China, the tactical mission is mentioned very discreetly but is consistent with the country's global military strategy documents. In general, these missions are likely to continue to change to reflect expected technological developments, the cost of systems, the dissemination of these technologies to new actors, the ability to distinguish between nuclear and conventional systems, and the existence or not of an arms control framework.

The emergence of hypersonic weapons, both gliders and cruise missiles, which has come after decades of R&D and is still at an early stage, is often described as a challenge for global efforts to regulate missiles. The revolution posed by these systems should not be over-emphasised. In the foreseeable future, they will probably not modify the strategic balance or be deployed in sufficient numbers to replace existing systems. However, the investments made on these programmes raise questions with regard to most of the international efforts aiming at reducing the spread of delivery vehicles and limiting their risks.

First, the implicit bias that has led the international community to focus on ballistic missiles as the prime technology for the delivery of WMDs continues to be called into question by the deployment of these weapons. While the MTCR, for instance, has clearly taken into account cruise missiles in its guidelines, efforts remain necessary to ensure that other mechanisms, such as sanctions or confidence-building measures, take into account all technologies that can be used to deliver WMDs. This need has recently been highlighted in the wake of North Korea's claims to have tested a cruise missile and a glider reportedly able to carry WMDs.

Second, and in an opposite sense, the spread of conventional long-range hypersonic gliders or cruise missiles illustrates the trend already displayed by major powers to develop long-range stand-off strike systems. While most of these were deployed aboard ships, submarines, and planes for the United States and Russia (primarily in order to follow the restrictions of the INF Treaty), ground-based conventional systems have been fielded by China for a number of years and are now being pursued by the United States (Precision Strike Missile) or by countries like South Korea (Hyunmoo-4). In this context, the focus of arms control and non-proliferation on WMD-capable systems may be challenged. Whether the aim should be to restrict only these systems is a political decision, but the fact is that the technical criteria used to distinguish between conventional and WMD-capable missiles are increasingly blurred. The efficacy of these norms is therefore called into question.

For a confidence-building measure such as the Hague Code of Conduct, the operationalisation of hypersonic gliders and cruise missiles leads to some questions and possible reflections.

In the short term

In the short term, it is important to ensure that gliders that rely on a ballistic booster are well reported by subscribing states according to their obligations, specifically within annual declarations and pre-launch notifications. A difficulty here might be to consider what part of the flight is actually ballistic, and, if this part is limited, whether the whole system can qualify as a ballistic missile. The absence of definition in the Code may create some ambiguity, as although there is no restriction in the text of the HCoC, some states may decide that if the ballistic flight is less than a few hundred kilometres, the missile is out of the scope of the Code. This interpretation might be even more relevant for strictly conventional systems and systems that do not use ballistic components, on which arms control mechanisms have traditionally been applied. Informal consultations and unilateral decisions may be enough to ensure that there is consistency in reporting practices and that the bulk of long-range systems is considered. Ideally, a formal agreement and clarification of definitions could be useful, especially to ensure that reporting practices are as inclusive as possible, within the current scope and without impinging on the security imperatives of states.

In the longer term

Consultation and informal discussions might be useful today to think about what the HCoC's main focus needs to be in the longer term. In particular, the question of whether conventional systems require the same level of transparency as WMD-capable delivery vehicles is a point to consider seriously. The scope of the Code has been defined through diplomatic compromise and the consideration of pragmatic questions.[78] However, if the purpose of the Code remains to limit the proliferation of WMD means of delivery and to avoid misunderstandings about currently deployed systems, then it might be indispensable to rethink the current exclusion of non-ballistic systems. If, however, there is a collective will to provide the same level of transparency for non-nuclear strategic weapons, the wording of the text of the Code may need to evolve. In parallel, fixing a minimum ceiling for pre-notification, for instance around 500 km of range, may keep with the pragmatic approach of the Code by ensuring that the current use of short-range missiles for military strikes (or tests), while concerning, does not entail the same risk of misunderstanding and misinterpretation as

78. Stéphane Delory, Emmanuelle Maitre, and Jean Masson, 'Opening HCoC to Cruise Missiles: A Proposal to Overcome Political Hurdles,' *HCoC Research Paper No. 5*, FRS, February 2019, https://www.nonproliferation.eu/hcoc/opening-hcoc-to-cruise-missiles-a-proposal-to-overcome-political-hurdles/.

longer-range tests, thereby not threatening the credibility of the instrument.

Gliders and hypersonic cruise missiles might therefore constitute the visible part of a trend that accentuates the need for transparency and confidence-building mechanisms specifically dealing with missiles, but also the need to reconsider the main vocation of these international agreements to ensure their relevance in the next ten to twenty years. □

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THE HAGUE CODE OF CONDUCT

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The Hague Code of Conduct

The objective of the HCoC is to prevent and curb the proliferation of ballistic missiles systems capable of delivering weapons of mass destruction and related technologies. Although non-binding, the Code is the only universal instrument addressing this issue today. Multilateral instrument of political nature, it proposes a set of transparency and confidence-building measures. Subscribing States are committed not to proliferate ballistic missiles and to exercise the maximum degree of restraint possible regarding the development, the testing and the deployment of these systems.

The Fondation pour la Recherche Stratégique, with the support of the Council of the European Union, has been implementing activities which aim at promoting the implementation of the Code, contributing to its universal subscription, and offering a platform for conducting discussions on how to further enhance multilateral efforts against missile proliferation.

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