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

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Foreword

In launching his new agenda for disarmament, *Securing Our Common Future*, Secretary-General António Guterres made the case for the cooperative pursuit of collective security, noting that global insecurity is the paradoxical but inevitable result of each country pursuing security individually.

This paradox is evident in the race, between a small number of States, to attain new long-range delivery systems, namely hypersonic boost-glide systems (commonly known as hypersonic weapons), we are witnessing today.

This blinkered pursuit of a novel technology with as yet unproven military utility could have potentially far-reaching and damaging ramifications. Those ramifications remain largely unexamined and almost wholly undiscussed within the multilateral disarmament machinery. This study urges the international community to take steps to remedy this inattention as a priority.

Strategic arms control is in crisis. Despite the clear benefits of cooperative arms limitation endeavours, some influential actors have seemingly turned away from this concept as the surest way to achieve security.

The development of hypersonic weapons is another source of concern in this context, threatening to destabilize arms control frameworks that have reduced nuclear risks for more than four decades or to usher in a new era of long-range conventional warfare. The relatively nascent state of this technology, however, also provides a potential opening. States have an opportunity to proactively seek to define and address the risks associated with hypersonic weapons in a cooperative manner in this crucial window before they are deployed.

Preventing the emergence of new and destabilizing strategic weapons is a vital task for the international community in our shared endeavour to preserve international peace, security and stability. I hope that this study can help foster discussion on this important topic.

Izumi Nakamitsu
Under-Secretary-General
and High Representative
for Disarmament Affairs
February 2019

Summary

The pursuit by several nuclear-armed States of novel long-range strike options has received little attention in multilateral disarmament discussions despite their potentially negative implications for security, arms control and disarmament. This study aims to raise awareness of these implications and to consider possible ways to address them in a multilateral context. It includes overviews of: the current state of technology; possible implications for international peace and security; possible implications for existing and future arms control and disarmament efforts; and different approaches States may pursue to address these challenges.

Current state of technology

Several States are actively pursuing novel long-range manoeuvrable weapons, most significantly hypersonic boost-glide systems comprising ballistic missiles equipped with hypersonic glide vehicles (HGVs). HGVs are unpowered after separation and do not follow a ballistic flight path after the boost phase. They may have an enhanced ability to overcome missile defences due to both this manoeuvrability as well as their depressed trajectories relative to standard ballistic missiles.

Research into boost-glide technology dates back to the 1930s but accelerated in the early 2000s. Today, three nuclear-armed States – China, Russia and the United States – have active HGV acquisition programmes and have each undertaken several

flight tests. These systems are expected to reach operational readiness within a decade in general, and as early as later in 2019 in one case.

In addition to these three States, it has been reported that Australia, France, India and Japan have conducted at least some investigation into hypersonic boost glide technology, although little information about these programmes is publicly available. At least one State is also actively investing in research on countermeasures for HGVs.

The United States has made explicit its intention to use boost-glide technology with conventional or kinetic (non-explosive) warheads. China and Russia have made no such statements, and it is plausible that they would deploy their boost-glide systems with nuclear warheads.

Implications for international peace and security

There is a clear arms race dynamic associated with the pursuit of HGVs. Relevant States appear to be at least in part motivated by the pursuit of this technology by rivals, as well as the pursuit or possession of other strategic technologies – in particular missile defences – in their own pursuit of HGVs. The burgeoning pursuit of counter HGV capabilities adds to this arms racing dynamic.

Although the military utility of hypersonic boost-glide systems remains uncertain, there are scenarios in which they may offer useful new capabilities. These capabilities may not necessarily be strategic in nature but could nevertheless have strategic ramifications. Ambiguity regarding the nature of an HGV's warhead (nuclear or conventional), together with the possible ambiguity of an HGV's intended target, means that the potential for misunderstanding is considerable, particularly given the high speeds and corresponding short decision-making and reaction times associated with HGV use. Further to the potential for misunderstanding, any use of a boost-glide system could be interpreted as signalling an imminent nuclear attack and thus be inherently escalatory.

It is possible that some States could amend doctrines to expand the conditions necessary for the use of nuclear weapons in response the deployment of hypersonic weapons. Postures might also be adapted, including by placing nuclear forces on higher alert levels.

Regardless of whether these weapons prove to have a directly destabilizing effect, the development of hypersonic boost-glide systems is part of a broader contemporary trend toward the development of new strategic capabilities, including missile defences and related-space based infrastructure, that poses serious challenges for the maintenance of international peace and security.

Implications for existing and future arms control and disarmament efforts

Emerging hypersonic weapon technologies present a challenge for the existing arms control and disarmament architecture at a time when it is already under strain. New START is the key arms control agreement limiting the strategic delivery systems of Russia and the United States. HGVs do not count towards the Treaty's limits as it covers only those missiles that have a ballistic trajectory. New START provides for either party to raise the issue of new strategic offensive arms if they believe they are emerging, leaving open the possibility that the two parties could discuss and reach agreement on including HGVs in the Treaty's scope. The prospects of this happening would not however appear to be very good in the current strategic environment.

The bilateral nature of New START – and the Intermediate-Range Nuclear Forces Treaty, which is also relevant – is a further complicating factor. The development of strategic systems that are excluded from these arrangements either due to a technical carve out or a treaty's bilateral nature risks further problematizing the perceived value of strategic arms reductions. This may also give credence to arguments against the utility of arms control for managing emerging security challenges.

The broader implications of the development and possible deployment of hypersonic weapons for arms control and nuclear disarmament processes are difficult to assess. Even a limited deployment could seriously disrupt nuclear disarmament efforts. One particularly worrying possibility is the resumption of nuclear testing to verify HGV warheads.

Arms control approaches

There are several existing international instruments and bodies that deal with the issue of missiles in general, including the United Nations General Assembly's First Committee, the Missile Technology Control Regime, the Hague Code of Conduct against Ballistic Missile Proliferation, the Wassenaar Arrangement, the United Nations Register of Conventional Arms, Security Council resolution 1540 (2004) and the bilateral arms control arrangements discussed above.

Arms control can, inter alia, reduce risks, provide incentives against escalatory actions and contribute to disarmament objectives. Arms control can take various forms. Arrangements can be legally binding or politically binding. They may be multilateral, plurilateral, bilateral or unilateral.

In the case of HGVs, States may also seek to pursue various transparency and confidence-building measures (TCBMs). Such measures could prepare the ground for eventual arms control measures. Possible TCBMs include the exchange of information on test flights, crisis communications, dialogue on risks, doctrines, strategies and policies, non-targeting statements, de-alerting, and the use of existing arms transparency instruments.

Although only three States have engaged in advanced HGV development at present, it is both feasible and desirable for States to pursue a multilateral process addressing issues related to the development of hypersonic weapons, the development of which cannot be seen in isolation from the prevailing deterioration in strategic arms control. It is clear that a significant amount of work is required before any formal multilateral process could proceed, including outreach and awareness raising activities. The United Nations Office for Disarmament Affairs and the United Nations Institute for Disarmament Research will seek to use this study as a platform for such outreach, in the hope of providing a constructive contribution to international debate on resurrecting effective strategic arms control and disarmament processes.

Introduction

1. Several States are actively pursuing novel long-range strike options with potentially negative implications for international security and global disarmament efforts. Despite the potentially destabilising consequences of these weapons technologies, they have received little attention in multilateral disarmament discussions and generally lie outside the scope of missiles covered by existing bilateral arms control treaties. This study follows from a recommendation by the Secretary-General's Advisory Board on Disarmament Matters that new forms of long-range conventional weapons, including those using hypersonic technologies, could "eventually upset strategic stability" and deserve further study.[1]

2. This study focuses on hypersonic boost-glide systems, which may be conventionally or nuclear-armed, and also considers manoeuvrable re-entry vehicles. A central point in this regard is that manoeuvrable missiles travelling at hypersonic speeds appear to offer new military capabilities and might be able to hold at risk assets deemed crucial to a targeted State's ability to use its nuclear forces. This potential could change the deterrence calculus for nuclear-armed States, increase ambiguity in terms of crisis thresholds, and dramatically escalate a crisis or conflict if used.

[1] A/71/176, para. 14.

3. The study is organized into four parts. The first part provides an overview of the current state of the relevant technology, including a snapshot of the weapon development programmes of key States. The second part considers possible implications for international peace and security, with a focus on the potential for these technologies to feed an arms race dynamic between nuclear-armed States and to raise the likelihood of strategic miscalculation or unintended escalation between those States. The third part examines implications for existing and future arms control and disarmament efforts. The final part focuses on arms control approaches, surveying existing international instruments relevant to the control of these technologies, considering different options States may pursue in seeking to address some of the challenges they raise, and providing some thoughts on possible ways to take forward consideration of these possibilities.

4. To inform the preparation of the study, the United Nations Office for Disarmament Affairs (UNODA) and United Nations Institute for Disarmament Research (UNIDIR) co-organized a track 1.5 meeting, held under the Chatham House rule, to provide a forum for a semi-structured consideration of these issues by a small number of invited government officials and non-governmental experts.[2] The purpose of the meeting was threefold: to raise awareness about hypersonic weapons and their possible implications, to promote intergovernmental discussion, and to gather views – in particular on possible arms control approaches. The meeting demonstrated that States have significant interest in learning more about these technologies and continuing discussion on the associated risks, implications and possible strategies for their management.

5. The pursuit of long-range hypersonic weapons cannot be seen in isolation from the prevailing deterioration in strategic arms control arrangements and efforts. It is hoped that this study

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[2] The meeting was held at the Palais des Nations in Geneva, Switzerland, on 12–13 November 2018.

can provide a constructive contribution to international debate on this worrying trend and provides a resource for States and other actors seeking to continue discussion on how to resurrect effective strategic arms control and disarmament processes.

6. The study was authored by John Borrie, Amy Dowler and Pavel Podvig. UNODA and UNIDIR would also like to thank the following individuals for their valuable advice and contributions: Torbjørn Graff Hugo, Chris King, Ankit Panda, Joshua Pollack, Michael Spies, Manpreet Sethi, Dmitry Stefanovich, Amy Woolf and Tong Zhao.

I. Current state of technology

Scope and general characteristics

7. The phrase "long-range conventional weapons, including those using hypersonic technologies" could be interpreted to mean various things. This study focuses on those systems that could "eventually upset strategic stability", which reflects a concern the Secretary-General's Advisory Board on Disarmament Matters highlighted in its discussion of this issue.[3] For this reason, and keeping in mind trends in related technologies, whether or not a hypersonic system is designed for use with conventional or nuclear warheads is less important than the fact that such systems are qualitatively different to traditional long-range nuclear-weapon delivery vehicles. In some cases, these technologies could allow a missile that previously only had military utility if nuclear-armed to be used with a conventional warhead. However, this is not necessarily so in all instances, and

[3] A/71/176, para. 14. It should be noted that the term "strategic stability" is open to interpretation. See Elbridge Colby and Michael S. Gerson (eds.), *Strategic Stability: Contending Interpretations* (Strategic Studies Institute and U.S. Army War College Press, 2013). Available at http://publications.armywarcollege.edu/pubs/2216.pdf.

a new conventional capability may not be a primary motivator for militaries pursuing these technologies.

8. While the term “long-range” has no specific definition, it is used here in the broadest sense to include any system with a range in excess of 1,000 km. For this reason, this study excludes hypersonic cruise missiles or scramjets, which typically have ranges below this threshold, although such technologies could eventually contribute to longer-range systems. The term hypersonic is broadly understood to refer to speeds in excess of Mach 5 (five times the local speed of sound).[4]

9. Long-range ballistic missiles in service today already exceed both these thresholds. These ballistic missiles were developed specifically to deliver nuclear weapons (although ballistic missiles of lesser ranges are deployed by some States without nuclear warheads). While there is nothing to stop long-range missiles being conventionally armed, in general they are not yet considered precise enough to be useful without nuclear payloads. Existing intercontinental ballistic missiles (ICBMs) are typically accurate to within a few hundred metres. A conventionally armed missile would need to be accurate to within a few metres to be effective.[5]

10. Rather than speed or range per se, it is the combination of range and speed with manoeuvrability that distinguishes the weapons considered in this study from earlier missiles and that, arguably, makes them strategically significant. While manoeuvrability may enable greater precision, and therefore give a system the capability to be used effectively with a conventional warhead, manoeuvrability at hypersonic speeds is also relevant

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[4] The speed of sound varies with medium and temperature. At 20˚C, the speed of sound in air is 343 m/s.

[5] James Acton, *Silver Bullet: Asking the Right Questions About Conventional Prompt Global Strike* (Carnegie Endowment, 2013), p. 5.

for seeking to evade missile defence interceptors, and possibly for missions involving moving or hardened targets.[6]

11. A small number of States are pursuing two main technological avenues in this regard: (i) ballistic missiles equipped with manoeuvrable re-entry vehicles (MaRVs)[7] and (ii) boost-glide systems comprising ballistic missiles equipped with hypersonic glide vehicles (HGVs).[8]

12. Research into MaRV technology started in the 1960s[9] and MaRVs have been deployed since the 1980s, with both nuclear and conventional payloads.[10] Their ability to manoeuvre in the terminal phase is intended to enable missiles equipped with MaRVs to better counter missile defences than missiles equipped with traditional re-entry vehicles.[11] Giving a re-entry vehicle

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[6] An ability to change the re-entry angle could make a missile more effective than systems without that ability for attacking hardened targets. See Amy Woolf, "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues" (Congressional Research Service, 2018), p. 7.

[7] The terms re-entry vehicle and warhead are often used interchangeably. It is beyond the scope of this study to examine the distinctions between the two terms, about which there are different views.

[8] One other relevant system that does not seem to fall into either of these categories is Russia's Kinzhal air-launched ballistic missile, which has a non-separating warhead and is reportedly capable of manoeuvring in its terminal phase.

[9] Acton, 2013, p. 37.

[10] The United States fielded a nuclear-armed MaRV on the Pershing II medium-range ballistic missile from 1983 to 1991. China is believed to field a number of missiles with manoeuvrable warheads. Russia has developed MaRV technology but does not appear to have fielded it to date. The Democratic People's Republic of Korea, India, Iran and Pakistan have also demonstrated interest in MaRV technology, including in the context of using these with conventional warheads.

[11] Ballistic missile trajectories can be divided into the boost, mid-course and terminal phases. The boost phase is the initial, powered segment of the flight. Mid-course refers to the segment of the flight after the missile's fuel-source has burnt out and before atmospheric re-entry. The terminal phase is the final phase of the missile's flight, commencing with re-entry into the atmosphere.

the capability to manoeuvre can also increase its accuracy and, at least in theory, provide an ability to attack moving targets. Although the introduction of MaRVs may have been a source of concern for some military planners, they are in many respects similar to traditional re-entry vehicles and, as such, will not be a major focus for the remainder of this study.

13. Like a regular re-entry vehicle, an HGV is launched from a ballistic missile (which acts as a booster rocket) and its flight is unpowered after separation. HGVs do not follow a ballistic fight path after the boost phase, however, and instead remain in the upper atmosphere for most of their flight path (unlike traditional ICBMs which spend most of their flight path above the Earth's atmosphere). This means these systems may be able to overcome missile defences designed to work during the mid-course phase, above the atmosphere. The ability of HGVs to manoeuvre over much of their trajectory could also make it more difficult to intercept them. An HGV's relatively depressed trajectory also means that early warning radars may not be able to detect them until much later than standard ballistic missiles, further contributing to their potential to overcome defences.

14. While research into vehicles resembling the boost-glide systems under development today dates back to at least the 1930s,[12] the current effort is generally dated to the early 2000s with the advent of the US Conventional Prompt Global Strike concept (subsequently renamed Conventional Prompt Strike).[13] The development of this technology is generally taking place within militaries, although some civilian (governmental and commercial) space technology development is also relevant.[14]

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[12] Acton, James M. "Hypersonic Boost-Glide Weapons." *Science & Global Security* 23, no. 3 (2015): 191.

[13] Woolf, 2018, p. 1.

[14] See for example paragraph 22 below. See also NASA, "X-37 Demonstrator to Test Future Launch Technologies in Orbit and Reentry Environments", Fact sheet number FS-2003-05-65-MSFC, March 2003. Available at https://www.nasa.gov/centers/marshall/news/background/facts/x37facts2.html.

15. There are several technical barriers to achieving a mature HGV weapon design. These include the need to manage extreme heat and the need to develop a guidance system that would be able to provide sufficient accuracy during the very challenging environment of manoeuvring hypersonic flight. Managing thermal loading (waste heat discharge) is a major technical hurdle as heating increases with velocity and atmospheric density and HGVs spend most of their flight in the atmosphere. Another factor is the massive aerodynamic forces the vehicle needs to withstand during its flight. These variables need to be managed not only to maintain the structural integrity of the vehicle, but also to ensure that the on-board instrumentation and payload remain functional. States are seeking to develop advanced materials for hypersonic glider applications.[15]

Past and current development programmes

United States

16. The United States has had several HGV research and development programmes. None of these programmes has reached the acquisition stage. All the programmes described here, other than Operational Fires and HIFiRE, were or are associated with the Conventional Strike Programme and hence designed to deliver force kinetically or with a conventional explosive warhead.

17. Lockheed Martin developed the **Hypersonic Test Vehicle** (HTV-2) as part of the Force Application and Launch from Continental United States (FALCON) project.[16] The HTV-2, which had a wedge-shaped design and an intended

[15] Robin Hughes, "Northrop Grumman tests new LEO warhead for hypersonic missiles", Jane's Missiles & Rockets, 29 October 2018. Available at https://www.janes.com/article/84118/northrop-grumman-tests-new-leo-warhead-for-hypersonic-missiles.

[16] A joint project of the United States Air Force (USAF) and the Defense Advanced Research Projects Agency (DARPA).

range of 17,000 km, was flight tested twice, in April 2010 and August 2011. In both cases it was boosted by a Minotaur IV missile (modified Minuteman II and Peacekeeper ICBMs).[17] Neither test was fully successful. In the first test, the HTV-2 reportedly achieved controlled flight in the atmosphere before telemetry was lost nine minutes into the flight. In the second, it successfully separated from the booster and transitioned to Mach 20 aerodynamic flight but soon after crashed into the ocean, a result of damage to the glider's surface from excessive heat.[18] No further flight tests are planned.

18. The United States Army has been working on an HGV known as the Advanced Hypersonic Weapon (AHW), subsequently renamed the **Alternative Re-Entry System**, since 2006. This glide vehicle is designed for placement on a booster missile of shorter range than the Minotaur-IV and it could be land, ship or submarine-based.[19] It has a conical design, making it easier to distribute heat across its surface than was the case for the HTV-2.[20] The current prototype has a range of around 8,000 km.[21] The AHW was successfully flight tested from a booster derived from the Polaris ballistic missile in November 2011.[22] The glider flew 3,800 km on a non-ballistic trajectory, sustaining hypersonic speeds and reaching its planned impact point.[23] The system's second flight test in August 2014 was a failure with the vehicle destroyed by controllers seconds after

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17 Woolf, 2018, p. 14.
18 Acton, 2013, p. 47.
19 Woolf, 2018, p. 15.
20 Acton, 2013, p. 47.
21 Acton, 2013, p. 41.
22 The Polaris was an intermediate-range submarine-launched ballistic missile, in service until 1996.
23 US Army, "DoD announces successful test of Army Advanced Hypersonic Weapon concept", Department of Defense, 17 November 2011. Available at https://www.army.mil/article/69484/dod_announces_successful_test_of_army_advanced_hypersonic_weapon_concept.

launch due to problems detected with the booster.[24] In October 2017, the US Navy conducted a third test of a modified AHW, scaled down to fit on a submarine-launched ballistic missile, which was deemed a success.[25] Future tests are planned.

19. Building on lessons learned from the HTV-2, Defense Advanced Research Projects Agency (DARPA) and United States Air Force (USAF) are partnering on the **Tactical Boost Glide Programme**, which commenced in 2014.[26] Under this programme, Lockheed Martin was awarded a $480 million contract in April 2018 to develop the Air-launched Rapid Response Weapon (ARRW).[27] Information about the intended range of this system is not currently available.

20. Lockheed Martin was also selected for the USAF **Hypersonic Conventional Strike Weapon** (HCSW) contract. As opposed to the ARRW, which has been described as "pushing the art of the possible", the HCSW is based on relatively mature technologies and would be of longer range than the ARRW.[28]

21. DARPA and the US Army recently commenced the **Operational Fires** programme, awarding three contracts in November 2018.[29] This programme aims to "demonstrate a novel ground-launched system enabling hypersonic boost-

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24 US Army, "Launch vehicle support equipment causes test failure", USASMDC/ARSTRAT Public Affairs Office, 5 February 2015. Available from https://www.army.mil/article/142263/launch_vehicle_support_equipment_causes_test_failure.

25 Woolf, 2018, p. 16.

26 Peter Erbland, "Tactical Boost Glide (TBG)", DARPA program information. Available at https://www.darpa.mil/program/tactical-boost-glide.

27 US Air Force, "Air Force awards hypersonic weapon contract", Secretary of the Air Force Public Affairs, 13 August 2018. Available at https://www.af.mil/News/Article-Display/Article/1600963/air-force-awards-hypersonic-weapon-contract/.

28 Ibid.

29 DARPA, "Program Targets Innovative Propulsion Solutions for Ground-Based Weapons Delivery System", 9 November 2018. Available at https://www.darpa.mil/news-events/2018-11-09.

glide weapons to penetrate modern enemy air defences and rapidly and precisely engage critical time sensitive targets."[30] Information about range is not currently available.

22. The US Air Force Research Laboratory partnered with Australia's Defence Science and Technology Organisation on the **Hypersonic International Flight Research Experimentation** (HIFiRE) programme from 2007 to 2017. While the programme was primarily concerned with scramjet (supersonic combustion ramjet) technology, it also involved the development and flight test of an HGV in July 2017.[31]

Russian Federation

23. Russia has explored HGV technology since at least the 1980s through the development of the **Yu-70** HGV.[32] While little is known about the Yu-70, analysts believe it was flight tested twice in 1990, and again in June 2001 and February 2004, with the UR-100NUTTH/SS-19 ICBM used as a booster.

24. **Avangard** consists of an HGV, sometimes referred to as Yu-71, deployed on a UR-100NUTTH/SS-19 ICBM. The Yu-71 appears to be a modernised version of the Yu-70. Avangard is thought to have been involved in a number of test flights, a mixture of failures and successes, between 2011 and 2019.[33] Its range is estimated to be around 10,000 km, although this has not been demonstrated in tests.[34] In his March 2018 state of the

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[30] Ibid.

[31] University of Queensland, "HIFiRE Program", Centre for Hypersonics. Available at http://hypersonics.mechmining.uq.edu.au/hifire (accessed 7 February 2019).

[32] Pavel Podvig, and Alexander Stukalin, "Russia tests hypersonic glide vehicle", *Jane's Intelligence Review*, 4 June 2015.

[33] Pavel Podvig, "Avangard System Is Tested, Said to Be Fully Ready for Deployment", *Russian Strategic Nuclear Forces* (blog), 26 December 2018. Available at http://russianforces.org/blog/2018/12/avangard_system_is_tested_said.shtml.

[34] Rahul Udoshi and Akshara Parkala, "Prompt strike: ground-launched hypersonics move against missile defences", *Jane's International Defence*

union address, Russian President Vladimir Putin said that the Avangard had successfully completed tests and confirmed that the Russian Strategic Missile Forces would receive these systems, which he described as capable of manoeuvring laterally and vertically at speeds in excess of Mach 20, "in the near future".[35] A video accompanying the speech depicted a wedge-shaped vehicle. In October 2018, Russian media quoted an industry source saying the Avangard would be deployed by the end of 2019 with the UR-100NUTTH/SS-19 ICBM as a booster.[36] There has also been speculation that the Avangard could be used with Russia's new ICBM, the RS-28 Sarmat, expected to enter service in 2021.[37] Although there is no public statement available on whether the Avangard would be nuclear-armed, most expect this would be the case given that the Strategic Missile Forces are responsible for the country's land-based nuclear missiles. In announcing the December 2018 test, President Putin reaffirmed that the system would enter into service in 2019.[38]

Review, 21 June 2018. Available at https://janes.ihs.com/Janes/Display/FG_957908-IDR.

35 President of Russia, "Presidential Address to the Federal Assembly", 1 March 2018. Available at http://en.kremlin.ru/events/president/news/56957.

36 TASS, "Russia's Avangard hypersonic missile system to assume combat duty in 2019, says source", Russian News Agency, 29 October 2018. Available at http://tass.com/defense/1028303.

37 Franz-Stefan Gady, "Russia Completes Ejection Tests of RS-28 Sarmat ICBM", *The Diplomat*, 20 July 2018. Available at https://thediplomat.com/2018/07/russia-completes-ejection-tests-of-rs-28-sarmat-icbm/.

38 President of Russia, "Visit to National Centre for State Defence Control", 26 December 2018. Available at http://en.kremlin.ru/events/president/news/59519.

China

25. The **DF-ZF**[39] HGV has been flight tested nine times since 2014, most recently in November 2017.[40] Six of those tests were deemed to be broadly successful by outside observers, although the specific objectives for each test are unknown. During these tests, the DF-ZF reportedly covered distances between 1,250 and 2,100 km and reached speeds of Mach 10.[41] The November 2017 tests reportedly involved a DF-17 MRBM booster specifically designed for use with HGVs.[42] Experts assess the DF-ZF will eventually be used with a DF-31 ICBM.[43] Whether the DF-ZF will carry a nuclear or conventional warhead remains an open question.

India

26. There is very little publicly available information on India's possible hypersonic boost-glide system, the **Shourya** (also spelled Sharuya). According to one source, it is a two-stage solid-fuel missile, capable of carrying a conventional or nuclear warhead.[44] There are reports of test flights in 2004, 2008, 2011 and 2016, with the most recent test involving manoeuvring and successfully impacting its target.[45] The version of the Shourya tested to date

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39 Also known as Wu-14.

40 January, August and December 2014, June, August and November 2015, April 2016, and twice in November 2017.

41 Tate Nurkin, "China's Advanced Weapons Systems", 12 May 2018, p. 188. Available at https://www.uscc.gov/sites/default/files/Research/Jane%27s%20by%20IHS%20Markit_China%27s%20Advanced%20Weapons%20Systems.pdf.

42 Ankit Panda, "Introducing the DF-17: China's Newly Tested Ballistic Missile Armed With a Hypersonic Glide Vehicle", *The Diplomat*, 28 December 2017. Available at https://thediplomat.com/2017/12/introducing-the-df-17-chinas-newly-tested-ballistic-missile-armed-with-a-hypersonic-glide-vehicle/.

43 Rahul Udoshi and Akshara Parakala, "Prompt strike: ground-launched hypersonics move against missile defences", 21 June 2018. Available at https://janes.ihs.com/Janes/Display/FG_957908-IDR.

44 Ajey Lele, "Hypersonic Weapons", *Institute for Defence Studies & Analyses Occasional Paper No. 46*, p. 31.

45 Udoshie and Parakala, 2018.

apparently has a range of only 700 km, but there are reports of possible plans to develop a variant with a range of 1,000 km.[46]

France

27. On 21 January 2019, France's Minister of the Armed Forces announced that France would issue a contract for the development of an HGV, under the project name **V-max**, to be flight tested by the end of 2021.[47]

Japan

28. Japan's 2019 defence budget request includes plans to develop an HGV called the **Hyper Velocity Gliding Projectile** (HVGP).[48] Japan reportedly plans to develop two variants of the HVGP, Block I to be deployed in 2026 and Block II, capable of higher speeds and more manoeuvrability, to be deployed around 2033.[49] Its range is likely in the order of hundreds of kilometres.

Possible countermeasures

29. Existing missile defence systems may not be effective against HGVs. This is for at least two reasons: unlike ballistic missiles, HGVs do not follow a predictable ballistic trajectory for most of their flight. In addition, the relatively low flight profile of an HGV means it would not be visible to line-of-sight early detection systems.

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[46] Jane's International, "Shaurya", 29 May 2018. Available at https://janes.ihs.com/Janes/Display/jswsa351-jsws.

[47] Speech by Florence Parly, Minister of the Army, France, delivered in Paris, 21 January 2019. Available at http://discours.vie-publique.fr/notices/193000129.html.

[48] Japan Ministry of Defense, "Defense Related Budget Request for JFY2019". Available at http://www.mod.go.jp/e/d_budget/pdf/300914.pdf.

[49] Kosuke Takahashi, "Japan developing hypersonic glide weapon to defend remote islands", 27 September 2018. Available at: https://janes.ihs.com/Janes/Display/FG_1101467-JDW.

30. There is little information available on what missile defence systems designed to counter hypersonic vehicles would look like, other than that they would likely incorporate space-based sensors. The 2019 US Missile Defense Review noted that the US Department of Defense has established an HGV defence programme within the Missile Defense Agency which had "demonstrated a limited capability to defend against HGVs in the terminal phase, and is pursuing new capability for early warning and tracking of HGVs."[50] The US National Defense Authorization Act (NDAA) for fiscal year 2017 provided for the establishment of defence against hypersonic boost-glide systems, including "kinetic and non-kinetic options".[51] The 2018 NDAA included $75.3 million for hypersonic missile defence.[52] The 2019 NDAA contains a section on the acceleration of the hypersonic missile defence programme, in conjunction with a "persistent space-based missile defense sensor program", providing $120.4 million.[53] DARPA is also investigating defence against hypersonic weapons, placing an emphasis on deterrence value.[54] The head of Raytheon's missile systems business was quoted in July 2018 saying that the company had discussed counter-hypersonics and using hypersonic missiles for missile defence purposes with the US Air Force and Missile Defence Agency.[55]

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[50] US Department of Defense, "Missile Defense Review 2019", p. 58.

[51] US Congress, "National Defense Authorization Act For Fiscal Year 2017", House of Representatives, 114th Congress, Report 114-840, p. 635. Available at https://www.congress.gov/114/crpt/hrpt840/CRPT-114hrpt840.pdf.

[52] US Congress, "National Defense Authorization Act For Fiscal Year 2018", 115th Congress, Public Law 115-91, p. 692. Available at https://www.congress.gov/115/plaws/publ91/PLAW-115publ91.pdf.

[53] US Congress, "John S. McCain National Defense Authorization Act for Fiscal Year 2019", 115th Congress, H.R. 5515, pp. 534, 739. Available at https://www.congress.gov/115/bills/hr5515/BILLS-115hr5515enr.pdf.

[54] DARPA, "Glide Breaker Proposers Day - July 10-11, 2018", Special Notice (SN) DARPA-SN-18-43. Available at https://www.fbo.gov/utils/view?id=5191ec06e0256914f8170a1ca65b8db0.

[55] Jill Aitoro, "4 questions with Raytheon's top missile systems executive", Defense News, 30 July 2018. Available at https://www.defensenews.com/

II. Implications for international peace and security

Potential to contribute to an arms race dynamic

31. Today's hypersonic weapon programmes appear to be driven at least in part by developments in technology rather than specific military objectives.[56] This creates a dynamic in which development in one country provides impetus for others to follow suit even if military applications of the system under development have yet to be clearly understood. As noted above, the United States began work on HGVs in the early 2000s, as part of its Conventional Prompt Global Strike programme.[57] This effort probably helped renew interest in the technology in Russia, which revived an old Soviet programme.[58] Similar considerations may have played a role when China decided to invest in hypersonic boost-glide systems as well.[59] The Russian and Chinese programmes have in turn become major factors sustaining interest in hypersonic systems in the United States.[60]

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newsletters/daily-news-roundup/2018/07/30/4-questions-with-raytheons-top-missile-systems-executive/.

56 Acton, 2013; James M. Acton, "Hypersonic Weapons Explainer" (Carnegie Endowment for International Peace, April 2, 2018). Available at https://carnegieendowment.org/2018/04/02/hypersonic-weapons-explainer-pub-75957.

57 For a discussion of the Conventional Prompt Global Strike program and the link between that program and hypersonic boost-glider systems, see Woolf, 2018.

58 Podvig and Stukalin, 2015.

59 Tong Zhao, "Calculus on Missile Defense and Hypersonic Glide", Carnegie-Tsinghua, Center for Global Policy / SIPRI, 31 March 2017. Available at https://carnegietsinghua.org/2017/03/31/calculus-on-missile-defense-and-hypersonic-glide-pub-68669.

60 See for example John A. Tirpak, "The Great Hypersonic Race", *Air Force Magazine*, August 2018. Available at http://www.airforcemag.com/MagazineArchive/Pages/2018/August%202018/The-Great-Hypersonic-Race.aspx; Amanda Macias, "'It's Real, It's Coming, It's a Matter of Time:' Missile Defense Agency Director on Hypersonic Weapons",

By all indications this reinforcing effect between different programmes will continue. The secrecy surrounding these programmes also fuels exaggerated threat perceptions, leading the arms racing dynamic.

32. Another arguably even more compelling reason for Russia to turn to this technology in the 2000s was its potential to offer means to counter US missile defence systems, especially after the US withdrew from the Anti-Ballistic Missile Treaty in 2002. In a March 2018 speech unveiling a series of new weapons, including the Avangard covered in this study, President Putin stated that the weapons had been created "in response to the unilateral withdrawal of the United States of America from the Anti-Ballistic Missile Treaty and the practical deployment of their missile defence systems both in the US and beyond their national borders."[61]

33. Another way in which hypersonic weapon programmes contribute to an arms race dynamics is the role they play in boosting the case for missile defence. Many arms control experts consider such systems to have a destabilizing effect on strategic relationships between nuclear-armed States. In the United States, the existence of Chinese and Russian hypersonic programmes has been used to advocate for deployment of space-based sensors for missile defences.[62] Russia and China, which traditionally object to the development of US missile defence capabilities, will certainly see this as a matter of concern and are likely to respond by intensifying their efforts to develop technologies that can overcome missile defences, such as hypersonic boost-glide

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CNBC, June 26, 2018. Available at https://www.cnbc.com/2018/06/26/missile-defense-agency-hypersonic-weapons-are-coming.html?__source=sharebar|twitter&par=sharebar.

[61] President of Russia, "Presidential Address to the Federal Assembly", March 1, 2018.

[62] Rebecca Kheel, "Russia, China Eclipse US in Hypersonic Missiles, Prompting Fears", *The Hill*, March 27, 2018. Available at http://thehill.com/policy/defense/380364-china-russia-eclipse-us-in-hypersonic-missiles-prompting-fears.

systems. The successful deployment of missile defence sensors in space could also strengthen the case for advocates of more far-reaching measures, such as deployment of space-based missile defence interceptors,[63] whether or not these could be used against HGVs, and ground-based anti-satellite weapons.[64]

34. The United States Missile Defense Agency has already stated that defending against hypersonic vehicles is its top priority.[65] It follows that other States may also be motivated to explore missile defences, especially if they perceive that conventionally-armed missiles may be more likely to be used than nuclear-armed missiles. Moreover, hypersonic boost-glide systems and the infrastructure supporting them are themselves vulnerable and some States may consider they require new defensive deployments to protect those assets. Missile defence, in turn, is likely to strengthen the case for expanding investment in hypersonic capabilities. Russia's hypersonic boost-glide programme apparently received significant support primarily because of its potential role in countering US missile defence plans. Should the United States move ahead with deployment of space-based sensors or begin investment in space-based interceptors, Russia can be expected to respond. That response could take different forms, from increasing the number of

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63 The plan to develop space-based interceptors already enjoys significant support in the United States. Jen Judson, "Congress Says Pentagon Must Come up with Boost Phase Missile Defense Plan next Year", *Defense News*, July 31, 2018. Available at https://www.defensenews.com/newsletters/daily-news-roundup/2018/07/27/congress-says-pentagon-must-come-up-with-boost-phase-missile-defense-plan-next-year/.

64 Aaron Mehta, "3 Thoughts on Hypersonic Weapons from the Pentagon's Technology Chief", *Defense News*, July 16, 2018. Available at https://www.defensenews.com/air/2018/07/16/3-thoughts-on-hypersonic-weapons-from-the-pentagons-technology-chief/.

65 Amanda Macias, "'It's Real, It's Coming, It's a Matter of Time:' Missile Defense Agency Director on Hypersonic Weapons", CNBC, 26 June 2018. Available at https://www.cnbc.com/2018/06/26/missile-defense-agency-hypersonic-weapons-are-coming.html.

deployed Avangard-like systems to investing in alternative delivery means.

35. China appears to be working on shorter-range systems.[66] If that is the case, that development is unlikely to affect the notional strategic balance between China and the United States. It could, however, potentially threaten some US strategic assets in Asia, which is likely to generate a response from the United States. Should the technology improve, China could also shift the emphasis of its programme to developing intercontinental-range systems. This would likely further contribute to an arms race dynamic.

Potential to contribute to strategic miscalculation or unintended escalation

36. Although the military utility of hypersonic boost-glide weapon systems is still uncertain in some respects, there are scenarios in which these systems would probably offer useful new capabilities. These capabilities would not necessarily be strategic in purpose but depending on the circumstances of their potential use may nevertheless have strategic ramifications. One complicating factor is that hypersonic weapon systems could have nuclear as well as conventional capability. Even though, in that regard, they do not differ from a number of other dual-capable systems such as cruise missiles or short-range ballistic missiles, the nature of some hypersonic systems and the circumstances in which they might be used could make this ambiguity more difficult to deal with.

37. So far, only the United States has publicly declared that its hypersonic delivery vehicles would be conventional-only systems. Its programmes are part of a broader effort to develop a "prompt strike" capability that would allow the United States to attack time-urgent targets globally; the current programme

[66] Acton, 2018.

calls for development of a hypersonic glider on a sea-based intermediate-range ballistic missile.[67] Configurations explored in the past would have involved deployment of hypersonic gliders on sea-based and land-based intercontinental ballistic missiles. While these projects have been discontinued, they could be revived once the technology is advanced enough to support them.

38. The missiles used to launch hypersonic gliders – whether intermediate- or long-range – are likely to be detected by early-warning satellites and potentially also by early-warning radars, if those are located close to the launch point. However, in a hypersonic weapon attack, the glide vehicle might not be visible to satellites or terrestrial radars during most of its flight time. This would in effect, create uncertainty about the target of the attack. This uncertainty might extend to the target country let alone the nature of the target within a country.[68] This latter ambiguity is even more complicated for States that co-locate nuclear and conventional forces. While it is possible that the country launching a hypersonic strike would seek to communicate the intent of the attack to States that are not targeted, and to those with early warning capabilities in particular, it is impossible to guarantee that this communication would be received or sufficiently reassuring. The potential for misunderstanding would be high, especially if one notes that sea-launched ballistic missiles or land-based intercontinental ballistic missiles have never been used in combat and it is impossible to know how the existing early-warning and

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67 Woolf, 2018, pp. 2, 4–5.

68 For a detailed discussion of various ambiguities related to the use of hypersonic glider vehicles see Acton, 2013, Chapter 5. Geography can also complicate the assessment of the attack. See for example Joshua Pollack, "Nuclear Deterrence and the Revenge of Geography", *Armscontrolwonk.com* (blog), 24 September 2017. Available at https://www.armscontrolwonk.com/archive/1204122/nuclear-deterrence-the-revenge-of-geography/.

command and control systems would react to their use.[69] Even if a hypersonic vehicle is detected and properly identified, it may not be known until the very last moment whether it is targeting conventional forces and facilities or nuclear forces, potentially leading to nuclear escalation.

39. Another example of the potential for escalation is the possible role of HGVs as means of attacking elements of missile defence systems. If boost-glide systems are deployed on silo-based missiles, there will be significant pressure to keep these missiles on high alert and launch them at the first indication of an attack, thus creating a very unstable situation. Such instability would be aggravated by the fact that since the number of deployed HGVs is expected to be relatively low, they would not be able to rely on 'safety in numbers' to the extent traditional silo-based ICBMs do. In addition, the potential utility of HGVs against hardened targets, including land-based nuclear forces, means that any use of such systems could be interpreted as signalling an imminent nuclear attack. Such ambiguities and escalatory attributes would be exacerbated by the short decision times involved. It should be noted that, unlike Russia and the United States, nuclear-armed States in Asia are at present largely dependent on land-based nuclear forces.

40. The potential nuclear capability of hypersonic boost-glide systems could be another source of escalatory ambiguity. For example, it is possible that a single hypersonic glider could be used to destroy a high-value target protected by missile defences, which could be the control system of the missile defence itself. Should a State consider this kind of mission, it would probably opt for using a conventional strike as the primary option. However, the adversary would have no reliable way of knowing whether the vehicle is carrying a conventional

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[69] Pavel Podvig, "Risks of Nuclear Command and Control Accidents", in John Borrie, Tim Caughley and Wilfred Wan (eds.), *Understanding Nuclear Weapon Risks* (UNIDIR, 2017). Available at http://www.unidir.org/files/publications/pdfs/understanding-nuclear-weapon-risks-en-676.pdf.

or nuclear warhead. To some extent similar considerations apply to other systems, such as certain forms of air-launched cruise missile that can be nuclear-armed.[70] It would be extremely difficult to remove the ambiguity regarding the type of payload that these systems carry, so the probability of miscalculation and escalation could be very high. Even if a State did know that an HGV launched toward it was conventionally armed, it may still view such a weapon as strategic in nature, regardless of how it was perceived by the State firing the weapon, and decide that a strategic response was warranted. Again, the short reaction times involved would complicate efforts to control escalation.

41. Whether or not hypersonic weapon systems are destabilizing, their development both reflects and contributes to broader contemporary strategic trends. As such there is interplay between developments in this domain and broader concerns, especially about missile defence capabilities and related space-based infrastructure. Nuclear-armed States also appear to be watching the development of hypersonic strike capabilities vigilantly, carefully considering whether or not it might constitute a threat to their nuclear retaliatory capabilities.

42. In this regard, it is possible that nuclear doctrines could be amended, and the conditions considered necessary for the use of nuclear weapons expanded. For example, China may change its strategic posture in light of the perceived vulnerability of its nuclear forces to HGVs and even reconsider its no first use policy. The 2018 US Nuclear Posture Review discussed the concept of a "non-nuclear strategic attacks" and said it would consider the employment of nuclear weapons in response to such attacks.[71] Other States may also consider altering their

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[70] Christine Parthemore, "The Unique Risks of Nuclear-Armed Cruise Missiles", in John Borrie, Tim Caughley and Wilfred Wan (eds.), *Understanding Nuclear Weapon Risks* (UNIDIR, 2017).

[71] Significant non-nuclear strategic attacks were said to include, but not be limited to, "attacks on U.S., allied, or partner civilian population or infrastructure, and attacks on U.S. or allied nuclear forces, their command and control, or warning and attack assessment capabilities".

nuclear doctrines, for instance by putting their nuclear forces on higher alert levels in response to the deployment of HGVs, which would be destabilizing and could contribute to unwanted escalation.

III. Implications for existing and future arms control and disarmament efforts

43. Emerging hypersonic weapon systems present an additional challenge for the existing architecture of arms control and disarmament agreements. The strategic arms control relationship between Russia and the United States is already under strain due to, inter alia, nuclear force modernization programmes, deteriorating bilateral relations, concerns about increased military competition in new spaces including cyber space and outer space, and the rise of other strategic powers, notably China. This architecture is important in itself, including for strategic stability, but also for making progress toward global nuclear disarmament objectives. Elements of this architecture in force today are the New Strategic Arms Reduction Treaty (New START) and the Intermediate-Range Nuclear Forces (INF) Treaty. New START was preceded by several other bilateral nuclear arms control and disarmament agreements. The Anti-Ballistic Missile Treaty had also been a part of this architecture until the US withdrawal in 2002. As discussed in the previous part, the US pursuit of missile defence capabilities following this withdrawal most likely gave further motivation to Russian (and

US Department of Defense, *Nuclear Posture Review 2018*, February 2018, p. 21. Available at https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF.

possibly Chinese[72]) efforts to pursue hypersonic boost-glide systems.

44. New START is the key arms control agreement limiting the strategic delivery systems of Russia and the United States. The agreement covers land-based ballistic missiles with a range of more than 5,500 km, submarine-launched ballistic missiles with a range of more than 600 km, and heavy bombers, which are defined as bombers that have a range of more than 8,000 km or that are equipped to carry long-range nuclear air-launched cruise missiles.[73] Conventionally-armed systems that meet these criteria are counted under the Treaty. The formal US position is that hypersonic boost-glide systems are excluded from the Treaty – even though they use a rocket booster during their launch – because the Treaty defines the latter as "a weapon-delivery vehicle that has a ballistic trajectory over most of its flight path."[74] Since the distinctive feature of HGVs is that they do not travel along a ballistic trajectory for the majority of their flight, they would not be covered by this definition.[75] Russia also stated that systems "that do not use ballistic trajectories of flight" should not be subject to the New START limits, although Moscow appears to be open to considering this possibility.[76]

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72 Although China has been less vocal than Russia about its opposition to US missile defences, it did make its opposition to the deployment of the US Terminal High Altitude Area Defense system in the Republic of Korea in 2017 clear. See Andray Abrahamian, "Moving On: China Resolves THAAD Dispute with South Korea", 38 North, Stimson, 9 November 2017. Available at https://www.38north.org/2017/11/abrahamianson110917/.

73 "Protocol to the Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms", 8 April 2010, Part One, Articles 37, 77, 25.

74 Ibid, Part One, Article 6.

75 For a detailed analysis of boost-glide vehicle flight trajectory, see Acton, 2015. Hypersonic cruise missiles, or scramjets, would be covered by New START.

76 Michael R. Gordon, "Russia Warns U.S. Moves Threaten 2011 Nuclear Pact", *Wall Street Journal*, 15 January 2019. Available at

45. The United States Senate explicitly adopted an understanding exempting HGVs from New START limits during the Treaty ratification process.[77] As noted earlier, Russia's position may be more flexible. Furthermore, New START allows either party to "raise the question" if it believes that "a new kind of strategic offensive arm is emerging."[78] This provides a possibility for Russia and the United States to reach an agreement that would include HGVs under the scope of New START. The prospects for an agreement of this kind, however, are not good given that neither side has indicated willingness to raise the issue. Furthermore, it is not clear if New START itself will be extended or replaced by a new agreement before it expires in 2021.

46. The consequences of a failure to subject HGVs to arms control measures are difficult to predict. For Russia as well as the United States these systems offer a niche capability, which could possibly be achieved by other means. The full extent of current plans is unknown, but by all indications respective deployment is unlikely to exceed about a dozen delivery vehicles on each side, which means that these systems are unlikely to affect the strategic balance between the United States and Russia. At the same time, if they are not constrained, HGVs could offer a way to expand the strike potential of strategic forces, leading to the instabilities and risks outlined earlier in this report. At a minimum, their ability to hold adversaries' nuclear forces at risk means that HGVs will have some impact on future nuclear arms control efforts.

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https://www.wsj.com/articles/russia-challenges-u-s-compliance-with-nuclear-treaty-11547548200.

77 US Department of State, "New START Treaty: Resolution of Advice and Consent to Ratification", 22 December 2010. Available at https://2009-2017.state.gov/t/avc/rls/153910.htm.

78 "Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms", 8 April 2010, Article V. Available at https://www.state.gov/documents/organization/140035.pdf.

47. Another complicating factor is that New START and the INF Treaty are bilateral Russia-United States arrangements and their limitations do not cover strategic forces of other States. Moreover, the INF Treaty is currently under severe stress as a result of a disagreement about compliance with its obligations (refer paragraph 53). There is considerable uncertainty about the future of the New START as well.

48. It can be argued, however, that if Russia and the United States agreed to subject hypersonic weapon systems to arms control measures, for instance by expanding the scope of New START, such an agreement would have a strong normative effect, even if it is not applicable to other States. On the other hand, an active HGV programme in a third country would complicate the task of reaching an agreement under New START. The development of strategic systems that are excluded from these arrangements either due to a technical carve out (arguably the case for New START) or the agreement's bilateral nature (more relevant for the INF Treaty) risks further undermining these strategic arms reduction agreements and giving credence to arguments against the utility of arms control for managing new and emerging security challenges.

49. The broader implications of current hypersonic weapon developments for existing arms control regimes and the nuclear disarmament process are rather difficult to assess. One worrying prospect is the possibility of the resumption of nuclear testing, justified by the need to verify the design of nuclear warheads for HGVs. Such a scenario would be extremely damaging for the prospects of the Comprehensive Nuclear-Test-Ban Treaty ever entering into force. As noted earlier in this study, the development of hypersonic systems has already generated arms race dynamics. Barring serious technological setbacks or a coordinated effort among States to limit these systems, this dynamic is likely to persist. At the very least, the lack of constraints on these (as well as other) new technologies could complicate future arms control and disarmament efforts and harm the international security situation.

IV. Arms control approaches

50. The preceding two sections have laid out various challenges associated with the pursuit of the technology under discussion, in particular hypersonic boost-glide systems. Arms control measures can address some of those problems, directly or indirectly. Given the anticipated deployments of HGVs, it is particularly timely for States to identify and consider possible arms control measures. Arms control can have various objectives, including to: reduce risks through increased transparency and predictability; reduce incentives to launch surprise attacks; reduce incentives to engage in arms racing; reduce the risk of miscalculation and accidents during crises; and reduce escalatory potential.[79] Arms control also contributes to ultimate disarmament objectives.

51. It should also be noted that there are various challenges complicating any prospective arms control efforts today, including challenges specific to HGVs. These include the prevailing climate of political mistrust coupled with a diminished sense that arms control can be mutually beneficial, particularly given the perception within some States that HGVs can provide real military advantage. This political mistrust is compounded by a growing perception that (some) States cannot guarantee future governments will abide by agreements entered into today. The multipolar strategic environment is a further complicating factor, much more so than when current and previous arms control agreements were negotiated. In the case of HGVs, the added complexity of the involvement of more than two key players is demonstrated by the very distinct motivations those key players have for pursuing these technologies (i.e.

[79] Corentin Brustlein, "The Erosion of Strategic Stability and the Future of Arms Control in Europe", *Proliferation Papers*, No. 60, November 2018, pp. 51–54.

evading missile defence versus attaining a prompt long-range conventional strike capability).

52. This section will describe international instruments or bodies that deal with or have historically dealt with the issue of missiles in general. It will then survey various different arms control initiatives, as well transparency and confidence-building measures, that could be applied specifically to hypersonic boost-glide systems and possibly manoeuvrable re-entry vehicles, including by drawing upon a track 1.5 meeting on the topic convened by UNODA and UNIDIR in November 2018. Finally, it will consider possible forums and strategies for taking consideration of these issues forward.

Relevant existing international instruments or bodies

53. The **First Committee** of the United Nations General Assembly has maintained an agenda item on missiles since its 55th session in 2000.[80] The Assembly has established three Panels of Governmental Experts on the issue of missiles in all its aspects, meeting in 2001-02, 2004 and 2007-08.[81] None of the Panels discussed boost-glide systems. While the issue remains on the agenda of the First Committee, there has been no resolution on the topic since 2008 (A/RES/63/55).

54. Missiles are covered in various legally binding **bilateral strategic arms reduction regimes** between the Russian Federation and United States, including the INF Treaty and New START. The former requires its two parties to eliminate all ground-launched missiles with ranges between 500 and 5,500 km, while the latter places limits on the number of their deployed ICBMs, SLBMs and strategic bombers. The Soviet Union and United States also agreed to limit missile defences

[80] It was first added to the agenda through resolution A/RES/54/54 F introduced by the Islamic Republic of Iran.

[81] A/57/229, A/61/168, A/63/176.

in the 1972 Anti-Ballistic Missiles Treaty, however the United States pulled out of that arrangement in 2002. Furthermore, on 1 February 2019, the United States announced it would suspend its obligations under the INF Treaty for six months effective 2 February 2019, and complete its withdrawal at the end of those six months unless Russia came "back into compliance by destroying all of its violating missiles, launchers, and associated equipment".

55. The **Missile Technology Control Regime** (MTCR) is a 35-member voluntary export control regime that aims to limit the spread of ballistic missiles and other uncrewed delivery vehicles capable of carrying weapons of mass destruction (WMD). It covers WMD delivery systems and components with ranges of at least 300 km and treats systems capable of delivering payloads of 500 kg or more (Category I) more stringently than those with smaller capacities (Category II). Payload is defined within MTCR as the mass that can be delivered that is not used to maintain flight, so even if an HGV delivered force kinetically, it would not itself be defined as the payload but as part of the delivery vehicle. As a result, while all systems discussed in this study would likely be covered by the MTCR by virtue of their range, it is conceivable that some could fall within its less restrictive Category II. Boost-glide systems have not been discussed to date at annual MTCR meetings.

56. Under the **Hague Code of Conduct** against Ballistic Missile Proliferation (HCoC) States have made a politically binding commitment to exercise maximum restraint in developing, testing and deploying ballistic missiles, and to transparency measures on policies and launches of ballistic missiles and civilian space vehicles. 139 States subscribe to HCoC. The ballistic missile boosters used in boost-glide systems, as well as the ballistic missiles delivering MaRVs, would be subject to the commitments made by HCoC subscribers. While boost-glide systems have not been explicitly discussed within the regime, it is likely that some flight tests of relevant systems have been reported on under the Code.

57. Forty-two States participate in the **Wassenaar Arrangement**, which seeks to promote transparency and greater responsibility in transfers of conventional arms and dual-use goods and technologies. Participating States apply export controls to items set forth in the arrangement's control lists. Ballistic missile systems and components are covered in the arrangement's dual-use list category 9 (aerospace and propulsion). Re-entry vehicles are included in the munitions list (ML4). HGVs could also fall under the "high velocity kinetic energy weapon systems" category in the arrangement's munitions list (ML12), although that category seems designed primarily with rail gun technology in mind.

58. The **United Nations Register of Convention Arms** includes missiles and missile launchers as a category. Ballistic or cruise missiles "capable of delivering a warhead or weapon of mass destruction" to a range of at least 25 km are covered.[82] The Group of Governmental Experts on the Register has not considered the implications of HGVs, which are not explicitly included in the missiles category (in contrast, remotely piloted vehicles and MANPADS are explicitly included). Only 36 Member States submitted reports to the Register for 2017.[83] Of those, 17 States reported on imports and/or exports of missiles and 13 States reported on their missile holdings.

59. In **resolution 1540** (2004), the Security Council decided that all States shall adopt and enforce laws prohibiting non-State actors from the manufacture, acquisition, possession, development, transport, transfer or use weapons of mass destruction or their means of delivery.

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82 For more information, see https://www.un.org/disarmament/convarms/transparency-in-armaments/.

83 A/73/185, p. 3.

Possible arms control approaches

60. Arms control can take various forms. Arrangements can be legally binding or politically binding. They may be multilateral, plurilateral, bilateral or unilateral. They may comprehensively ban a class of weapons, place restrictions on their use, limit their numbers or seek to curb their proliferation. An arms control measure covering hypersonic boost-glide systems or HGVs could be standalone or form part of a broader arrangement covering other strategic systems. Given the importance of other weapons systems, particularly missile defences, as a motivating factor for the pursuit of this technology, the latter may be more realistic. Ultimately, the form an arms control measure takes will be determined by its objectives and what is feasible given the States involved. Possible outcomes are surveyed below.

61. The most direct and robust way to address the issues raised by boost-glide systems would be a **multilateral international legally binding regime**. This could take the form of an outright ban or something in the style of the Nuclear Non-Proliferation Treaty that restricts the technology to those States already in possession. A legally binding instrument would likely require some form of verification to be effective and acceptable to a broad range of parties. Verification measures could include continuous monitoring systems, facilities declarations, inspections and regular data exchanges. Given the current deadlock in the Conference on Disarmament, such an agreement could be pursued directly by the interested parties. Alternatively, a process under the auspices of the United Nations could proceed through a dedicated negotiating body, which could be created and mandated by the General Assembly, following the examples of the Arms Trade Treaty and Treaty on the Prohibition of Nuclear Weapons.

62. Given the relatively small number of States currently pursuing hypersonic weapon technologies, and the likelihood that this number will stay relatively low, another option could to pursue a **bilateral or plurilateral legally binding instrument**,

either specifically on the issue of hypersonic weapons or as part of a broader bilateral (or possibly, trilateral) strategic arms reduction agreement (refer paragraph 44). Article V(2) of New START provides a party believing that a "new kind of strategic offensive arm is emerging" the right to raise it within the Treaty's Bilateral Consultative Commission. Even if the Treaty is not extended in 2021, there could be a useful norm-setting value to these consultations.

63. Another avenue for pursuing a legally binding prohibition or limitation on these technologies would be the **revival and expansion of the INF Treaty**. In 2007, Russia held consultations on a draft proposal to the First Committee aimed at multilateralizing the INF Treaty. The same year, Russia and the United States issued a joint statement during the sixty-second session of the General Assembly, marking the Treaty's 20th anniversary, calling on all interested States to "discuss the possibility of imparting global character" to the INF.[84] The proposal did not gain any traction and the United States dissociated itself from these efforts soon afterwards. Following the US announcement about its intention to withdraw, Russian President Vladimir Putin reaffirmed his country's position that it would be worth pursuing broadening the Treaty.[85] While Russia and the United States are the Treaty's two main parties, Soviet successor States Belarus, Kazakhstan and Ukraine also actively participate in the Treaty's implementation.[86]

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84 US Department of State, "Joint U.S.-Russian Statement on the Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles at the 62nd Session of the UN General Assembly", 25 October 2007. Available at https://2001-2009.state.gov/r/pa/prs/ps/2007/oct/94141.htm.

85 Reuters, "Putin: Nothing to stop new states joining nuclear pact with U.S. and Russia", 18 December 2018. Available at https://www.reuters.com/article/us-usa-russia-missiles-putin/putin-nothing-to-stop-new-states-joining-nuclear-pact-with-u-s-and-russia-idUSKBN1OH15Y.

86 US Department of State, "Treaty Between The United States Of America And The Union Of Soviet Socialist Republics On The Elimination Of Their Intermediate-Range And Shorter-Range Missiles (INF Treaty)".

64. Another legally binding measure would be a **flight test ban,** which could be viewed as sufficient in itself or as an interim step toward a comprehensive prohibition. This would likely only be useful for HGVs, not MaRVs, since the latter are already deployed. Moreover, given how close some States are to deployment, this could lead to a temporary acceleration in testing.

65. If legally binding approaches are not feasible, **politically binding measures** that go beyond transparency and confidence-building measures (which are outlined in the next section) to impose limitations or reductions may be an option. Such arrangement may be bilateral or plurilateral, or even unilateral as in the Presidential Nuclear Initiatives of 1991–92.

66. States may also seek to limit the spread of relevant technologies through **export control measures**. This could for instance be done by seeking to explicitly include hypersonic weapon technology under the existing regimes discussed above (Missile Technology Control Regime and Wassenaar Arrangement).

Possible transparency and confidence-building measures

67. In addition to hard arms control measures, various transparency and confidence-building measures (TCBMs) could be pursued. These approaches are not necessarily mutually exclusive and may rather be mutually reinforcing. TCBMs could prepare the ground for eventual arms control measures. Some of the verification measures listed in paragraph 60 above could be pursued as TCBMs in their own right. Possible TCBMs are outlined below.

Available at https://www.state.gov/t/avc/trty/102360.htm (accessed 7 February 2019).

68. States could formalize the **exchange of information on flights**, including test flights, of relevant systems. States subscribing to HCoC should already use that mechanism to provide flight notifications. States which do not participate in HCoC could seek to opt in for flights involving specific technologies, such as HGVs, or to enter into specific bilateral or plurilateral arrangements. While practice and infrastructure for such information sharing already exists between Russia and the United States, it does not include China, which is also not an HCoC subscribing State.

69. In a similar vein, while infrastructure is in place between Russia and the United States for **communications at times of crisis**, no such channels are known to exist between China and the United States. Establishing hot lines or similar would have broader benefits for crisis stability but would be especially important given the ambiguities relating to HGV warheads and targets.

70. Many participants in the November 2018 meeting were of the view that the risks and doctrine associated with the deployment of boost-glide systems had not been adequately explored, either within States, or collectively between relevant States. An exchange of information or **dialogue on risks and doctrines, strategies and policies** associated with these technologies could as such be worthwhile and serve to build confidence.

71. Relevant States could seek to formalize arrangements for an information exchange on nuclear weapons-related and other critical infrastructure, with the aim of agreeing to reciprocal **non-targeting** statements.[87]

72. While addressing much more than the technologies under consideration here, many participants in the November meeting pointed out that **de-alerting** nuclear forces would help

87 Brustlein, 2018, p. 65.

address some of the particularly destabilizing aspects of HGVs, particularly in relation to the short reaction times they entail.

73. The Group of Governmental Experts on the continuing operation of the **United Nations Register on Conventional Arms** and its further development will meet again in 2019. It could seek the explicit inclusion of HGVs and MaRVs in the Register's category on missiles as a contribution to transparency about these sensitive technologies. In its most recent report (A/71/259), the Group recommended including unmanned combat aerial vehicles as a new subcategory, a recommendation subsequently endorsed by the General Assembly.[88]

Possible ways forward

74. Although only three States are believed at present to have engaged in advanced HGV development, it is feasible and desirable for States to pursue a multilateral process that would address issues related to the development of hypersonic weapons (or, more narrowly, boost-glide systems). The goal of this process could be to consider measures that minimize the risks associated with weapons of this kind and perhaps agree on transparency measures or even restrictions on development and deployment. This process, however, would have to deal with the fact that the States developing these systems are likely to have quite different understandings of their purpose, and diverging perceptions about the dangers associated with their development and deployment. This could make it challenging to reach a common understanding.

75. A formal multilateral negotiation process could be mandated by the General Assembly and could be preceded by a General Assembly-mandated Group of Governmental Experts (GGE). This GGE could either be dedicated specifically to the issue of hypersonic weapons, or it could be a broader GGE such

[88] A/RES/71/44.

as a revived group on the issue of missiles in all its aspects or a group on on strategic arms control more broadly. Alternatively, intergovernmental consideration between a larger number of States (GGEs are typically limited to 20 members) could proceed without a General Assembly mandate. Such discussions could take place in the context of the Conference on Disarmament or as a standalone plurilateral process led by a group of interested States.

76. It is clear that a significant amount of groundwork needs to take place before any such formal process could be initiated. In the meantime, States can be expected to continue to raise the issue only marginally in multilateral settings such as the First Committee, Conference on Disarmament and United Nations Disarmament Commission.

77. Several participants in the November meeting expressed the view that although the topic was ripe for discussion, many States had little or no awareness of the technologies and issues related to HGVs. For this reason, informal and ad hoc discussions and awareness-raising is necessary in the immediate term. To this end, UNODA and UNIDIR intend to raise awareness, including through the preparation of this study and events promoting it to States at relevant meetings.