# The Emerging Defence Against Hypersonic Systems: An Analysis

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In April 2024, the head of the Russian Ministry of Defence announced that the Russian "troops will receive the first samples of the new generation S-500 anti-aircraft missile systems."[1] The statement further noted that the S-500 anti-aircraft missile system will have two modifications: "the long-range anti-aircraft missile systems and missile defence systems." While the statement does not carry any direct reference to the capability of the S-500 in intercepting hypersonic weapons, it, however, noted that the system will give Russia the capability to target and destroy current and future aerospace weapons in "the entire range of altitudes and speeds."[2] The press release comes as Russia has already used its hypersonic missiles multiple times against Ukraine in the current Russia-Ukraine War. The Russian side's claims about the S-500's capabilities are significant, as currently, there is no defence system that can intercept hypersonic missiles. However, countries are making progress in developing defence systems that

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1. "Shoigu: The S-500, Modified for Missile Defense, will Enter Service with the Troops in 2024", *TACC,* April 23, 2024, https://tass.ru/armiya-i-opk/20624633. Accessed on May 18, 2024.
2. Ibid.

could help intercept hypersonic weapons. This article explores the current progress made by countries such as the US and Russia in developing missile defence systems capable of intercepting hypersonic weapons.

## UNDERSTANDING HYPERSONIC DELIVERY SYSTEMS

Hypersonic delivery systems, the new parlance of offensive strategies, have a historical context. While the interest in hypersonic systems is not new, dating back to the Cold War era, the latest surge in interest can be traced back to the early 2000s. This was when the US initiated its hypersonic glide delivery vehicle programme under the Conventional Prompt Global Strike strategy.[3] Russia also made a significant claim in February 2004, stating that it had tested a warhead that "will fly at hypersonic speed and will be able to change trajectory both in terms of altitude and direction, and missile defence systems will be powerless against them."[4] China also tested its Hypersonic Glide Vehicle (HGV), dubbed the 'Wu-14', in 2014[5] and has since deployed several types of hypersonic delivery systems. Both Russia and China have managed to outpace the US in the hypersonic race and now possess a variety of these weapon systems. This historical backdrop sets the stage for the current developments in hypersonic technology. Currently, countries are interested in developing two kinds of hypersonic

3. "Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues", Congressional Research Service, July 16, 2021, p. 9, https://sgp.fas.org/crs/nuke/R41464.pdf. Accessed on May 18, 2024.
4. Pavel Podvig, "Russian Hypersonic Vehicle: More Dots Added to Project 4202", *Russian Strategic Nuclear Forces,* August 26, 2014. https://russianforces.org/blog/2014/08/russian_hypersonic_vehicle_-_m.shtml. Accessed on May 18, 2024.
5. Mimi Lau, "China Mounts Third Hypersonic 'Wu-14' Missile Test, US Report Says", *South China Morning Post,* December 6, 2014, https://www.scmp.com/news/china/article/1656748/china-mounts-third-hypersonic-wu-14-missile-test-us-report-says. Accessed on May 18, 2024.

delivery systems. One is the Hypersonic Glide Vehicle (HGV), and the other is the Hypersonic Cruise Missile (HCM).

The following table explains the differences between the HGV and HCM:

**Table I**

| | **Hypersonic Glide Vehicles** | **Hypersonic Cruise Missiles** |
|---|---|---|
| **Speed** | Mach 5+ | Mach 5+ |
| **Propulsion** | Rocket-boosted gliders. | Air-breathing supersonic-combustion ramjet or scramjet. |
| **Trajectory** | Unpredictable mid-course/ glide phase flight. | Unpredictable mid-course/ glide phase flight. |
| **Manoeuvres** | Significant in the terminal phase. | Significant in the terminal phase. |
| **Altitude** | Although it may or may not enter space during the boost phase, it remains in the atmosphere for most of the flight, thus, avoiding surface radar detection range. | It spends most of its flight in the lower altitudes of the atmosphere, reducing the radar detection range. |
| **Examples** | DF-17 (China)<br>Avangard (Russia)<br>ARRW (USA) | Zircon (Russia)<br>HAWC (USA)<br>CJ-100/DF-100 (China)[6] |

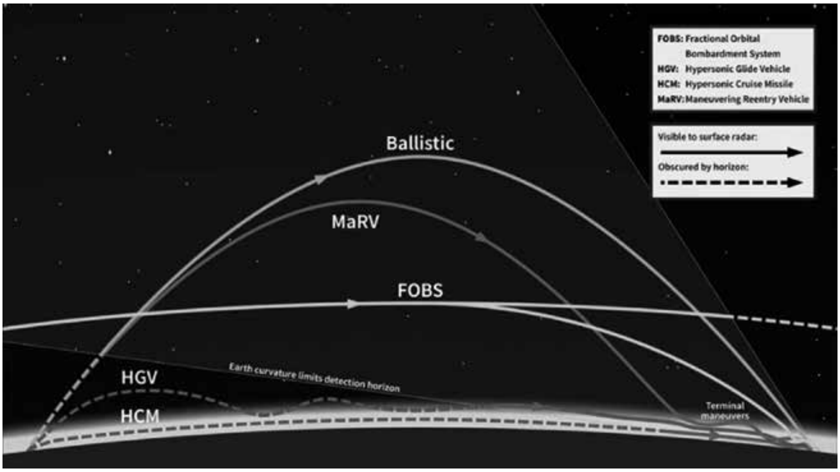
Source: Author's creation.

Besides the basic differences, a hypersonic delivery vehicle, whether an HGV or HCM, differs greatly from a ballistic missile or Manoeuvring Reentry Vehicle (MaRV). The most important difference arises from the fact that ballistic reentry vehicles and MaRVs do not induce the same hypersonic conditions regarding aerothermal conditions that an HGV or HCM tackles. Secondly, the combination of lower altitude and manoeuvrability capability

6. Speculated to be a hypersonic cruise missile. For more information, see http://eng.chinamil.com.cn/SpecialReports/2023/T/M_244588/16207147.html. Accessed on May 18, 2024.

essentially differentiates an HGV or HCM from a MaRV. Fig 1 further clarifies the existing altitude dimensions of the HGV, HCM, MaRV, and ballistic missiles.

**Fig. 1**




Source: CSIS Missile Defense Project, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/220207_Karako_Complex_AirDefense.pdf?VersionId=SmaHq1sva9Sk.TSlzpXqWY72fg8PdLvA. Accessed on May 19, 2024

Because of their advantages in speed, precision, and manoeuvrability, hypersonic systems have become a strategic priority for countries like the US, Russia, and China. However, hypersonic systems are also becoming important because they bypass legacy defence systems. An HGV, for example, can remain undetected through terrestrial-based radar until late in the flight trajectory.[7] The delay in detection fundamentally compresses the response option available to the decision-makers and permits a very narrow window, potentially just a single attempt to intercept.

7. Richard H. Speier, et al., "Hypersonic Missile Proliferation: Hindering the Spread of a New Class of Weapons", *RAND*, 2017, https://apps.dtic.mil/sti/pdfs/AD1085823.pdf. Accessed on May 19, 2024.

## THE RISING CONCERN FOR HYPERSONIC DEFENCE SYSTEMS

So far, efforts to develop hypersonic defence systems have been limited, and only the US and Russia have claimed to be working in this domain. The threat of hypersonic systems has been raised over the years because of their advantage against ground-based missile systems. The following sections examine the current state of development of hypersonic interceptors in the US and Russia.

## THE US

The US has been following the development of hypersonic systems by its adversaries such as Russia and China, and has noted the development in the Missile Defence Review (MDR) of 2019 and 2022. The 2019 MDR noted the emerging threats from hypersonic systems, particularly Russia's and China's HGV development and deployment.[8] The 2022 MDR also pointed to the same hypersonic system development by Russia and China and the need for the US to develop appropriate defence mechanisms.[9] The US Congress mandated the Missile Defence Agency (MDA) as the prime agency to develop and deploy hypersonic defences in 2016.[10] However, it was not until Fiscal Year (FY) 2018 that a proper funding line emerged. The MDA has been tasked with developing defences against hypersonic systems, and it is currently engaged in a two-phase programme. The first or initial phase is to "develop a limited defense for its near-term effort" and the second phase is about "advancing a longer-ranged defense to detect and defeat

8. Department of Defence, *Missile Defence Review*, 2019, https://www.defense.gov/Portals/1/Interactive/2018/11-2019-Missile-Defense-Review/The%20 2019%20MDR_Executive%20Summary.pdf. Accessed on May 20, 2024.
9. *2022 Missile Defence Review Facts Sheet*, https://media.defense.gov/2022/Oct/27/2003103921/-1/-1/1/MISSILE-DEFENSE-REVIEW-MDR-FACTSHEET.PDF. Accessed on May 20, 2024.
10. "National Defense Authorization Act for Fiscal Year 2017", Pub. L. No. 114–328, § 1686-1687, 130 Stat. 2628-2630 (2016), https://www.congress.gov/114/plaws/publ328/PLAW-114publ328.pdf. Accessed on May 20, 2024.

hypersonic weapons in their glide phase of flight."[11] To do that, the MDA is involved in two projects:

- The Hypersonic and Ballistic Tracking Space Sensor (HBTSS).
- A Glide Phase Interceptor (GPI).

***Hypersonic and Ballistic Tracking Space Sensor (HBTSS)***

As argued earlier, a hypersonic system works on the principles of speed, manoeuvrability, and altitude, making it harder to detect and intercept, especially in the terminal phase. More importantly, during the terminal phase, because of the manoeuvring capability, a hypersonic system gives a relatively very short window "for commuting a fire control solution, communicating with command authorities, and completing an engagement."[12] In 2019, the Donald Trump Administration initiated research on space-based sensors, and the HBTSS was the direct outcome of this study. The foremost task of the HBTSS is to "provide birth to death tracking of ballistic and hypersonic missiles, which will include detection, tracking, and discrimination of these capabilities." Once functional, the HBTSS will work on the principle of placing hundreds of satellites in Low Earth Orbit (LEO), which will be "a proliferated constellation of sensors in low earth orbit, [and] be able to detect, track and maintain custody of hypersonic weapons as they traverse the globe, feeding that information to fire control systems that can eliminate the threat."[13] The HBTSS will assist

11. Tom Karako and Masao Dahlgren, "Complex Air Defense: Countering the Hypersonic Missile Threat", Centre for Strategic and International Studies, February 2022, p. 18, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/220207_Karako_Complex_AirDefense.pdf?VersionId=SmaHq1sva9Sk.TSlzpXqWY72fg8PdLvA. Accessed on May 20, 2024.
12. Ibid.
13. Nathan Strout, "The MDA is Still in Charge of Hypersonic-Tracking Space Sensors", C4ISRNET, March 17, 2020, https://www.c4isrnet.com/battlefield-tech/space/2020/03/16/the-mda-is-still-in-charge-of-hypersonic-tracking-space-sensors/. Accessed on May 20, 2024.

other new satellites having Medium Field-of-View (MFoV) sensors to "provide fire control data to missile defence system to intercept incoming threats."

The Space Development Agency (SDA) has also been tasked with placing an initial constellation of satellites in an orbit known as 'Tranche Zero' (T0). According to the FY 2022 plan, this tranche will deploy 20 small satellites. Eight of these 20 will be Wide-Field-of-View (WFoV) satellites with infrared sensors that can track hypersonic systems. On April 2, 2023, the SDA successfully launched 10 satellites under the T0 orbit.[14] On February 15, 2024, the MDA and SDA launched two HBTSS satellites and the final four T0 satellites. It is important to note that both MFoV and WFoV have been considered by the MDA to track the capabilities of the Russian Avangard and Chinese Starry Sky-2, both of which are HGVs.

***Glide Phase Interceptor (GPI)***

Since hypersonic systems travel in a domain that bypasses surface-based radars, the only time they can be intercepted is in the terminal phase. However, because of the given manoeuvre capability, especially in the terminal phase, a hypersonic system becomes much more elusive for interception. This raises concern about whether interception of hypersonic systems is possible. On March 12, 2020, Vice Admiral Jon A. Hill of the United States Navy reported that the Sea-Based Terminal (SBT) capability has "demonstrated performance against these advanced manoeuvring ballistic threats in flight-testing in the high atmosphere and just above it, kinetic terminal intercept is a stressing challenge."[15] This

14. Greg Hadley, "SDA Launches Missile Tracking Satellites; All of 'Trance 0' Now in Orbit", *Air & Space Forces Magazine,* February 14, 2024, https://www.airandspaceforces.com/sda-launch-missile-tracking-satellites-tranche-0/. Accessed on May 20, 2024.
15. Vice Admiral Jon A. Hill, USN Director, Missile Defence Agency, before the House Armed Services Committee Subcommittee on Strategic Forces,

is one of the reasons why the US is more interested in developing interceptors that can engage with a hypersonic system in the early phase of the flight. To do that, the MDA is following two interceptor programmes. These two programmes are:

- The terminal intercept programme.
- The glide-phase intercept programme.

The US is investing in the Sea-Based Terminal (SBT) system to fulfil the terminal intercept programme's needs. The SBT system, which was deployed in 2018, consists of an Aegis Baseline 9 destroyer and an SM-6 interceptor. In 2016, the US Navy and MDA successfully tested the SBT Increment 1 system against a manoeuvring target. The MDA again conducted a second test in August 2017 to further validate SBT capabilities. In FY 2023, the MDA reported that it looks forward to testing the SBT against a "next-generation hypersonic-threat representative target."[16] Currently, the US says the Aegis SBT has the capability of active defence against hypersonic systems.[17]

The US is also working to develop and deploy a glide phase hypersonic interceptor by the late 2020s. On May 15, 2024, the US signed a cooperative agreement with Japan to co-develop a hypersonic missile defence capability.[18] According to the signed agreement, the would-be interceptor will be designed to fit into the US Navy's Aegis ballistic missile defence system, the

March 12, 2020, https://www.congress.gov/116/meeting/house/110671/witnesses/HHRG-116-AS29-Wstate-HillJ-20200312.pdf. Accessed on May 21, 2024.

16. Karako and Dahlgren, n.11, p. 25.
17. David Vergun, US Department of Defence, "General Says Countering Hypersonic Weapons Is Imperative" https://www.defense.gov/News/News-Stories/Article/article/3391322/general-says-countering-hypersonic-weapons-is-imperative/. Accessed on May 21, 2024.
18. Jen Judson, "US and Japan Sign Agreement to Co-develop Hypersonic Interceptor", *Defense News*, May 15, 2024, https://www.defensenews.com/global/asia-pacific/2024/05/15/us-and-japan-sign-agreement-to-co-develop-hypersonic-interceptor/. Accessed on May 21, 2024.

modified Baseline 9 Aegis weapon system. In addition to these programmes, the Defence Advanced Research Projects Agency (DARPA) is developing what is known as the 'glide breaker' to offset "highly manoeuvrable weapons zooming through the upper atmosphere at speeds of at least Mach 5."[19] Phase 1 of the blide breaker programme exhibited the capability of the Divert and Altitude Control System (DACS) meant to help the glide breaker manoeuvre. Currently, this programme is entering the second phase, where the endo-atmospheric effects will tested on the glide breaker. According to DARPA, "if successful, the results of Phase 2 will provide the foundation for a future programme of a record interceptor."[20]

**RUSSIA**

Russia's interest in hypersonic systems goes back to the late Cold War, particularly during the 1980s. Russia focussed on developing the Avangard hypersonic glide vehicle programme during this time. After the disintegration of the Soviet Union in 1991, the Avangard project was shelved for some time, but, in the mid-1990s, under Project 4202, it was restored. From the mid-1990s to 2018, Russia conducted approximately 14 flight tests of the Avangard. Besides the Avangard, Russia has managed to deploy the Kinzhal hypersonic missile and the Zircon hypersonic cruise missile. While Russia is looking to outpace the US in developing and deploying new hypersonic systems, it is also working to deploy a new generation of missile defence systems while keeping hypersonic defence in mind.

19. Elizabeth Howell, "DARPA's 'Glide Breaker' Hypersonic Missile Interceptor Program Enters New Phase", Space.com, March 11, 2022, https://www.space.com/darpa-glide-breaker-hypersonic-interceptor-new-phase. Accessed on May 21, 2024.
20. Theresa Hitchens, "Boeing Nabs DARPA Contract for Hypersonic Interceptor Testing", *Breaking Defense,* September 11, 2023, https://breakingdefense.com/2023/09/boeing-nabs-darpa-contract-for-hypersonic-interceptor-testing/. Accessed on May 21, 2024.

In 2020, Russian President Vladimir Putin stated in his annual press conference that Russia is "working, among other things, on the 'antidote' against future hypersonic weapons."[21] It was speculated that the so-called antidote that Putin spoke about was related to the development of the S-500 system. In 2022, Russia also tested the S-550 air defence system and claimed the system could target "spacecraft, ballistic missile reentry vehicles and hypersonic targets."[22] While it is not clear if the S-550 has the capability to target an HGV or HCM, a hypersonic target can also mean a ballistic missile. More importantly, whether the S-550 can engage with the hypersonic system in the terminal phase remains unclear.

In the current context, Russia has declared that its S-500 Prometheus air defence missile system can intercept hypersonic targets. To showcase its S-500 capability against hypersonic targets, the Prometheus was engaged against an R-29RMU2 Sineva Intercontinental Ballistic Missile (ICBM). It was reported that the Prometheus successfully intercepted the Sineva ICBM. However, as in the case of the S-550, it is not clear if the S-500 can really intercept an HGV or HCM. It has been reported that the S-500 has an operational altitude of up to 200 km. Technically, a ballistic missile such as the Sineva is also hypersonic but has a predictable trajectory and low manoeuvre capability, thus, making it vulnerable, especially during the mid-course flight. In comparison, as argued earlier, an HGV or HCM has a different trajectory with added inputs of low-level altitude and greater

21. "Experts Name S-500 Air Defense System as Possible 'Antidote' to Hypersonic Weapons", *TASS*, https://tass.com/defense/1236865. Accessed on May 22, 2024.
22. "Russia Tests S-550 System Capable of Hitting Spacecraft, Hypersonic Targets", *TRT World*, https://www.trtworld.com/europe/russia-tests-s-550-system-capable-of-hitting-spacecraft-hypersonic-targets-53127. Accessed on May 22, 2024.

manoeuvrability. It remains to be seen if the S-500 can intercept hypersonic systems as gliders.

**CONCLUSION**

As the strategic rivalry between the US and Russia intensifies, the prospects of developing and deploying new weapon systems will increase. Hypersonic systems are one such weapon system that will help countries like the US, Russia, and China project counter-force weapons with first-strike capability. Developing a hypersonic defence system projects the classic sword and shield phenomenon. Both the US and Russia understand the first-strike capabilities of these hypersonic systems, and while looking forward to deployment, both countries also want to figure out how to defend against these systems. As argued in this paper, the US is currently working towards the induction of hypersonic interceptors and is interested in comprehensively developing the system. As argued in this paper, the US would prefer space-based sensors and glide-phase interceptors to help evade the vulnerability of legacy ballistic missile defence systems. Conversely, Russia is currently improving its already established missile defence systems with capabilities to counter hypersonic threats. As countries like the US, Russia, and China move forward to induct both offensive hypersonic systems and the means to defend against the same, the near future will be more unstable for arms race stability and crisis stability. Though the prospects of any kind of arms-control mechanisms between the US and Russia, and China and the US seem bleak, the next arms control dialogue, either on a bilateral or trilateral level, would require the inclusion of hypersonic systems such as gliders, missiles and interceptors.