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India's Hypersonic Ambitions: Tracking the Progress

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On February 5, 2024, it was reported that the Indian Institute of Technology Kanpur (IIT-K) “successfully established and tested India’s first Hypervelocity Expansion Tunnel Test Facility, S2.”¹

The ground-breaking establishment and test have been lauded as a major step for India to further enhance its aerospace research and defence capabilities. Hypersonic technologies have become the new buzzwords in the strategic domain. Major powers, such as the US, Russia and China, are actively looking forward to deploying hypersonic weapons, along with the less advanced powers, such as Iran and North Korea. India is also showing interest in hypersonic technologies. India’s hypersonic interest is in its infancy and will take some years to operationalise. However, the Hypervelocity Expansion Tunnel Test Facility have pointed to India’s continuous interest in the hypersonic sphere.

Understanding Hypersonic Technology

Hypersonic delivery platforms fly at speeds of at least Mach 5. There are two essential types of hypersonic weapons: Hypersonic Glide Vehicles (HGV) and Hypersonic Cruise Missiles (HCM). An HGV is a glide vehicle which uses a rocket as a launch platform before gliding to a target. The HCM, on the other hand, is powered by air-breathing engines, known as scramjets, once the missile acquires its target. Hypersonic technology differs from ballistic missiles as the former does not follow a ballistic trajectory and can manoeuvre on the way to their target. Hypersonic weapons have the potential to avoid detection because of their speed, manoeuvrability, and low altitude of flight.

The Facility and Test

The press release states, “S2 is capable of generating flight speeds between 3-10 km/s, simulating the hypersonic conditions encountered during atmospheric entry of vehicles, asteroid entry, scramjet flights, and ballistic missiles.”² Achieving such results is not easy, and the team involved in this project has stated that “Building S2 has been extremely challenging, requiring in-depth knowledge of physics and precision engineering. The most crucial and challenging aspect was perfecting the ‘free piston driver’ system, which requires firing a piston at high pressure between 20-35 atmospheres down a 6.5 m. compression tube at speeds of 150-200 m/s, and bringing it to a complete stop or ‘soft landing’ at the end.”³ The S2, nicknamed ‘Jigarhanda’, is a 24-meter-long facility located at IIT Kanpur’s Hypersonic Experimental Aerodynamics Laboratory (HEAL) within the Department of Aerospace Engineering. Establishing such kind of scientific results will help India in its ongoing missions of the Indian Space Research Organisation (ISRO), Defence Research and

Development Organisation (DRDO), Reusable Launch Vehicle (RLV), and Hypersonic Cruise Missiles.

Tracking the Progress

India's interest in the hypersonic domain can be traced back to the year 2007 when former President of India, APJ Abdul Kalam while commencing the delivery of the BrahMos missile system to the Army, mooted the idea of having a Mark-II version of BrahMos hypersonic cruise missile.⁴ Then, in September 2009, a Memorandum of Understanding (MoU) was signed between India and Russia. The 2009 MoU essentially paved the way for the realisation of what would be the final parameters of the new version of the BrahMos missile. The new version was given the name 'BrahMos-2'.⁵ The 2009 MoU presented certain specifications of BrahMos-2. The specifications were as follows:

- (a) BrahMos-2 will be based on a hypersonic scramjet technology.
- (b) The prime purpose of such a weapon is to target deeply buried enemy nuclear bunkers and heavily protected locations.
- (c) All three defence services will utilise this weapon.⁶

Scramjet technology is one of the central elements of a hypersonic weapon. Unlike standard subsonic or ramjet engines, a scramjet uses an inlet force in supersonic compressed air before mixing it with hydrogen fuel, thus allowing the engine to achieve Mach 5 speeds and beyond.⁷ India began testing scramjet technology in 2016. On August 28, 2016, the ISRO successfully tested two indigenously developed scramjet engines.⁸ To further enhance its scramjet capabilities, India, in 2019 and 2020, tested an indigenously developed hypersonic technology demonstrator vehicle (HSTDV). A scramjet engine powered the HSTDV.⁹ While the 2019 test was deemed failed, the 2020 test was successful. During the 2020 test, the scramjet-powered HSTDV flew for about 22-23 seconds at Mach 6 speed. For the 2020 HSTDV test, the solid motor of the Agni-I ballistic missile was used as a launch vehicle. The 2020 HSTDV test helped India's hypersonic ambitions cross-check many crucial elements of a hypersonic weapon. Essentially, the following critical technologies were proven successful:

- (a) aerodynamic layout for hypersonic manoeuvres;
- (b) use of scramjet propulsion for ignition and constant combustion at the hypersonic stream;
- (c) thermo-structural enactment of high-temperature materials;
- (d) separation mechanism at hypersonic velocities.¹⁰

The 2020 HSTDV test, however, only established a “powered flight duration of 20 seconds at an altitude of 31 km at Mach 6.” A 20-second flight duration may not produce adequate results for isentropic flows, the implication of shockwaves on boundary layers and, more importantly, the impact of the atmosphere on thermodynamics. To further learn about the critical issues concerning developing and eventually deploying a hypersonic weapon, the DRDO conducted its third-phase test of HSTDV in 2023. It was reported in 2020 when India conducted its second test of HSTDV, that the third phase test “will include 600 seconds of controlled, sustained, powered flight to a distance of about 1,500 km while carrying a 300-400 kg payload.”¹¹ India conducted the third test of its HSTDV in 2023 to further expand its hypersonic ambitions. It is not clear whether the third test was a success or not. The Indian defence ministry or the DRDO did not release any information about the test’s parameters. However, reports in the public domain stated, “The initial launch and take-off was successful. But there are question marks on the subsequent performance of the scramjet engines of the HSTDV, for which the data has to be analysed in detail.”¹²

Conclusion

The use of hypersonic technology in the Russia-Ukraine conflict has generated increased interest among nations regarding developing similar technologies. China is one of the pioneers in the hypersonic arena and has already deployed the DF-17 HGV-armed Medium-Range Ballistic Missile (MRBM). China is also developing advanced nuclear delivery systems, such as the fractional orbital bombardment (FOB) system. In July 2021, China managed the “first fractional orbital launch of an ICBM with a hypersonic glide vehicle.”¹³ Once deployed, the FOB system will substantially increase China’s nuclear second-strike capabilities and will work as a hedge against deploying adversary’s missile defence systems. India’s hypersonic ambitions are on the right path, and the recent developments in this domain are a testament to it. In 2023, the BrahMos Aerospace Corporation stated, “If we want a hypersonic missile, we will take only eight years to develop it after the approval from the government.”¹⁴ India’s interest in hypersonic technology needs priority attention with an increasingly belligerent China.

NOTES:

¹ Sibu Kumar Tripathi, "Hypervelocity facility at IIT Kanpur: How it will propel India's high-speed dreams," *India Today*, February 05, 2024, <https://www.indiatoday.in/science/story/hypervelocity-facility-at-iit-kanpur-how-it-will-propel-indias-high-speed-dreams-2497864-2024-02-05>. Accessed on February 07, 2024.

² "IIT Kanpur achieves major milestone with India's First Hypervelocity Expansion Tunnel Test Facility," IIT Kanpur, February 05, 2024, <https://www.iitk.ac.in/new/hypervelocity-expansion-tunnel-test-facility>. Accessed on February 09, 2024.

³ Ibid.

⁴ "Kalam asks BrahMos team to develop 'Mark-II' version" *Hindustan Times*, June 21, 2007, <https://www.hindustantimes.com/india/kalam-asks-brahmos-team-to-develop-mark-ii-version/story-4v5htemS0MfLQT5oGU7w3L.html>. Accessed on February 09, 2024.

⁵ "India, Russia to develop new hypersonic cruise missile" *The Indian Express*, October 09, 2009, <https://indianexpress.com/article/india/latest-news/india-russia-to-develop-new-hypersonic-cruise-missile/>. Accessed on February 09, 2024.

⁶ "India to develop BrahMos-II missile," BrahMos Aerospace, August 03, 2009, <https://brahmos.com/newscenter.php?newsid=95>. Accessed on February 09, 2024.

⁷ A. Misra, J. Njuguna (ed.), "Composite materials for aerospace propulsion related to air and space transportation," *Lightweight Composite Structures in Transport: Design, Manufacturing, Analysis and Performance*, (Oxford: Woodhead Publishing, 2016).

⁸ "ISRO's Scramjet Engine Technology Demonstrator Successfully Flight Tested" *Indian Space Research Organisation*, <https://www.isro.gov.in/ScramjetEngineTechnology.html#:~:text=The%20August%2028%20test%20was,Scramjet%20engines%20at%20supersonic%20conditions>. Accessed on February 10, 2024.

⁹ Rajat Pandit, "India successfully test scramjet technology for hypersonic missiles," *The Times of India*, September 08, 2020, <https://timesofindia.indiatimes.com/india/india-successfully-test-scramjet-technology-for-hypersonic-missiles/articleshow/77973889.cms>. Accessed on February 10, 2024.

¹⁰ Ministry of Defence, "DRDO successfully flight tests Hypersonic Technology Demonstrator Vehicle", September 07, 2020, <https://www.pib.gov.in/PressReleasePage.aspx?PRID=1651956>. Accessed on 10 February 2024.

¹¹ Kapil Kajal, "India test-flies Hypersonic Technology Demonstrator Vehicle" *Janes*, February 02, 2023, <https://www.janes.com/defence-news/news-detail/india-test-flies-hypersonic-technology-demonstrator-vehicle>. Accessed on February 12, 2024.

¹² Rajat Pandit, "India conducts another test in a bid to develop hypersonic weapons," *The Times of India*, January 28, 2023, <https://timesofindia.indiatimes.com/india/india-conducts-another-test-in-a-bid-to-develop-hypersonic-weapons/articleshow/97389386.cms>. Accessed on February 12, 2024.

¹³ Department of Defense, "Military and Security Developments Involving the People's Republic of China," 2023, p. 111, <https://media.defense.gov/2023/Oct/19/2003323409/-1/-1/1/2023-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF>. Accessed on February 12, 2024.

¹⁴ Manjeet Negi, "India can develop hypersonic missiles in 8 yrs post govt nod: BrahMos Aerospace" *India Today*, February 21, 2023, <https://www.indiatoday.in/india/story/can-develop-hypersonic-missiles-within-eight-years-brahmos-aerospace-2337780-2023-02-21>. Accessed on February 12, 2024.