



### 2021 - THE YEAR OF HYPERSONIC TECHNOLOGY

**Gp Capt Amitabh Mathur**

*Senior Fellow, Centre for Air Power Studies*

Russia test-fired around ten new Tsirkon (Zircon) hypersonic cruise missiles from a frigate and two from a submarine on December 31, 2021. President Putin lauded the test as a significant event for the country. It is the second known test in the recent past after the successful testing of Tsirkon HCM from a Submarine in July 2021. Putin had announced an array of hypersonic weapons in 2018 and claimed that these weapons could evade a US-built missile shield and hit a target almost anywhere in the world. Russia already has Avangard HGV (currently being carried on SS-19 ICBM now and later on Sarmat and the air-launched Kinzhal (Dagger) ) hypersonic ALBM in its arsenal.<sup>1</sup>

**Putin had announced an array of hypersonic weapons in 2018 and claimed that these weapons could evade a US-built missile shield and hit a target almost anywhere in the world.**

Though the development of hypersonic weapons started in the US in the 1980s, it had not gained momentum until recently. However, in 2021, several countries, including China, the US, Russia, India and North Korea, tested hypersonic weapons. In September 2021, the US announced the testing of an air-breathing hypersonic weapon sustainable through the atmosphere like a cruise missile as part of DARPA's Hypersonic Air-breathing Weapon concept program for which Raytheon and Northrop Grumman are in competition. It is estimated that the Pentagon will deploy its first hypersonic weapons by 2025.

North Korea test-fired their newly developed hypersonic missile (Hwasong-8) soon after the US test in late September 2021 and fired another test on January 5, 2022. UK and France are co-developing, Germany and Japan are still developing hypersonic weapons and plan to test them in the coming years.

*Financial Times* reported on October 21, 2021, “China tested a nuclear-capable hypersonic missile in August 2021, that circled the globe before speeding towards its target”.<sup>2</sup> Furthermore, the report indicated a Fractional Orbital Bombardment System (FOBS) while quoting, “the Chinese military launched a rocket that carried an HGV, which flew through low-orbit space before cruising down towards its target”. It is also claimed that Chinese scientists have developed next-generation hypersonic weapons with technical breakthroughs in infrared homing technology, which can even hit fleeting targets.

**Given their unique flight altitude profile and high speed, the HGVs and the HCMs are a challenge to several existing air and missile defences, and this is the most critical feature of such hypersonic weapons.**

The series of rapidly conducted tests is a sign of the intensifying race for dominance of long-range weapon systems of the next generation, which are not only more effective but also difficult to intercept.

### **Hypersonic Weapons**

While most traditional cruise missiles are subsonic (< Mach-1) and are primarily intended for regional use, the supersonic missiles operate between Mach-1 to Mach 5 and are for intercontinental use. In contrast, hypersonic weapons fly at altitudes lower than ICBMs and greater than conventional cruise missiles. They operate beyond Mach-5 and can be used for regional as well as intercontinental targeting. Two new categories of hypersonic weapons are under development - Hypersonic Glide Vehicles (HGVs) and Hypersonic Cruise Missiles (HCMs).

HGVs are rocket launched. They fly at a lower altitude than a ballistic missile (40 to 100 km) before gliding towards the target and feature significant manoeuvrability. First, the missile and an attached glide-vehicle-mounted warhead are injected into space on an arching trajectory. Then the glide vehicle re-enters the atmosphere, and because of its aerodynamic shape, it can ride on its own shockwaves, thereby giving it enough speed to outperform existing missile defences. Currently, there are two types of HGVs, first-generation, which can hit stationary targets and second-generation, which can hit moving targets.

HCMs are powered by high-speed scramjets engines during flight and fly at higher speeds and altitudes (20 to 30 km) than conventional cruise missiles. Both can carry conventional or nuclear payloads or even use the kinetic energy impact to destroy their targets, unlike ballistic missiles, which uses gravitational force to reach their target.<sup>3</sup>

Given their unique flight altitude profile and high speed, the HGVs and the HCMs are a challenge to several existing air and missile defences, and this is the most critical

feature of such hypersonic weapons. Ballistic missiles may execute quick manoeuvres during initial ascent and the final descent, only if they are fitted with manoeuvring re-entry vehicles (MaRV), and their path is easily predictable. Missile defence sensors can track these missiles from the mid-course stage and predict their targets with reasonable accuracy.

Hypersonic weapons flying through the atmosphere use aerodynamic forces to manoeuvre through most of their flight. Hence, sensors can detect them much later in their flight. On the other hand, HGVs' relatively low altitude flight results in drag penalty, reduced speed, erosion of surface materials and loss of communication with satellites, thereby weakened control. Therefore, they will reduce their speed, and as a result, point defences, which protect particular targets, may prove more efficient against HGVs.

HCMs are not much affected by the heating problems but face challenges like controlling the hypersonic flow & temperature of air through the scramjet engine and stability of combustion. In addition, the development of submarine-launched HCMs would further raise the threat perception by combining the speed of a hypersonic missile with the inherent stealth of nuclear-powered submarines.<sup>4</sup>

The lethal combination of high-speed, agility, unique altitudes, high accuracy, and detection resilience enhances hypersonic weapons' effectiveness. There are currently no reliable or operational systems to intercept a hypersonic weapon. Technologies such as particle beams, directed energy weapons, and other non-kinetic weapons are potential candidates for defence against these weapons. Lockheed Martin of the US is developing a space-based countermeasure strategy, where persistent infra-red satellites will track the glide path of hypersonic weapons.

A missile system that could launch a glide vehicle into orbit is called FOBS. It would strip an adversary of both reaction time and the effectiveness of traditional defence mechanisms as it can remain in orbit for a longer duration than the ICBMs. The induction of this category of weapons is arguably a game-changer, given its unique flight altitude profile, high speed, difficulty to intercept and efficacy.

### **China's Advances in Hypersonic Technology**

China's nuclear ambitions appear to have been accelerated by the heightened geopolitical stress with the US and the ongoing cross-strait tensions with Taiwan poised to become a flashpoint. Therefore, China is developing hypersonic weapons at a fast pace. Multiple reports have indicated intensive development and deployment of DF-17 by PLA RF.

Space-based deployment of nuclear or other Weapons of Mass Destruction (WMD) is banned under Article IV of the 1967 UN Treaties and Principles On Outer Space.<sup>5</sup> The classic FOBS was a soviet-era system that carried nuclear weapons through space orbit. In contrast, the Chinese FOBS test in Aug 2021 carried an

**China is reportedly developing DF-ZF, a short to mid-range hypersonic missile glide vehicle with speeds ranging from 5-10 Mach and reach from 1800-2500 km.**

HGV and was the first such test worldwide. It was called “Sputnik moment”, indicating the technological surprise as the weapon can remain in space for hours and launch the HGV or Manoeuvrable Re-Entry Vehicle at an opportune moment from any direction.

China is reportedly developing DF-ZF, a short to mid-range hypersonic missile glide vehicle with speeds ranging from 5-10 Mach and reach from 1800-2500 km. China is understood to have successfully tested the Starry Sky-2 hypersonic vehicle, called “Waverider”, because it derives lift from the shockwaves generated by its hypersonic flight.<sup>6</sup> It can achieve a top speed of Mach-6 (4603 mph), switch direction mid-flight, and carry conventional warheads or nuclear weapons. The prototype was flight-tested in 2018, and it is likely to become operational by 2025. China is further building a 12,000 mph hypersonic plane capable of carrying up to ten passengers anywhere on the globe within an hour.<sup>7</sup>

The following sections identify the ongoing technological developments and capability build-up to improve China’s hypersonic delivery systems.

### **Development of Wind Tunnels**

On November 21, 2021, the Global Times reported China’s one-meter-class hypersonic aerodynamic wind tunnel, the FL-64, made by the Aerodynamics Research Institute under the state-owned Aviation Industry Corp of China (AVIC), passed major calibration tests.<sup>8</sup> The wind tunnel can conduct tests to simulate speeds from Mach-4 to 8 for all future projects. China is also building the JF-22 hypervelocity wind tunnel that can simulate a speed of Mach-30 at high altitudes. Its construction is expected to be finished by 2022, and the facility will contribute to the country’s hypersonic and aerospace aircraft program.<sup>9</sup> The developments indicate that China’s program on engine’s for hypersonic weapons is on track.

### **Development of Hypersonic Engines**

A ramjet is a modification of an air-breathing jet engine, which uses the vehicle’s forward motion to compress the air input without a rotating compressor. Instead, fuel is injected directly into the combustion chamber, mixing with the hot compressed air and

auto-ignites. Ramjet operates between 3 to 6 Mach as its efficiency drops when it reaches hypersonic speeds. Scramjet technology improves over ramjet technology and operates at hypersonic speeds efficiently as it allows supersonic combustion. Unlike a typical jet engine, such as turbojet or turbofan, it does not have

**Chinese scientists now claim technical breakthroughs in heat-seeking homing technology in developing next-generation hypersonic weapons.**

fan type rotating components to compress the air; instead, scramjet requires the high kinetic energy of a hypersonic flow to compress air to operational conditions.

Scramjet engines used in HCMs carry their fuel and use ambient ram air as the oxidiser. Since technology is still nascent, sustaining the temperatures while maintaining controlled combustion inside the hypersonic missile engine poses the biggest challenge in developing engines for hypersonic weapons.

Recently, it was reported that a team of Chinese scientists had tested prototypes of a hypersonic flight engine based on a 20-year-old design by a US-born Chinese scientist Min Han Tang, which NASA rejected at that time.<sup>10</sup> Similar to the scientist's proposal of a Two-Stage Vehicle (TSV) X-plane, the current prototype was uniquely powered by two different engines on its sides, in contrast to the most hypersonic aircraft having their engines in the fuselage. The prototype engines worked as regular turbine engines at lower speeds and switched to high-speed mode at hypersonic speed.

### **New Metallurgical Process**

A new manufacturing method developed by Chinese Scientists allows making titanium alloy components that perform far better than those made using traditional methods. According to a paper published in the Journal of Propulsion Technology, Yin Zhongwei and other scientists, working with the Aerospace Research Institute of Materials and Processing Technology, have deduced that this breakthrough would "pave the way for developing more advanced components" for hypersonic flight.<sup>11</sup>

The air inlet of the rocket engine is one of the biggest and most significant components and is designed to protect the engine's body from turbulence which can extinguish burning fuel. This meter-long part has an irregular shape and is difficult to manufacture, which involves parts welded together and reprocessed in a time-consuming and expensive method with significantly varying quality outputs.

In the new approach, called the near-net-shaping hot isostatic pressing method, Yin and his colleagues adopted a different method involving putting a fine powder of titanium and rare earth elements into a mould made of steel, pumping out of the air

from the steel mould and then putting it in an inert gas-filled oven. Heated gas expands and compresses the mould causing titanium particles to squeeze together, crystallising and merging. The complete inlet is made after approximately three hours of compression, and no further processing is required as the surface is already smoothed. The new method is four times more precise than previously used techniques.

**There is a need to build adequate and effective counter-defence against these hypersonic weapons and match the pace by developing indigenous capabilities**

### **Development of IR Capability in Hypersonic Delivery Systems**

The first generation of hypersonic weapons was designed to penetrate missile defence systems and hit only the fixed targets on the ground. Chinese scientists now claim technical breakthroughs in heat-seeking homing technology in developing next-generation hypersonic weapons. The IR capability allows these missiles to target stealth aircraft, aircraft carriers and moving vehicles with very high accuracy and speed.<sup>12</sup>

### **Implications for India and the World**

There is a debate that China may shift its 'No-First-Use Doctrine' to maintain a sizable force dedicated to 'Launch on Warning' to tackle the Taiwan threat. China feels that the US might use low yield weapons to check any invasion of Taiwan by them. China has developed infrastructure like early warning command and control systems using space-based assets. The Chinese are developing the space-based capability to increase the land-based silos equipped with DF-31 A, DF-5 and DF-41 missiles for Launch on Warning. In addition, road-mobile SRBMs and IRBMs are being inducted in large numbers. For India, the increase in the Chinese inventory of intermediate, medium and short-range missiles is a genuine concern.

The uncanny race to develop and deploy hypersonic weapon systems will provide advanced countries with significantly enhanced strike capabilities and potentially be a tool for coercion.<sup>13</sup> However, since this weapon technology is still under development, tighter international controls on dual-use technologies, such as hypersonic engines, sensors and navigation aids used in the weapons system, are needed.

Despite the fresh 'Omicron scare', India is on the cusp of becoming the sixth-largest economy globally.<sup>14</sup> Therefore, there is a need to build adequate and effective counter-defence against these hypersonic weapons and match the pace by developing indigenous capabilities. The development of Brahmos II and other hypersonic systems is a welcome sign. However, the development of robust intelligence, surveillance, target acquisition

and reconnaissance network using space and ground-based surveillance also needs to be undertaken.

## Notes:

<sup>1</sup> Reuters, “Russia Test-Fires New Hypersonic Tsirkon Missiles from Frigate, Submarine” *The Times of India*, December 31, 2021, [http://timesofindia.indiatimes.com/articleshow/88611096.cms?utm\\_source=contentofinterest&utm\\_medium=text&utm\\_campaign=cppst](http://timesofindia.indiatimes.com/articleshow/88611096.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst). Accessed on December 31, 2021. Also see Reuters, “Russia Test-Fires New Hypersonic Tsirkon Missiles from Frigate, Submarine.” SRN News, December 31, 2021, <https://www.srnnews.com/russia-test-fires-new-hypersonic-tsirkon-missiles-from-frigate-submarine/>. Accessed on December 31, 2021.

<sup>2</sup> Bleddyn Bowen and Hunter Cameron, “Chinese Fractional Orbital Bombardment” Asia-Pacific Leadership Network. APLN, November 1, 2021, <https://aplن.network/analysis/policy-briefs/chinese-fractional-orbital-bombardment>. Accessed on December 31, 2021.

<sup>3</sup> Shannon Bugos and Rief Kingston “Understanding Hypersonic Weapons: Managing the Allure and the Risks.” An Arms Control Association Report, September 10, 2021, [https://www.armscontrol.org/sites/default/files/files/Reports/ACA\\_Report\\_HypersonicWeapons\\_2021.pdf](https://www.armscontrol.org/sites/default/files/files/Reports/ACA_Report_HypersonicWeapons_2021.pdf). Accessed on December 31, 2021.

<sup>4</sup> James Bosbotinis. “Hypersonic Missiles: What Are They and Can They Be Stopped?” *Defence IQ*, April 9, 2020, <https://www.defenceiq.com/defence-technology/articles/hypersonic-missiles-what-are-they-and-can-they-be-stopped>. Accessed on December 31, 2021.

<sup>5</sup> United Nations, “Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.” United Nations Treaties and Principles On Outer Space. UN, 1967, [https://www.unoosa.org/pdf/publications/ST\\_SPACE\\_061Rev01E.pdf](https://www.unoosa.org/pdf/publications/ST_SPACE_061Rev01E.pdf). Accessed on December 31, 2021.

<sup>6</sup> James Bosbotinis, n. 4.

<sup>7</sup> A Christyadanga and Joe Davies Mailonline. “China Is Building a 12,000mph Hypersonic Aircraft Capable of Transporting 10 Passengers.” Eminentra New Zealand, December 11, 2021, <https://eminetra.co.nz/china-is-building-a-12000mph-hypersonic-aircraft-capable-of-transporting-10-passengers/435501/>. Accessed on December 31, 2021.

<sup>8</sup> Liu Xuanzun. “China’s New Wind Tunnel Ready to Shape Development of Hypersonic Weapons, Equipment.” CHINA / MILITARY. *Global Times*, November 21, 2021, <https://www.globaltimes.cn/page/202111/1239529.shtml>. Accessed on December 31, 2021.

<sup>9</sup> Ibid.

<sup>10</sup> EurAsian Times Desk “An Unorthodox Aircraft Design Rejected by NASA 20 Years Ago Propels China’s Hypersonic Flight Program.” *The Eurasian Times*, December 10, 2021, <https://eurasianimes.com/aircraft-design-rejected-by-nasa-propels-chinas-hypersonic-flight/>. Accessed on December 31, 2021.

<sup>11</sup> Stephen Chen. “Chinese Scientists Build Hypersonic Engine with Technology ‘That Would Never Work’.” *South China Morning Post*, December 23, 2021, <https://www.scmp.com/news/china/science/article/3160874/chinese-scientists-hail-success-new-hypersonic-engine-military>. Accessed on December 31, 2021.

<sup>12</sup> Chen Stephen. "China Says It Has Hypersonic Missiles with Heat-Seeking Tech – Years before US." *South China Morning Post*, December 31, 2021, [https://www.scmp.com/news/china/military/article/3161762/china-says-it-has-hypersonic-missiles-heat-seeking-tech-years?utm\\_source=email&utm\\_medium=share\\_widget&utm\\_campaign=3161762](https://www.scmp.com/news/china/military/article/3161762/china-says-it-has-hypersonic-missiles-heat-seeking-tech-years?utm_source=email&utm_medium=share_widget&utm_campaign=3161762). Accessed on December 31, 2021.

<sup>13</sup> James Bosbotinis. "Hypersonic Missiles: What Are They and Can They Be Stopped?". *Defence IQ*, April 9, 2020, <https://www.defenceiq.com/defence-technology/articles/hypersonic-missiles-what-are-they-and-can-they-be-stopped>. Accessed on December 31, 2021.

<sup>14</sup> Shankkar Aiyar. "Hope 2022: India's Rise in \$100 Trillion Global GDP." *The New Indian Express*, January 2, 2022, <https://www.newindianexpress.com/opinions/columns/shankkar-aiyar/2022/jan/02/hope-2022-indias-rise-in-100-trn-global-gdp-2402051.html>. Accessed on January 03, 2022.



Centre for Air Power Studies

The Centre for Air Power Studies (CAPS) is an independent, non-profit think tank that undertakes and promotes policy related research, study and discussion on defence and military issues, trends, and development in air power and space for civil and military purposes, as also related issues of national security. The Centre is headed by Air Marshal Anil Chopra PVSM AVSM VM VSM (Retd).

Centre for Air Power Studies

P-284, Arjan Path, Subroto Park, New Delhi 110010

Tel: +91 11 25699130/32, Fax: +91 11 25682533

Editor: Dr Shalini Chawla e-mail: shaluchawla@yahoo.com

Formatting and Assistance: Mr Shantanu Roy Chaudhury, Mr Mohit Sharma and Mr Rohit Singh

The views expressed in this brief are those of the author and not necessarily of the Centre or any other organisation.