2021—ASCENT OF HYPERSONICS

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HYPERSONIC WEAPONS

Most traditional cruise missiles are designed subsonic (< Mach 1) primarily with regional use intention. Intercontinental supersonic missiles operate between Mach 1 to Mach 5. In contrast, hypersonic weapons operate beyond Mach 5, at altitudes lower than ICBMs and more significant than conventional cruise missiles intended for regional and intercontinental targeting. The nascent Hypersonic technology requires a blend of cutting-edge developments in proven technologies—aerodynamics, thermodynamics, materials science, guidance, navigation and control, space capabilities, high-speed processing and communications. Hypersonic weapon systems can carry conventional as well as nuclear weapons. For example, a Hypersonic weapon can release an EMP nuclear weapon at high altitudes, which can wipe out communication and power supply lines by generating an intense electromagnetic pulse.

The development of military hypersonic aircraft is almost a century old, albeit with little success. The first hypersonic aircraft glider, Silbervogel, was designed by Austrian engineer Eugen Sänger and German physicist Irene Bredt in the late 1930s. It was

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rocket-launched, flew within the atmosphere and stayed afloat like any other glider using the aerodynamic lift. Still, Nazi planners considered it too expensive and complex to build. In 1963, the US abandoned developing the X-20 Dyna-Soar hypersonic glider as it was too expensive. After the Bush administration exited from the 1972 Anti-Ballistic Missile Treaty with the Soviet Union, both the adversaries stopped building defensive shields against each other's ballistic missiles, thus, halting the race for technologies. Post the Al Qaeda attack of 9/11, the US started developing interceptors to protect against long-range ballistic missiles. As a result, Russia and China later started developing Hypersonics to counter the US Shield.[1] Only two nations, China and Russia, possess operational hypersonic weapons.[2]

In 2018, Putin had announced an array of hypersonic weapons, claiming that these weapons could evade a US-built missile shield and hit a target anywhere in the world. Russia already has Avangard HGV, which is currently being carried on SS-19 ICBM but will later be mounted on Sarmat ICBM and Kinzhal (Dagger) hypersonic air-launched ballistic missile.

UK and France are co-developing HCM. Australia, Germany and Japan are still developing hypersonic weapons and plan to test them in the coming years.

Hypersonic weapons, currently being developed, are of two types—*Hypersonic Glide Vehicles* (HGVs) and *Hypersonic Cruise Missiles* (HCMs). Conventional ballistic missiles execute manoeuvres only if fitted with manoeuvring re-entry vehicles (MaRV), that too, only during ascent/descent and their paths are easily predictable. Missile shields can track these missiles from the mid-course stage and accurately predict their targets. On the other hand, the HGVs and HCMs dodge most existing air and missile defences with their unique flight altitude profile and high speeds, agility, high

1. Wright, D. and Tracy, C. "The physics and hype of Hypersonic Weapons". *Scientific American*, August 2021, https://www.scientificamerican.com/article/the-physics-and-hype-of-hypersonic-weapons/. Accessed on February 14, 2022.
2. Hollings, A. "Russia's hypersonic weapons: Nothing more than a paper tiger?" *19FortyFive*. February 14, 2022, https://www.19fortyfive.com/2022/01/russias-hypersonic-weaspons-nothing-more-than-a-paper-tiger/. Accessed on February 13, 2022.

accuracy, and detection resilience. Technologies such as particle beams, directed energy weapons, and other non-kinetic weapons are potential candidates for defence against these weapons.

HYPERSONIC GLIDE VEHICLES

HGVs are rocket launched and fly lower than a ballistic missile (40 to 100 km) before gliding towards the target and demonstrating significant manoeuvrability. First, the missile and an attached glide-vehicle-mounted warhead are injected into space on an arching trajectory, and then the glide vehicle re-enters the atmosphere. Because of its aerodynamic shape, it can ride on its shockwaves, thereby acquiring high speeds to outperform existing missile defences. While first-generation HGVs can hit stationary targets, the second-generation can hit even moving targets.

Hypersonic weapons manoeuvre using aerodynamic forces rather than fuel while in the atmosphere; hence, sensors can detect them much later in their flight. In contrast, HGVs' relatively low altitude flight results in drag penalty, reduced speed, erosion of surface materials and weakened control due to link-loss with satellites. Therefore, with their reduced speeds, point defences, protecting particular targets may prove more efficient against HGVs.

The drag on a flying object increases in proportion to the square of its velocity and is particularly debilitating at hypersonic speeds. For example, a glider at Mach 5 has 25 times more drag than experienced at Mach 1. The kinetic energy of the glider transforms into thermal energy and shockwaves. Resultant intense heat may be thousands of kelvins at the leading edges, threatening the vehicle's integrity, and is a problem for designers.[3]

Significant force is required to manoeuvre at hypersonic speeds. During manoeuvres, an HGV must use lift forces to impart a horizontal velocity—which might have to be hypersonic. At the same time, the glider needs to retain enough vertical lift to stay aloft.[4] Such manoeuvres can cost significant speed and range.

3. Wright and Tracy, n. 1.
4. Ibid.

The Space shuttles are designed with a blunt nose to slow them when they re-enter the atmosphere and glide down for a soft landing on a runway. On the other hand, the design of most HGVs involves a sharp nose-cone designed to reduce atmospheric drag.[5]

HYPERSONIC CRUISE MISSILES

HCMs are powered by high-speed scramjet 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 use gravitational force to reach their target.[6]

HCMs are not much affected by heating problems but face challenges like controlling the hypersonic flow and 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.[7]

FRACTIONAL ORBITAL BOMBARDMENT SYSTEM

A missile system that could launch a glide vehicle into orbit is called Fractional Orbital Bombardment System (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.

5. Theresa Hitchens, "China's Mysterious Hypersonic Test May Take a Page from DARPA's Past", *Breaking Defense*, November 25, 2021, https://breakingdefense.com/2021/11/chinas-mysterious-hypersonic-test-may-take-a-page-from-darpas-past/. Accessed on January 8, 2022.
6. 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. Accessed on December 31, 2021.
7. 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.

The classic FOBS was a Soviet-era system that carried nuclear weapons through space orbit and launched the weapon at an opportune moment from any direction. 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.[8]

AIR-LAUNCHED HYPERSONIC MISSILES

The US Air Force stated that it could externally mount an advanced stealth cruise missile on the B-1B Lancer outside of its internal bomb bay for the first time, a step forward in plans to have the B-1 carry future ordnance—like hypersonic missiles.[9]

Russia has an air-launched Kh-47M2 Kinzhal (Dagger) hypersonic air-launched ballistic missile with a speed of Mach 10 and a range of 2,720 km in its arsenal.[10]

2021—A YEAR OF INTERNATIONAL DEVELOPMENTS IN HYPERSONIC DELIVERY PLATFORMS

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 tested an air-breathing hypersonic weapon sustainable through the atmosphere like a cruise missile as part of DARPA's Hypersonic Air-breathing Weapon concept programme for which Raytheon and

8. 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. Accessed on December 31, 2021.
9. Oriana Pawlyk, "In First, Air Force Flies B-1 Bomber with Externally Mounted Stealthy Cruise Missile", November 24, 2020, https://www.military.com/daily-news/2020/11/24/first-air-force-flies-b-1-bomber-externally-mounted-stealthy-cruise-missile.html. Accessed on February 8, 2022.
10. 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. Accessed on December 31, 2021.
See also 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.

Northrop Grumman are competing. It is estimated that the Pentagon will deploy its first hypersonic weapons by 2025.

Russia successfully test-fired a Tsirkon (Zircon) HCM from a submarine in July 2021, around ten new Tsirkon HCMs from a frigate and two more from a submarine on December 31, 2021. Tsirkon is a ground/sea-launched missile with speeds between Mach 4.5 and Mach 6 and a 480-1,000 km test range.

North Korea test-fired their newly developed hypersonic missile (Hwasong-8) in late September 2021. On January 5, 2022, the glide vehicle split from its rocket booster and manoeuvred 120 km laterally before hitting a target 700 km away from the launch site. This launch has a cone-shaped lifting body, which is liquid-fuelled and features an "ampoule" rocket booster.[11] North Korea also claimed a successful flight test of a hypersonic missile on January 11, 2022, which would remarkably increase the country's nuclear "war deterrent".[12] Korean Central News Agency said the launch involved a hypersonic glide vehicle, which after its release from the rocket booster demonstrated "glide jump flight" and "corkscrew manoeuvring" before hitting a sea target 1,000 km (621 miles) away.[13]

*Financial Time*s reported on October 21, 2021, "China tested a nuclear-capable hypersonic missile in August 2021, that circled the globe before speeding towards its target."[14] Furthermore, the report indicated a 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." China denied it, saying it was a routine test of a reusable space vehicle. However, the capability to launch a submunition from an HGV at speeds over Mach 5 was indeed an achievement. The US reports claim that the Chinese have

11. "Ampoulisation" is a Soviet-era concept that refers to factory-sealed liquid rocket motors that are considerably easier and safer to handle. This concept makes it easier to deploy and fire the missile swiftly, minimising its vulnerability to pre-emptive strikes.
12. Tong-hyung, K. "North Korea claims successful test of Hypersonic Missile". AP NEWS, February 14, 2022, https://apnews.com/article/business-united-states-seoul-south-korea-north-korea-c0c7c9c39f353ac34e6a83fb6243b695 Accessed on February 10, 2022
13. Ibid .
14. Bleddyn Bowen and Cameron Hunter, "Chinese Fractional Orbital Bombardment", *Asia-Pacific Leadership Network*, APLN, November 1, 2021, https://apln.network/analysis/policy-briefs/chinese-fractional-orbital-bombardment. Accessed on December 31, 2021.

experimented using an FOBS, and was called "Sputnik moment" as the weapon can remain in space for hours and launch the HGV or MaRV at an opportune moment from any direction. Further, Chinese scientists have developed next-generation hypersonic weapons with technical breakthroughs in infrared homing technology, which can engage even moving targets.

ENTRY OF HYPERSONIC VEHICLES IN CIVIL AVIATION

Eighteen years after the last touchdown of the Concorde, dreams of high-speed civil air travel, ranging from supersonic to hypersonic, are now back in fashion. US President Joe Biden evinced interest in this newfound dream while delivering his speech in 2021 on transport infrastructure. In the summer of 2021, "*BOOM Technology*", a US start-up, signed an agreement with United Airlines to purchase fifteen Mach 1.7 Overture Airliners with an option to add another 35. Another venture called Venus Aerospace plans to develop a small 12-seater Mach 12 vehicle that will fly at the edge of space at 150,000 ft and cover the flight from Los Angeles to Tokyo in an hour as against 11 hours today. Venus plans to use these aircraft for applications like VVIP travel, "hyper-logistics", where critical goods like vaccines, spare parts can be delivered urgently to save lives and in military roles to deploy troops globally rapidly.[15]

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.

China is reportedly developing DF-ZF, a short to mid-range hypersonic missile glide vehicle with speeds ranging from Mach 5 to 10 and reach from 1,800 to 2,500 km. China is understood to have successfully tested the Starry Sky-2 hypersonic vehicle, called

15. Tim Robinson, "Hype or Hypersonics?", *Royal Aeronautical Society*, FRAeS, April 20, 2021, https://www.aerosociety.com/news/hype-or-hypersonics/. Accessed on January 8, 2022.

"Wave-rider" because it derives lift from the shockwaves generated by its hypersonic flight.[16] The prototype, capable of achieving top speeds of Mach 6 (4,603 mph), mid-flight direction switching, and carrying conventional warheads or nuclear weapons, was tested in 2018 and will likely 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.[17]

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

DEVELOPMENT OF WIND TUNNELS

Wind tunnels allow experimenting with new designs or improving the efficiency of existing ones for making better and safer vehicles. China makes no secret of having developed at least one aerodynamic wind tunnel capable of conducting hypersonic weapons and equipment tests. Though spacecraft and many rockets travel in space vacuum, these have to be tunnel tested as their significant transit is through the atmosphere.[18]

On November 21, 2021, the *Global Times* reported that China's one-meter-class hypersonic aerodynamic wind tunnel, the FL-64, designed and developed by China's state-owned Aerodynamics Research Institute, had passed major calibration tests.[19] The wind tunnel can conduct tests to simulate speeds from Mach 4 to 8 for all future projects. In addition, the JF-22 hypervelocity wind tunnel, capable of simulating speeds of Mach 30 at high altitudes, is also under development in China. The facility will likely be ready

16. James Bosbotinis, n. 7.
17. A. Christyadanga and Joe Davies Mailonlines, "China Is Building a 12,000 mph Hypersonic Aircraft Capable of Transporting 10 Passengers", *Eminetra 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.
18. AFP. "China Stuns West with Hypersonic Missile Test", MSN. February 14, 2022, https://www.msn.com/en-us/news/world/china-stuns-west-with-hypersonic-missile-test/ar-AAR2GOq, Accessed on February 14, 2022.
19. Liu Xuanzun, "China's New Wind Tunnel Ready to Shape Development of Hypersonic Weapons, Equipment", *Global Times*, November 21, 2021, https://www.globaltimes.cn/page/202111/1239529.shtml. Accessed on December 31, 2021.

by 2022 and contribute to China's hypersonic and aerospace aircraft programme.[20] The developments indicate that China's programme on engines for hypersonic weapons is on track.

DEVELOPMENT OF HYPERSONIC ENGINES

Unlike HGV, which glides on shockwaves, HCM requires a scramjet to fly. 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 Mach 3 to 6 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 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 oxidisers. 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.

EurAsian Times recently 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.[21] 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 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.

20. Ibid.
21. 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://eurasiantimes.com/aircraft-design-rejected-by-nasa-propels-chinas-hypersonic-flight/. Accessed on December 31, 2021.

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 pioneer the development of more advanced components for hypersonic flight.[22]

The air-inlet of the rocket engine is one of the biggest and most significant components designed to protect the engine's body from turbulences, which can extinguish burning fuel. This one-metre-long part is irregularly shaped. Its complex manufacture involves welding parts together and reprocessing in a time-consuming and expensive manner with inconsistent 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 smoothened. The new method is four times more precise than previously used techniques.

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

22. 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.

stealth aircraft, aircraft carriers and moving vehicles—with very high accuracy and speed.[23]

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. Modern command and control (C2) systems depend on connectivity to collect information, issue orders, detect changes in the environment, and exploit successes. In a conflict, adversaries can distort data reliability and degrade technological dominance. If they succeed in causing degraded operations, adversaries gain a temporary window of superiority that can develop into a permanent relative advantage.

DEVELOPMENT OF RAILGUNS TO DEFEND AGAINST HYPERSONIC MISSILES

The Japanese newspaper *Nikkei Asia* reported that the Ministry of Defense is hoping to develop a fast and accurate railgun that will not only destroy missiles in flight but will be able to deter the launch of those missiles in the first place. Japan had been planning to develop the railgun since as early as 2015, and in 2016, it even demonstrated a prototype that launched a projectile at a speed of 4,470 mph.[24]

Unlike a regular weapon that uses an explosion to propel a shell out of the barrel, known as explosive propulsion, a railgun uses an electromagnetic field to eject a projectile at speeds greater than hypersonic missiles. According to *Popular Science*, "A railgun works by generating a strong electromagnetic current that flows from one rail, through a U-shaped back end of the projectile, and into another parallel rail. This configuration generates three magnetic fields—a parallel one around each rail and a perpendicular one around the projectile. Squeezed forward by the magnetic fields, the projectile

23. 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. Accessed on December 31, 2021.
24. "Railguns to defend against hypersonic missiles: What are they and why is Japan betting on this Next Gen weapon", *Firstpost*, January 15, 2022, https://www.firstpost.com/world/railguns-to-defend-against-hypersonic-missiles-what-are-they-and-why-japan-is-betting-on-this-nextgen-weapon-10285911.html. Accessed on January 31, 2022.

accelerates rapidly along the rails and, after that, is launched forward, breaking the circuit. The result is a large metal slug that can go very far, very fast."[25] The entire railgun measures roughly 65 feet from turret rear to barrel muzzle, with the barrel itself about 33 feet long and 12-20 feet in diameter. A wide barrel provides parallel magnetic rails that propel metal projectiles to over Mach 7.[26]

So far, only China seems to have developed and deployed a working railgun atop a naval ship, according to *Popular Science*. However, a set of photos that appeared online in 2018 showed a Chinese warship with a full-scale railgun mounted on top.

After spending nearly two decades and half a billion dollars, the US stalled the project to develop railguns last year due to fiscal constraints, combat system integration challenges and the prospective technology maturation of other weapon concepts.[27] However, the Pentagon has now awarded defence giants Raytheon, Lockheed Martin, and Northrop Grumman to develop missiles that could protect the United States from hypersonic attacks using the development of glide phase interceptors.[28]

IMPLICATIONS FOR INDIA

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. Therefore, to compress the seeker to shooter loop, the development of these weapons systems has unleashed a new race to develop robust intelligence surveillance, target acquisition and reconnaissance networks is required to support the conventional targeting role. The role for early detection of a launch will likely be filled by satellites.

25. Ibid.
26. Ibid.
27. "Railguns to Defend against Hypersonic Missiles: What are they and why Japan is betting on this Next Gen Weapon", *Firstpost*, February 14, 2022, https://www.firstpost.com/world/railguns-to-defend-against-hypersonic-missiles-what-are-they-and-why-japan-is-betting-on-this-nextgen-weapon-10285911.html Accessed on February 2, 2022.
28. Staff, WION, "How are Hypersonic Missiles different, is it the new 'Wonder Weapon'?", WION, February 14, 2022, from https://www.wionews.com/photos/how-are-hypersonic-missiles-different-is-it-the-new-wonder-weapon-444335#hypersonics-the-new-frontier-in-missile-technology-444327. Accessed on February 14, 2022.

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.[29] However, while this weapon technology is still under development, India must have a two-pronged approach. First, to facilitate tighter international controls on dual-use technologies, such as hypersonic engines, sensors and navigation aids used in the weapons system are needed to control proliferation; Second, indigenous development of hypersonic weapons to augment strike capability and defence systems to defend against such threats.

Investments in network-centric warfare have ballooned to the point that all echelons of war now possess C2 systems inextricably tied to the space satellite infrastructure and its associated electromagnetic spectrum (EMS) linkages. Space capabilities depend on the space segment, link segment, and ground segment. The link and ground segments are the most vulnerable to EW assets out of these three. China has raised PLA SSF wherein its Space and EW assets have been merged. Therefore, to have a robust C2 system, India should continue investments in hardening and simultaneously develop other countermeasures that require alternative means to gain access, accomplish missions, and enable all-domain operations within them.

29. James Bosbotinis, "Hypersonic Missiles: What Are They and Can They Be Stopped?", *Defence IQ. 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.