NUCLEAR-ARMED HYPERSONIC DELIVERY SYSTEMS—A CASE STUDY OF CHINA

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INTRODUCTION

The challenge that technology advancements will pose to nuclear deterrence has become a subject of great concern in recent times. These technologies, which may spawn advancements in accuracy, remote sensing, delivery, range, artificial intelligence, cyber capabilities and speed, could make nuclear weapons either more vulnerable or more secure, and hence affect nuclear deterrence in either an adverse or benign manner. Hypersonic delivery systems constitute one such emerging technology. According to some experts, hypersonic technology is an evolution, and not a revolution, given that it dates back to the Cold War era.[1] Ballistic missiles, for instance, are hypersonic in their exo-atmospheric phase. What is new, however, is making a missile fast and manoeuvrable through most of its flight time. So, speed (between Mach 5 and Mach 25) and manoeuvrability are the two characteristics of modern hypersonic systems. These delivery systems are

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1. Stephen Reny, "Nuclear-Armed Hypersonic Weapons and Nuclear Deterrence", *Strategic Studies Quarterly*, vol. 14, no. 4, 2020, pp. 47–68, at https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-14_Issue-4/SSQWinter2020Rev.pdf?ver=2020-05-27-132858-983. Accessed on July 22, 2021.

Many countries are investing in developing nuclear-armed hypersonic systems. China, for example, has been rapidly expanding its hypersonic capabilities and equipping itself with delivery systems to ensure the penetration of its missiles despite US BMD.

of various types, including the following: (a) boost-glide; (b) air-breathing; (c) gun-launched and (d) unmanned aerial vehicles.

The military utility of nuclear-armed hypersonic systems has been a significant focus of debate within the academic, strategic and political circles. Are they fruitful or are they futile? Certain scholars point out that they can increase the chances of survivability and hence be good for deterrence.[2] The difficulty of interception, combined with the severely compressed time for response and the limited time available to detect the launch, discriminate the target, and prepare for countermeasure, can be useful in defeating missile defence.[3] However, certain other scholars say they pose a danger to deterrence due to their features of ambiguity, which can give rise to misperception and inadvertent escalation.[4]

Many countries are investing in developing nuclear-armed hypersonic systems. China, for example, has been rapidly expanding its hypersonic capabilities and equipping itself with delivery systems to ensure the penetration of its missiles despite US BMD. It sees these systems as necessary for its nuclear deterrence. It is the second country to operationalise its hypersonic delivery systems, DF-17, tipped with DF-ZF HGV in 2020, following Russia, which operationalised its hypersonic delivery systems, the Avangard HGV,

2. Nathan B. Terry and Paige Price Cone, "Hypersonic Technology: An Evolution in Nuclear Weapons?", *Strategic Studies Quarterly*, vol. 14, no. 2, 2020, pp. 74-93, at https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-14_Issue-2/Terry.pdf. Accessed on June 12, 2021.
3. John T. Watts, Christian Trotti and Mark J. Massa, "Primer on Hypersonic Weapons in the Indo-Pacific Region", Atlantic Council, August 17, 2020, at https://www.atlanticcouncil.org/in-depth-research-reports/report/primer-on-hypersonic-weapons-in-the-indo-pacific-region/. Accessed on June 12, 2021.
4. Joseph Dillon, "Hypersonic Weapons: Challenging the Hype", *The Security Distillery*, March 20, 2021, at https://thesecuritydistillery.org/all-articles/hypersonic-weapons-challenging-the-hype. Accessed on June 17, 2021.

in December 2019. Apart from this, China has also been developing several other platforms. What capabilities is China developing? How does it plan to use these? What would be its implications for India? Would it lower the nuclear threshold, increase misperceptions and ambiguities and lead to an expensive arms race?

Hypersonic systems operate with the speed of ballistic missiles while incorporating the manoeuvrability of a cruise missile... hypersonic systems travel five times faster than the speed of sound.

The paper attempts to answer these questions. It begins by analysing hypersonic technology, its unique attributes and types. Secondly, it examines the need, utility, significance and challenges surrounding hypersonics. Third, it studies China's hypersonic programme, and lastly, it analyses the implications for India and on strategic stability in the region, including arms control.

HYPERSONIC DELIVERY SYSTEMS: A CONCEPTUAL UNDERSTANDING

Hypersonic systems operate with the speed of ballistic missiles while incorporating the manoeuvrability of a cruise missile.[5] As mentioned earlier, hypersonic systems travel five times faster than the speed of sound. They are further categorised as: "hypersonic speed" (between Mach 5 and Mach 10) and "high-hypersonic speed" (between Mach 10 and Mach 25). Table 1 briefly explains the different speed regimes.

Table 1: Different Speed Regimes

Speed Regime	Mach Number	Speed in Km/hr	Application of Speed
Subsonic	< 0.8	< 980	Turbojet planes, commercial airlines
Transonic	0.8-1.2	980-1480	Jet aircraft, cruise missiles

5. "Hypersonic Weapon Basics", Missile Defense Advocacy Alliance, May 30, 2018, at https://missiledefenseadvocacy.org/missile-threat-and-proliferation/missile-basics/hypersonic-missiles/. Accessed on June 23. 2021.

Supersonic	1.2-5.0	1480-6170	Jet Aircraft, cruise missiles, anti-missile systems
Hypersonic	5.0-10.0	6170-12,340	Re-entry vehicle, SRBMs, MRBMs, Hypersonic Cruise Missiles, Hypersonic Glide Vehicles, ICBMs
High-hypersonic	10.0-25.0	12,340-30,870	Re-entry vehicle, ICBMs, Advance Hypersonic Vehicles, Boost-glide vehicles
Ultrasonic	> 25.0	> 30,870	Space and Lunar re-entry vehicles

Source: Ajay Lele, "Hypersonic Weapons-IDSA Occasional Paper No. 46", Manohar Parrikar Institute for Defence Studies and Analyses, 2017, at https://idsa.in/occasionalpapers/op_46_hypersonic_weapons; Nancy Hall, "Mach Number", Glenn Research Center, NASA, May 13, 2021, at https://www.grc.nasa.gov/www/k-12/airplane/mach.html. Accessed on May 18, 2021.

The majority of hypersonic delivery vehicles operate at speeds of between Mach 5 and Mach 10. They also enjoy enhanced manoeuvrability, making them difficult to intercept and defend against as compared to traditional missiles.[6] This results in increased survivability. They are characterised not only by their speed and manoeuvrability, but also by their trajectory and target accuracy.[7] These systems may be of various types, but the scope of this article is limited to a discussion of only two: (a) hypersonic glide vehicles (HGVs); (b) hypersonic cruise missiles (HCMs). They can be launched from land, air, and sea and can carry conventional and nuclear warheads (dual-capable systems).

Hypersonic Glide Vehicles (HGVs) are "boost-glide" systems that are rocket launched and take to hypersonic speeds in Earth's lower orbit. They may reach an altitude between 25 and 62 miles.[8] After reaching

6. Kris Osborn, "Hypersonic Weapons: Everything You Need to Know About the Ultimate Weapon", The National Interest, The Center for the National Interest, July 22, 2017, at https://nationalinterest.org/blog/the-buzz/hypersonic-weapons-everything-you-need-know-about-the-21637.
7. Sergey Batsanov, and Kevin Miletic, "Pugwash Briefing Paper: Hypersonic Weapons Series #1-What Is Hypersonic Weapon?", British Pugwash, The Pugwash Foundation, November 2, 2020 at https://britishpugwash.org/report-pugwash-workshop-on-hypersonics-9-10th-dec-2019/.
8. Richard M Harrison, Margot van Loon, and Mark A. Bucknam, "Strategic Primer - Hypersonic Weapons", American Foreign Policy Council, June 28, 2019 at https://www.afpc.org/publications/special-reports/strategic-primer-hypersonic-weapons.

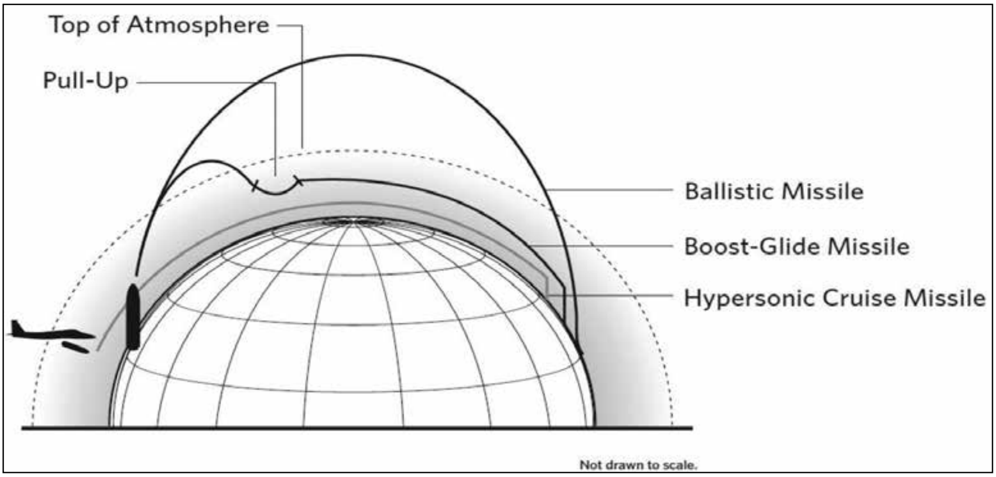
the lower orbit, they detach themselves from the rocket, attain a gliding equilibrium and glide along the top of the atmosphere (based on its aerodynamic features), unpowered towards a target, at speeds up to Mach 10 or more. It is imperative to note that the HGV is launched into the atmosphere through a rocket comparable to a ballistic missile. However, unlike ballistic missiles (ICBMs) that arc above the atmosphere in space and travel between Mach 17 and Mach 25,[9] HGVs have an unpredictable flight path that does not follow a ballistic trajectory. They are highly manoeuvrable and can change their paths, making a significant area of territory vulnerable to an attack and difficult to intercept and defend against.[10]

Hypersonic Cruise Missiles (HCMs) are "air-breathing" systems, which operate using a supersonic combustion ramjet (Scramjet). A scramjet engine is an upgradation over the ramjet engine as it functions at hypersonic speeds and is capable of supersonic combustion.[11] These missiles fly at an altitude between 12 and 19 miles, where a rocket or a launch vehicle can accelerate the missile to Mach 3 or 4 and at this point the missile's scramjet engine takes over to reach a speed of Mach 9 or Mach 10.[12] It is worth noting that HCMs have an advantage over rocket propulsion systems since operating within the Earth's atmosphere gives them greater thrust efficiency and lighter weight.[13] However, the trajectory is not the differential point between traditional cruise missiles and HCMs, as with HGVs. Both may follow nearly identical flight paths. The difference, in this case, lies in the speed regimes. HCMs can hit

9. James M. Acton, "Hypersonic Weapons Explainer", Carnegie Endowment for International Peace, April 2, 2018, at https://carnegieendowment.org/2018/04/02/hypersonic-weapons-explainer-pub-75957.
10. Kelley M. Sayler, and Amy F. Woolf, "Defense Primer: Hypersonic Boost-Glide Weapons", Congressional Research Service, December 1, 2020, at https://crsreports.congress.gov/product/pdf/IF/IF11459.
11. "ISRO's Scramjet Engine Technology Demonstrator Successfully Flight Tested", Indian Space Research Organisation, at https://www.isro.gov.in/launchers/isro%E2%80%99s-scramjet-engine-technology-demonstrator-successfully-flight-tested.
12. Timothy M. Persons, "Science & Tech Spotlight: Hypersonic Weapons." GAO, September 16, 2019. https://www.gao.gov/products/gao-19-705sp.
13. Hans-Ludwig Besser, Dennis Göge, Michael Huggins, Alan Shaffer and Dirk Zimper. "Hypersonic Vehicles: Game Changers for Future Warfare." *Transforming Joint Air Power: The Journal of the JAPCC*, no. 24, 2017, pp. 12-26, at https://www.japcc.org/hypersonic-vehicles/.

their targets faster, making them difficult to intercept and counter as against traditional missiles.[14] HCMs have a longer range and can fly undetected at lower altitudes making them more stealthy than traditional cruise missiles that are prone to be detected.

Figure 1: Diagrammatic Representation of Trajectories of Ballistic Missiles, HGVs and HCMs



Source: James M. Acton, "Silver Bullet?: Asking the Right Questions About Conventional Prompt Global Strike." Washington, DC, USA: Carnegie Endowment for International Peace, 2013, at https://carnegieendowment.org/2013/09/03/silver-bullet-asking-right-questions-about-conventional-prompt-global-strike-pub-52778. Accessed on May 19, 2021.

Major powers like the US, Russia and China primarily focus their R&D on HGVs and HCMs, carrying both conventional and nuclear warheads.[15] However, many of these countries are also researching hypersonic or electromagnetic railguns and hypersonic UAVs, which offer a significant technological advantage over existing systems.

14. Ian Williams, "Adapting to the Hypersonic Era." Nuclear Network. Project of Nuclear Issues, Center for Strategic and International Studies, November 17, 2020, at https://nuclearnetwork.csis.org/adapting-to-the-hypersonic-era/.
15. Michael T. Klare, "An 'Arms Race in Speed': Hypersonic Weapons and the Changing Calculus of Battle", Arms Control Today, Arms Control Association, June 2019, at https://www.armscontrol.org/act/2019-06/features/arms-race-speed-hypersonic-weapons-changing-calculus-battle#endnote02.

Technical Challenges of Hypersonic Systems

It is necessary to realise the technical, engineering and material challenges these hypersonic systems encounter when operating at high-speed regimes. These include having to withstand atmospheric heat and thermal management. At that speed, the exterior temperatures of these vehicles are incredibly high and can be more than 2200°C.[16] Intense heat, coupled with gas dynamics, can cut off and affect communications. In addition, the high airflow temperature leads the particles to ionise and create an electrically charged plasma sheath, disrupting the communication of electromagnetic signals and resulting in difficulty in operating the system (navigation, manoeuvrability, among others).[17] Thus, to manage this, new metal alloys and coatings with necessary material combinations are required to withstand the high temperatures while re-entering and manoeuvring at lower altitudes.

Flight control is another technical challenge. It is essential to keep the vehicle stable to cope with the highly dynamic lift and drag forces caused by G-force.[18] This requires an improvement in the aerodynamic design to guarantee stability. At the same time, improvement in propulsion technology, which includes refinement of engine technology, is needed for scramjet operated HCMs.[19] Cruise missiles powered by standard turbojets are incapable of reaching hypersonic speeds. Thus, it is necessary to operate the missiles with a scramjet or a highly advanced ramjet, which are delicate systems to operate since they become functional only within a specific range.[20] There is also a challenge of achieving accuracy in hitting the target.

16. Alex Gatopoulos, "Project Force: Hypersonic Weapons and the New Space Race", Al Jazeera, March 9, 2021, at https://www.aljazeera.com/features/2021/3/9/project-force-hypersonic-weapons-and-the-new-space-race.
17. Mark J. Lewis, "Global Strike Hypersonic Weapons", AIP Conference Proceedings 1898, 020005, AIP Publishing, November 15, 2017, https://aip.scitation.org/doi/abs/10.1063/1.5009210.
18. Mark McWhinney, "The Risks of Hypersonic Weapons." Project Ploughshares, December 3, 2020, at https://ploughshares.ca/pl_publications/the-risks-of-hypersonic-weapons/.
19. Timothy Andrew Barber, "A Survey of Gaps, Obstacles, and Technical Challenges for Hypersonic Applications", Master's Thesis, University of Tennessee, 2012 at https://trace.tennessee.edu/utk_gradthes/1131.
20. Sergey Batsanov and Kevin Miletic. "Pugwash Briefing Paper: Hypersonic Weapons Series #2-What technical challenges do Hypersonic Weapons raise?" British Pugwash. The Pugwash Foundation, November 2, 2020. https://britishpugwash.org/report-pugwash-workshop-on-hypersonics-9-10th-dec-2019/.

Scholars have argued that more than speed and manoeuvrability, the range and payload of HGVs and HCMs will define their utility in strategic and tactical contexts.

Hypersonic systems have a greater chance of missing their targets or impact points due to the high speeds they operate at across extended ranges.[21]

Other challenges include a lack of proper testing facilities, such as testing in wind tunnels and flight tests, ensuring funding for associated R&D (especially in developing countries) and limited simulation possibilities.[22]

Utility of Hypersonics

Nations may pursue hypersonic technologies for a variety of reasons, including strategic and tactical security calculations, the state of current techno-military R&D and national pride.[23] The system promises a strategic and tactical edge in the speed, manoeuvrability of the trajectory and accuracy in reaching the target by evading detection. The military significance lies in compressed time for the adversary to react and decide on the interception. As a result, these delivery systems are a "game-changer" in terms of penetrability. Scholars have argued that more than speed and manoeuvrability, the range and payload of HGVs and HCMs will define their utility in strategic and tactical contexts (both defence and offence missions).[24]

These systems may be used for enhancing the first strike or pre-emptive capabilities (strategic offensive missions); boosting second-strike capabilities (strategic defensive missions); increasing anti-access/area-denial capabilities (tactical defensive missions); and developing the ability to eliminate the targets while attempting to gain an operational superiority (tactical and strategic offensive missions).[25] The most likely targets would be high-value,

21. Barber, n. 19.
22. Roshan Khanijo and P.K. Chakravorty. "Hypersonic Vehicles and Their Impact on Military Operations and Strategic Stability—USI Occasional Paper No. 12", United Service Institution of India, 2017, at https://usiofindia.org/wp- content/uploads/2019/04/12_Hypersonic_Vehicles_and_Their_Impact_on_Military_Operations_and_Strategic_Stability_Final.pdf.
23. Batsanov and Miletic, n. 20.
24. Ibid.
25. Ibid.

highly defended, time-sensitive assets such as air defence radars, fighter aircraft bases, aircraft carriers, military installations, road-mobile missiles, surface-to-air missiles, underground and maritime facilities, command and control, and hardened assets like laboratories and manufacturing sites, among others.[26] However, uncertainty over the utility and probable target will remain until expressed in the military doctrines. Until then, one can speculate on their possible roles and targets.

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Whether these delivery systems are an evolution or a revolution in technology remains an ongoing debate in academia. Some scholars have argued that they represent a technological revolution, are "unstoppable,"[27] and "phenomenally accurate,"[28] and hence advantageous. According to these scholars, such systems will be crucial for achieving superiority over adversaries in future warfare. On the other hand, some other scholars have questioned the uniqueness of the system and opine that they are just an evolution, a "gimmick,"[29] and is "hyped,"[30] and "overrated."[31] They have argued along these lines based on the history of this technology,

26. Klare, n. 15.
27. R. Jeffrey Smith, "Hypersonic Missiles Are Unstoppable. And They're Starting a New Global Arms Race", *The New York Times*, June 19, 2019, at https://www.nytimes.com/2019/06/19/magazine/hypersonic-missiles.html.
28. Elliot Negin, "Ask a Scientist: Calling Out the Hype Over Hypersonic Weapons", The Equation. Union of Concerned Scientists, April 2, 2021, at https://blog.ucsusa.org/elliott-negin/calling-out-the-hype-over-hypersonic-weapons/.
29. Melanie Marlowe and Bryan McGrath, "Net Assessment: Hypersonic Weapons—Gimmick or Game Changer?", War on the Rocks, August 21, 2020, at https://warontherocks.com/2019/05/net-assessment-hypersonic-weapons-gimmick-or-game-changer/.
30. Michael Unbehauen, "Hypersonic Weapons Hype?", Modern Diplomacy, March 20, 2020, at https://moderndiplomacy.eu/2020/03/20/hypersonic-weapons-hype/.
31. Kristin Huang, "Are Hypersonic Missiles a Game Changer? Not so Fast, Says Study", *South China Morning Post*, January 19, 2021, at https://www.scmp.com/news/china/military/article/3118221/are-hypersonic-missiles-game-changer-not-so-fast-says-new-study.

which dates all the way back to the 1930s, and research undertaken over the years.[32] They elaborate that these delivery systems do not change the status quo, as existing ballistic and cruise missiles are difficult to defend against and can hit targets more accurately.[33] Though the technology has existed for long, over the years, the methods to achieve target accuracy through speed and manoeuvrability have made hypersonic systems a cause of concern.

Defending Against Hypersonic Systems

Hypersonic systems present significant challenges and are difficult to defend against. Since the systems operate at high speeds, coupled with manoeuvrability and lower altitudes, they can easily penetrate a highly defended area, rendering any early-warning, air- or missile-defence systems ineffective. For instance, hypersonic delivery systems may challenge the layered missile defence systems (designed to intercept missiles in the exo-atmosphere) since they are manoeuvrable in their midcourse phase and travel at lower altitudes inside the Earth's atmosphere, making them difficult to intercept.[34] They can also change their target once launched, making larger territory vulnerable to an attack. This increases the probability of hypersonic systems successfully hitting a target and their survivability.. Moreover, the compressed timeline to intercept, distinguish and retaliate, shortens decision-making time, making strategic assets vulnerable and overwhelming command and control structures.

Besides, some of the most advanced missile defence systems, such as THAAD or S-400s, may only defend a comparatively small area. But the characteristic features of hypersonic systems may increase susceptibility to penetration.[35] The extensive kinetic energy, in addition to the warhead,

32. Ajay Lele, "Hypersonic Weapons—IDSA Occasional Paper No. 46", Manohar Parrikar Institute for Defence Studies and Analyses, 2017, at https://idsa.in/occasionalpapers/op_46_hypersonic_weapons.
33. Cameron Tracy, "Slowing the Hypersonic Arms Race: A Rational Approach to an Emerging Missile Technology", Union of Concerned Scientists, May 5, 2021, at https://www.ucsusa.org/sites/default/files/2021-04/slowing-the-hypersonic-arms-race.pdf.
34. S. Bugos and K. Reif, "Understanding Hypersonic Weapons: Managing the Allure and the Risks", Arms Control Association, September 2021, at https://www.armscontrol.org/sites/default/files/files/Reports/ACA_Report_HypersonicWeapons_2021.pdf.
35. Besser, n. 13.

poses yet another challenge.[36] Although very few countries have invested in developing countermeasures for hypersonics (such as space-based sensors and over-the-horizon backscatter radars), the difficulty in defending has continuously led to a need for a 360-degree defence system that can counter the manoeuvrability of hypersonic systems.[37] The future will determine whether hypersonic systems are truly defence penetrating panacea or are overrated, and whether the countermeasures are effective or not.

CHINA'S HYPERSONIC PROGRAMME

China is the second country to deploy hypersonic delivery systems capable of carrying nuclear and conventional warheads on field and has undertaken significant research on hypersonics. While one must understand that an accurate assessment of Chinese capabilities is quite difficult due to limited authentic information available in the public domain, it is evident that China is leading the hypersonic arms race, having conducted 20 times as many tests as the United States.[38] China's rapid modernisation of its capabilities and upgrading its Rocket Force (earlier Second Artillery) with state-of-the-art equipment is another dimension of President Xi's "China Dream", which envisions China completely developed and modernised by 2049, the 100th anniversary of the founding of PRC. China's hypersonic delivery system's programme has reached a stage where it falls between levels six and eight on the Department of Defence's Technological Readiness Level (TRL) scale.[39] This means that some of its prototype systems have been demonstrated (six), tested in a relevant environment (seven), and qualified to work in the required conditions (eight).[40]

36. Richard H. Speier, "Hypersonic Missiles: A New Proliferation Challenge", RAND Corporation, March 29, 2018, at https://www.rand.org/blog/2018/03/hypersonic-missiles-a-new-proliferation-challenge.html.
37. Watts, n. 3.
38. Marc Selinger, "DoD's New Research Chief Eyes Faster Hypersonics Development", *Defence Daily*, March 6, 2018, at https://www.defensedaily.com/dods-new-research-chief-eyes-faster-hypersonics-development/pentagon/.
39. Peter Wood and Roger Cliff, "A Case Study of The PRC's Hypersonic Systems Development", Air University, September 2, 2020, at https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Other-Topics/2020-08-25%20CASI_Hypersonic%20Case%20Study_WEB.pdf?ver=2WiFcyYi1dquXp7kfG_8UA%3D%3D.
40. "Technology Readiness Levels in the Department of Defence (DoD)", 2010, at https://api.army.mil/e2/c/downloads/404585.pdf. Accessed on June 1, 2021.

China's development of different types of ballistic and cruise missiles, manoeuvrable re-entry vehicles, MIRVs, and early warning systems indicates its intent to be technologically advanced.

Perceptions of Motivations and Threats

According to Chinese scholars, the current motivation for hypersonic technologies is a deep-seated desire to modernise in the footsteps of other major powers in the world. China's development of different types of ballistic and cruise missiles, manoeuvrable re-entry vehicles, MIRVs, and early warning systems indicates its intent to be technologically advanced. China's dream to overcome its harrowing past experiences (Century of Humiliation) and modernise rapidly has encouraged the hypersonic arms race with the US. Many scholars in China have often recommended that the government invest extensively in developing the countries' own hypersonic systems, since they see American efforts in this direction as part of a revolution in the military affairs and aerospace industry.[41] They opine that China must respond and has no reason to delay creating a technology that will be "a revolution and a breakthrough for future warfare."[42]

China's second motivation comes from its security threats. At the global level, these are perceived from US missiles and missile defences. Tong Zhao of the Carnegie-Tsinghua Center for Global Policy points out that many experts in China have argued for China to research and develop hypersonic technology not only to understand it but also to find different ways to counter US hypersonic capabilities.[43] At the regional level, Japan, Australia and India's hypersonic development efforts also impact the region's strategic stability, though these matter little to China at this moment.[44]

41. Tong Zhao, "Conventional Challenges to Strategic Stability: Chinese Perceptions of Hypersonic Technology and the Security Dilemma", in Adam N. Stulberg and Lawrence Rubin (eds.), *The End of Strategic Stability?: Nuclear Weapons and the Challenge of Regional Rivalries* (Washington DC: Georgetown University Press, 2018), pp. 174-202, at https://www.jstor.org/stable/j.ctv75db5d.12.
42. Wood, n. 39.
43. Zhao, n. 41.
44. Huang Panyue, "How about Japan's Real Strength in Hypersonic Weapon Field?", China Military, December 3, 2019, at http://eng.chinamil.com.cn/view/2019-12/03/content_9688517.htm.; Ji Cheng, "Why Australia, US Work Together to Develop Hypersonic Cruise Missiles?" Edited by Liu Yuyuan, China Military, April 9, 2021, at http://english.chinamil.com.cn/view/2021-04/09/content_10019113.htm.

Third, China invests in hypersonics to boost its nuclear survivability. It wishes to make its stockpile safer and secure in order to sustain deterrence.[45] In addition, the penetration capability of the system can help evade the adversary's missile defences.[46] For the reasons mentioned above, China is conducting extensive research on hypersonics and is not shying away from flaunting its technological breakthroughs. Western scholars also attribute China's motivations to maintaining its superiority in the South China Sea.[47] They point out that rapid modernisation and R&D efforts in hypersonics have been primarily because of US ABM systems, such as THAAD in South Korea, which the US justifies as a means to countering the North Korean threat.[48] In addition, they see China's developments as a direct countermeasure to the US power projection in the South China Sea and Taiwan Straits in recent years due to the Freedom of Navigation exercises that it has carried out.[49]

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Western experts use China's Military Strategy of 2015 to directly quote its motivations and threat perceptions to protect its maritime assets by improving its long-range precision strike capabilities. For example, the document pointed out that "some of its offshore neighbours take provocative actions and reinforce their military presence on China's reef and islands that are illegally occupied" and

45. Wu Riqiang, "Living with Uncertainty: Modelling China's Nuclear Survivability." *International Security* vol. 44, no. 4, 2020, pp. 84-118, at https://doi.org/10.1162/isec_a_00376.
46. Li Bin, Sun Xiangli and Wu Riqiang, "Why Is China Modernising Its Nuclear Arsenal?", Carnegie International Nuclear Policy Conference 2015, Carnegie Endowment for International Peace, March 24, 2015, at https://carnegieendowment.org/2015/03/24/why-is-china-modernizing-its-nuclear-arsenal-pub-57516.
47. Andrew Davies, "Coming Ready or Not: Hypersonic Weapons", Australian Strategic Policy Institute, March 2021, at https://www.aspi.org.au/report/coming-ready-or-not-hypersonic-weapons.
48. Tate Nurkin, "China's Manoeuvrable Re-Entry Vehicles (MaRVs)", in *China's Advanced Weapons Systems: Research Report Prepared for U.S.-China Economic and Security Review Commission*, 177-200, Jane's by IHS Markit, 2018, at https://www.uscc.gov/sites/default/files/Research/Jane's%20by%20IHS%20Markit_China's%20Advanced%20Weapons%20Systems.pdf.
49. Connie Lee, "Motivations Behind China's Hypersonic Weapons Development", John Hopkins Sheridan Libraries, Dissertation, John Hopkins University, 2020, at https://jscholarship.library.jhu.edu/handle/1774.2/62693?show=full.

that "some external countries are busy meddling in South China Sea affairs."[50] As a result of this approach, Beijing would gain superiority over forward bases and ships, allowing it to secure its maritime assets without getting detected.

According to a 2017 SIPRI study, the development of hypersonics is more "utilitarian",[51] since China sees these systems for their conventional and nuclear utility and may deploy them over medium-, intermediate-, or longer-range missiles to increase its penetration capabilities. Since 2014, China has extensively increased its R&D activities, first to know the technology and second, to gain advantage and deploy it in no time.

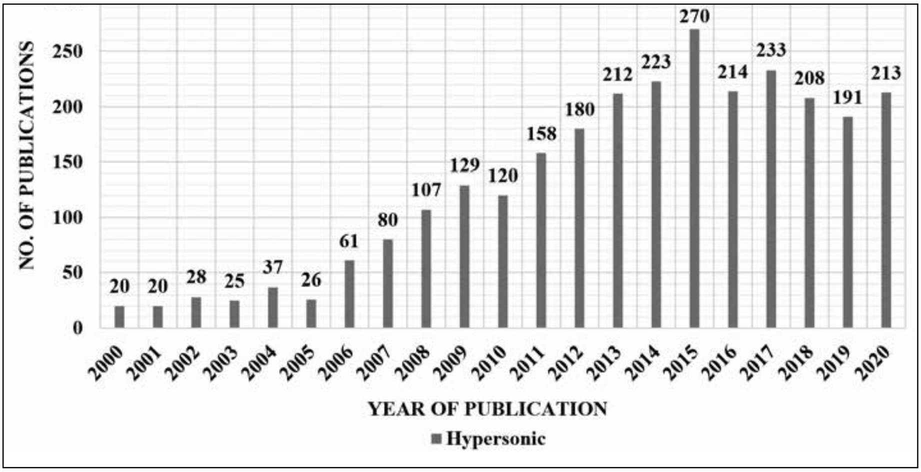
Hypersonic Research in China

Since the 1960s, China's state-run laboratories have focussed on hypersonic flight as part of the ballistic and cruise missiles, though the work was then more theoretical.[52] In the 1980s, it began research on the scramjet capabilities, and in the 1990s, substantial progress was made on the scramjet research as part of Project 921, China's manned space programme.[53] However, a serious effort to work on hypersonics began only in the 2000s. The "Hypersonic Flight Vehicle Science and Technology Project" was initiated in 2006 under the National Medium-to-Long Term S&T Development Plan (2006-2020), when a coherent effort was made to research the hypersonics.[54] Several yearly publications came out from China during this period, outlining the research progress in the hypersonic field. Figure 2 points out the number of yearly publications from China on the word "hypersonic" from 2000 to 2020. This is around the same time the US started working on its Conventional Prompt Global Strike programme.

50. "China's Military Strategy (Full Text)", The State Council, the People's Republic of China, May 27, 2015, at http://english.www.gov.cn/archive/white_paper/2015/05/27/content_281475115610833.htm.
51. Lora Saalman, "Factoring Russia into the US–Chinese Equation on Hypersonic Glide Vehicles", SIPRI, January 2017, at https://www.sipri.org/publications/2017/sipri-insights-peace-and-security/factoring-russia-us-chinese-equation-hypersonic-glide-vehicles.
52. John Grady, "Panel: China Leading the World in Hypersonic Weapon Development" USNI News, March 14, 2019, At https://news.usni.org/2019/03/14/panel-china-leading-world-hypersonic-weapon-development.
53. Wood, n. 39, p. 7.
54. Ibid., p. 7.

Many research papers were authored in the fields of aerospace and aircraft, weapons and military affairs.[55] The US CPGS programme and its destabilising effects are frequently debated in China. One expert elaborates that one-quarter of Chinese research has focused on defeating the US missile defence systems, while roughly one half concentrates on developing long-range capabilities.[56] Additionally, research has also been conducted on near-space attack systems, increasing HGV's manoeuvrability, managing heat and gas dynamics and improving the trajectories of present systems to expand their range.[57] These are only a handful of the many categories.

Figure 2: China's Yearly Publications on the term "Hypersonic"



Source: Author's compilation from "CNKI Database", at https://global.cnki.net/kns/brief/Default_Result.aspx?code=CIDX&kw=&korder=0&sel=1. Accessed on May 31, 2021.

Several institutions in China are monitoring the R&D of hypersonics. The CMC Science and Technology Commission, as per western literature, seems to have taken the project under its auspices and has been determining longer-

55. "CNKI Database", at https://global.cnki.net/kns/brief/Default_Result.aspx?code=CIDX&kw=&korder=0&sel=1. Accessed on May 31, 2021.
56. Lora Saalman, "China's Calculus on Hypersonic Glide", SIPRI, August 15, 2017, at https://sipri.org/commentary/topical-backgrounder/2017/chinas-calculus-hypersonic-glide.
57. Ibid.

term goals for developing hypersonics and other military technologies.[58] Table 2 highlights some of the significant institutions involved in hypersonic research, development and testing in China.

Table 2: Key Institutions Associated with Hypersonic Research in China

Name of Institution	Location	Work Undertaken
China Academy of Aerospace Aerodynamics	Beijing	Credited for the development of Starry Sky II hypersonic glide vehicle
China Academy of Launch Vehicle Technology	Beijing	Probable developer of HGV-tipped DF-17 MRBM and has undertaken development of several ballistic missiles and space vehicles
China Aerospace Science and Industry Corporation	Beijing	Producing the DF-ZF HGV
College of Aerospace Science and Engineering, National University of Defence Technology	Changsha, Hunan	Has two National Key Academic Departments undertaking research
Institute of Mechanics, Chinese Academy of Sciences	Beijing	Has several key laboratories that are researching hypersonics
State Key Laboratory for High-Temperature Gas Dynamics, Chinese Academy of Sciences	Beijing	Developing hypersonic wind tunnel for tests. Driving force in the implementation of JF12 wind tunnel
State Key Laboratory for Powder Metallurgy, Central South University	Changsha, Hunan	Announced a breakthrough in the ceramic coating for thermal management, which has been necessary for hypersonic vehicles

Source: Peter Wood and Roger Cliff, "A Case Study of The PRC's Hypersonic Systems Development." Air University, September 2, 2020, at https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Other-Topics/2020-08-25%20CASI_Hypersonic%20Case%20Study_WEB.pdf?ver=2WiFcyYi1dquXp7kfG_8UA%3D%3D.

58. Office of Secretary of Defence, "Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020", US Department of Defence, August 2020, at https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF.

China has primarily been facing a technical challenge of overcoming the thermal and heat management dynamics. To overcome it, China has kept a keen eye on other countries' hypersonic capabilities, including seeking opportunities for cooperation. For instance, Central South University in Changsha, Hunan, collaborates on hypersonic testing and material sciences with the University of Manchester from the UK. In 2017, both collaborated to develop a new ceramic coating material that is useful for hypersonic vehicles.[59] This addresses the technical challenges and improves the heat resistance on hypersonic vehicles. Although China states that this is for civilian use, the research undertaken can significantly benefit the military applications. Recently, many in the UK have questioned such collaborations with Chinese academic institutions, arguing that they may aid the Chinese military in developing stealth and advanced defence systems, threatening the national security of Western countries.[60]

Hypersonic Wind Tunnel Testing Facilities

China uses many facilities to undertake its scale-model testing and has invested heavily in testing facilities that replicate the conditions for accurate assessment. China's Aerodynamics Research and Development Center claims to have 18 wind tunnels.[61] China has two major facilities: the JF12 and JF22 hypersonic wind tunnels. These tunnels allow for better testing of hypersonic air flow, atmospheric heat and heat-resistant materials required for re-entry vehicles.[62] The JF12 Hypersonic Shockwave Duplication wind tunnel is 265 metres long and is the world's largest hypersonic wind tunnel. Chinese have dubbed it as the

59. Angus McNeice, "Future of Hypersonic Flight Hot Thanks to China-UK Research", China Daily, July 10, 2017, at https://www.chinadaily.com.cn/world/2017 07/10/content_30061981.htm#:~:text=British%20and%20Chinese%20scientists%20have,high%2Dvelocity%20planes%20and%20rockets.
60. David Schullion, "Are UK Dons Hopelessly Naive on China?: David Scullion", *The Critic Magazine*, February 11, 2021, at https://thecritic.co.uk/are-uk-dons-hopelessly-naive-on-china/.
61. Jeffrey Lin, and P.W. Singer. "A Look at China's Most Exciting Hypersonic Aerospace Programs." Popular Science, April 18, 2017. https://www.popsci.com/chinas-hypersonic-technology/.
62. Peter Wood and Alex Stone. "China's Ballistic Missile Industry", China Aerospace Studies Institute, May 11, 2021, https://www.airuniversity.af.edu/CASI/Display/Article/2599627/chinas-ballistic-missile-industry/.

'Hypersonic Dragon'.[63] Researchers can replicate conditions at altitudes of 25-40 km and speeds from Mach 5 to 10. The tunnel can also simulate high temperatures up to 3226°C.

China's latest large-scale operating wind tunnel is the JF22 hypersonic wind tunnel. It can test hypersonic speeds between Mach 7 and 30, which can last for approximately 130 milliseconds. Recent media reports point out that this will put China's hypersonic testing at least '30 years ahead of the West.'[64] Additionally, China operates three more hypersonic wind tunnels—FD-02, FD-03, FD-07—capable of reaching speeds of Mach 8, Mach 10 and Mach 12, respectively. Furthermore, it operates the FD-21 wind tunnel, operating at speeds between Mach 10 and Mach 15.[65]

Hypersonic Capabilities

Since 2014, China has conducted several tests on hypersonic vehicles. China has claimed that these tests were not directed against any specific country or target and were normal.[66] As per reports, there are currently many developed systems out of which one has been deployed, and many more are under development, summarised in Table 3. There is a significant ambiguity regarding China's intention to outfit these systems with nuclear or conventional warheads. However, the focus here would be on nuclear-armed.

DF-ZF: Previously, WU-14, is an HGV that has been tested approximately nine times since 2014, out of which six were claimed to be successful.[67] The DF-ZF is said to be capable of flying at speeds between Mach 5 and Mach 10, has an approximate range between 1600-2400 km and is capable of

63. Anil Chopra, "China's Aggressive Aerospace Push", *Air Power Asia*, December 10, 2020, at https://airpowerasia.com/2020/12/10/chinas-aggressive-aerospace-push/.
64. Mark Hodge, "China Unveils Plan for 23,000mph Wind Tunnel '30 Years Ahead' of the West", *The US Sun*, May 31, 2021, at https://www-the--sun-com.cdn.ampproject.org/c/s/www.the-sun.com/news/2989000/china-hypersonic-wind-tunnel/amp/.
65. Kelley M. Sayler, "Hypersonic Weapons: Background and Issues for Congress", Congressional Research Service, April 26, 2021, at https://crsreports.congress.gov/product/pdf/R/R45811.
66. "Hypersonic Tests Target No Specific Country", People's Daily Online, December 11, 2014, at http://en.people.cn/n/2014/1211/c202936-8821063.html.
67. Sayler, n. 65.

Table 3: China's Hypersonic Capabilities

	Name of the System	Range/Speed	Status
Current Developments	DF-ZF HGV	1600-2400 km	Deployed/Operational
	DF-17 MRBM	1800-2500 km	Deployed/Operational
	XINKONG-2	Mach 6	Underdevelopment
	CM-401 Hypersonic ASBM	Speed: Mach 4-6 Range: 9-180 miles	Underdevelopment
Possible Future Developments	DF-21 D MRBM	450-1550 km	Speculated for Development
	DF-26 IRBM	3000-4000 km	
	DF-31A ICBM	Over 11000 km	
	DF-41 ICBM	12000-15000 km	
	CH-AS-X-13 ALBM	3000 km	
	JL-2 SLBM	7200 km	

Source: Author's compilation from various online sources.

performing extreme manoeuvres that can evade missile defences.[68] It is expected to hit the targets anywhere in the world within an hour. The DF-17 MRBM is designed explicitly to carry it.[69] DF-ZF was publicly displayed in 2019 and has been operational since 2020, making it an essential part of China's penetration capability.

DF-17: This is a solid-fuelled and road-mobile MRBM. China conducted several tests on the DF-17, said to have rocket booster capabilities of the DF-16B SRBM, which is already operational.[70] The DF-17 is the first HGV-equipped tactical ballistic missile that is operational since 2020.[71] It has a

68. Paul Bernstein and Dain Hancock. "China's Hypersonic Weapons", *Georgetown Journal of International Affairs*, January 27, 2021, at https://gjia.georgetown.edu/2021/01/27/chinas-hypersonic-weapons/.
69. Prakash Katoch, "Hypersonic Weapons", *Indian Defence Review*, June 16, 2020, at http://www.indiandefencereview.com/news/hypersonic-weapons/.
70. Ankit Panda, "Introducing the DF-17: China's Newly Tested Ballistic Missile Armed With a Hypersonic Glide Vehicle", *The Diplomat*, December 30, 2017, at https://thediplomat.com/2017/12/introducing-the-df-17-chinas-newly-tested-ballistic-missile-armed-with-a-hypersonic-glide-vehicle/.
71. Wood, n. 39.

Western scholars speculate that China might aim to equip its LRBMs with HGVs, thereby increasing the range of its first-strike capabilities.

range of about 1800-2500 km.[72] This can easily help China protect its regional interests, specifically in the South China Sea and the Taiwan Straits. It will also enhance China's power projection strategy and penetration capability against its regional rivals such as India, Japan and South Korea, which are also developing hypersonic technology. Recently, rumours were circulating that the DF-17 was deployed near the Taiwan Straits to deter the US from meddling in China's internal matters.[73]

Considerations on other Ballistic Missiles: Western scholars speculate that China might aim to equip its LRBMs with HGVs, thereby increasing the range of its first-strike capabilities. Additionally, China may tip the DF-21D MRBM (range 450 to 1550 km) and DF-26 IRBM (range 3000 to 4000 km) with DF-ZF HGV to increase its long-range strike capabilities.[74] The DF-21D is operational as an anti-ship ballistic missile. China may also consider tipping DF-31A[75] (range over 11,000 km) or DF-41 (range between 12,000-15,000 km) ICBMs capable of reaching critical targets in the United States with HGVs.[76] Possibilities are that China may deploy a nuclear-armed HGV on a JL-2 SLBM, increasing the survivability of nuclear forces.[77] This will defeat the US missile defences, rendering them vulnerable. HGVs dual-use capability makes it more beneficial for the Chinese, as they can equip their nuclear missiles with conventional HGVs to increase their penetration capabilities at low trajectories. However, they also increase the risk of lowering the nuclear threshold.

72. "DF-17", Missile Threat - CSIS Missile Defence Project, June 23, 2020, at https://missilethreat.csis.org/missile/df-17/.
73. Liu Xuanzun, "Rumored PLA Deployment of DF-17 Hypersonic Missiles near Taiwan Straits Could Deter US Meddling in China's Internal Affairs: Analysts", *Global Times*, October 18, 2020, https://www.globaltimes.cn/content/1203846.shtml.
74. Saalman, n. 56.
75. Katoch, n. 69.
76. Dominika Kunertova, "Weaponized and Overhyped: Hypersonic Technology", Center for Security Studies, ETH Zurich, June 2021, at https://css.ethz.ch/en/center/CSS-news/2021/06/weaponized-and-overhyped-hypersonic-technology.html.
77. Bernstein and Hancock, n. 68.

Xingkong-2 (Starry Sky-II): This is a waverider hypersonic vehicle, reported to be still under trial phase.[78] The first known tests were done in August 2018 by the China Academy of Aerospace Aerodynamics. Waveriders are hypersonic aircraft designed using shock waves generated by their own flight as a lifting surface to improve their lift-to-drag ratio.[79] Waveriders can carry conventional or nuclear payloads and can also act as kinetic kill vehicle. It was carried by a solid-propellant rocket in the tests and, after separation, glided back to Earth at speeds reaching 7344 km/hr or Mach 6, displaying high manoeuvrability before landing back.[80] Chinese experts claim that Xingkong-2 will use a different flight pattern than the DF-17 MRBM. The difference is that the former has a fairing, whereas the latter does not.[81] Some reports suggest that this system might be operational by 2025 as an advanced anti-ship missile.[82]

Waveriders are hypersonic aircraft designed using shock waves generated by their own flight as a lifting surface to improve their lift-to-drag ratio. Waveriders can carry conventional or nuclear payloads and can also act as kinetic kill vehicle.

CM-401 Hypersonic Anti-Ship Ballistic Missile: In 2018, China Aerospace Science and Industry Corporation Limited showcased a new hypersonic ASBM at the 2018 Airshow China.[83] As per reports, it can reach a speed between Mach 4 and Mach 6, be launched into a near-space trajectory, and be capable of manoeuvrable flight throughout the course. Its range approximately lies between nine miles to just over 180 miles

78. Liu Xuanzun, "DF-17 May Not Sole Hypersonic Missile Program: Media", *Global Times*, December 1, 2019, at https://www.globaltimes.cn/page/201912/1171896.shtml.
79. Ajey Lele, "Hypersonic Weapons", in *Disruptive Technologies for the Militaries and Security*, 47-78 (Singapore: Springer, 2019), at https://www.springer.com/gp/book/9789811333835.
80. Steve Mollman, "China Just Tested a Hypersonic Weapon the US Can't Defend Against", *Quartz*, August 7, 2018, at https://qz.com/1350327/china-tested-a-hypersonic-weapon-the-us-cant-defend-against/.
81. Xuanzun, n. 78.
82. Bernstein and Hancock, n. 68.
83. Joseph Trevithick, "China Reveals Short-Range Anti-Ship Ballistic Missile Designed to Dodge Enemy Defenses", *The Drive*, November 5, 2018, at https://www.thedrive.com/the-war-zone/24699/china-reveals-short-range-anti-ship-ballistic-missile-designed-to-dodge-enemy-defenses.

categorising it as an SRBM. The company claims that CM-401 can conduct a terminal diving attack at extremely high velocity.[84] It can also deliver rapid and precise strikes on medium to large vessels, vessel formations and port targets. Its ability to evade the enemy defence and higher terminal speed make it a valuable addition to the Chinese military. CM-401 is also available for exports, however, the range is unknown at this time. Given the capabilities of this missile, one can speculate that Pakistan may wish to have it in their inventory to deter any possible threats from the Indian Navy.

Other Developments: There are speculations that China is developing an air-launched ballistic missile, closely resembling the DF-17.[85] A video had surfaced showing a Xian H-6N bomber of PLAAF carrying a payload on the bottom of its fuselage. Western experts designate it as CH-AS-X-13, which are nuclear-capable.[86] The missile has been tested since 2016 and is not expected to be operational until 2025, according to reports. However, there are speculations that the missile is somewhat like DF-21 MRBM. The missile with about a 3000 km range and a radius of 6000 km, the missile may easily reach Hawaii.[87] China has also been developing hypersonic UAVs for future ISR operations and electromagnetic railguns that can operate up to Mach 6 for its naval ships. Once operational, these guns will be used for anti-ships, long-range artillery bombardment and missile defence missions.[88] China has also developed a scramjet engine testbed, Lingyun-1, capable of testing

84. Liu Xuanzun, "CASIC Unveils New Anti-Ship Ballistic Missile, Providing Greater Deterrence against Aircraft Carrier Attacks", *Global Times*, November 6, 2018 at https://www.globaltimes.cn/content/1126120.shtml.
85. Mike Yeo, "Video Reveals Chinese H-6N Bomber Carrying Suspected Hypersonic Weapon", Defence News, October 19, 2020, at https://www.defensenews.com/global/asia-pacific/2020/10/19/video-reveals-chinese-h-6n-bomber-carrying-suspected-hypersonic-weapon/.
86. Ankit Panda, "Revealed: China's Nuclear-Capable Air-Launched Ballistic Missile," *The Diplomat*, April 18, 2018, at https://thediplomat.com/2018/04/revealed-chinas-nuclear-capable-air-launched-ballistic-missile/.
87. H.I. Sutton, "China's New Aircraft Carrier Killer Is World's Largest Air-Launched Missile", Naval News, November 1, 2020, at https://www.navalnews.com/naval-news/2020/11/chinas-new-aircraft-carrier-killer-is-worlds-largest-air-launched-missile/.
88. Jeffrey Lin and P.W. Singer, "China's Hypersonic Military Projects Include Spaceplanes and Rail Guns." *Popular Science*, June 26, 2018 at https://www.popsci.com/chinas-hypersonic-work-speeds-up/.

at Mach 6 and above, to research HCM technologies and thermal resistant materials and components.[89]

These systems that are either operational or are under development provide China with the ability to increase its regional warfighting capabilities, ensure penetration capability against regional rivals and the US, provide strategic deterrence to Chinese forces and ensure a CPGS like that of the US. It will also increase China's global power projection. However, these may have severe implications for countries like India and arms control initiatives.

Arms Control

Nuclear-armed hypersonic delivery systems complicate arms control and non-proliferation efforts. Countries like China, which are leading in hypersonic R&D, do not see the advantage in limiting their progress. Tong Zhao notes that "China has a clear advantage over the US in terms of land-based medium- and intermediate-range missiles (ballistic and cruise missiles)" since the INF Treaty never constrained it.[90] Moreover, he says, "China acquired considerable experience in developing and operating such weapon systems, which makes China confident that it will be able to maintain this advantage in the future," pointing out that China may not restrain the future developments.

The growing threat posed by the US missile defence system, the existing lack of trust between the US and China, and the US's withdrawal from the ABM and INF Treaties all contribute to China's decision to abstain from arms control negotiations. Besides, experts say there are gaps between China's nuclear arsenal and that of US and Russia due to China's commitment to the principle of limited development of nuclear

89. Rajaram Nagappa, "Hypersonic Cruise Missiles: An Overview", International Strategic and Security Studies Programme, National Institute of Advanced Studies, November 24, 2020, at http://isssp.in/hypersonic-cruise-missiles-an-overview/.
90. Tong Zhao, "Conventional Missiles, Missile Defence, and Strategic Stability: Chinese Perspective", in Patricia M. Kim (ed.), *Enhancing US-China Strategic Stability in an Era of Strategic Competition: US and Chinese Perspectives*, pp. 26-29, United States Institute of Peace, 2021, at https://www.usip.org/publications/2021/04/enhancing-us-china-strategic-stability-era-strategic-competition.

weapons and non-engagement in nuclear competition.[91] Chinese Experts suggest that the US and Russia should take the lead in international nuclear disarmament.[92] Therefore, the idea of a trilateral arms control framework has been declined, stating it as means of "coercion or blackmail."[93] Therefore, from China's perspective, any arms control on nuclear-armed hypersonic delivery systems will only be international, negotiated at the UN, that is more inclusive and equitable.[94] Until then, China will continue to develop arms unrestrained.

IMPLICATIONS FOR INDIA

Even though an accurate assessment of the threat is difficult due to information being limited, sometimes even inflated, China's hypersonic delivery systems still have significant implications for India, which has only recently begun testing its hypersonic capabilities. Moreover, the asymmetrical military postures between India and China, India's limited capabilities in hypersonics, and China's rapid modernisation in hypersonics may significantly impact strategic stability.

China's signalling of the deployment and use of nuclear-armed hypersonic missiles against India may raise insecurities for its nuclear assets and nuclear command and control. Compressed timelines to respond, combined with lack of countermeasures against hypersonics, will add to the country's vulnerability since the ambiguities related to warheads and targets, added with a short duration (hardly minutes) to respond, can put the country at risk. India may be tempted to lower the nuclear threshold, posturing the nuclear forces to either launch on warning or launch under attack to enhance

91. Liping Xia, "China's Nuclear Doctrine: Debates and Evolution", Carnegie Endowment for International Peace, June 30, 2016, at https://carnegieendowment.org/2016/06/30/china-s-nuclear-doctrine-debates-and-evolution-pub-63967.
92. John Dotson, "Beijing Rejects Any Involvement in Nuclear Arms Limitation Talks", The Jamestown Foundation, October 30, 2020, at https://jamestown.org/program/beijing-rejects-any-involvement-in-nuclear-arms-limitation-talks/.
93. Ibid.
94. Ibid.

deterrence,[95] hence increasing the chances of inadvertent escalation.[96] Thus, strategic miscalculations can occur in a crisis.

The confusion about whether the weapon carries a conventional or nuclear payload (warhead ambiguity), the delivery platform it operates on and the uncertainty of what target it was chosen to strike (target ambiguity) can lead to an escalation.[97] However, the counter analysis points out that hypersonics may not increase a country's first-strike capabilities, given the adversary already possesses a secure second-strike capability and it can effectively retaliate nevertheless.[98] This will also be the case with India and China, where established second-strike capabilities exist, and there can be an overwhelming retaliatory strike from India if China uses a nuclear-tipped hypersonic missile.

Another implication for strategic stability lies in the possibility of an expensive arms race in the region. Although China's motivation for developing hypersonics is primarily to counter the United States, the rapid modernisation will pose a security dilemma for India. This will make it necessary for India to take steps to secure itself. As a result, an action-reaction cycle of offence-defence capabilities will emerge. To counter the threats, India will have to develop countermeasures, such as space-based sensors and over the horizon backscatter radars to detect, discriminate and decapitate the incoming missile.[99] This will be expensive and eat into other heads as India is still completing its nuclear triad and associated capabilities.

However, this does not mean that India should be left behind in terms of technology. It must develop the capability to ensure the survivability of its nuclear forces. India is taking significant strides in developing hypersonic

95. Manpreet Sethi, "The Hype over Hypersonics", *The Hindu*, January 26, 2020, at https://www.thehindu.com/opinion/op-ed/the-hype-over-hypersonics/article30659477.ece.
96. John Borrie, Amy Dowler and Pavel Podvig, "Hypersonic Weapons: A Challenge and Opportunity for Strategic Arms Control", UNIDIR, February 14, 2019, at https://unidir.org/publication/hypersonic-weapons-challenge-and-opportunity-strategic-arms-control.
97. James M. Acton, *Silver Bullet?: Asking the Right Questions About Conventional Prompt Global Strike*. *Carnegie Endowment for International Peace* (Washington, DC, USA: Carnegie Endowment for International Peace, 2013) at https://carnegieendowment.org/2013/09/03/silver-bullet-asking-right-questions-about-conventional-prompt-global-strike-pub-52778
98. Terry and Cone, "Hypersonic Technology", n. 2.
99. Richard H. Speier, George Nacouzi, Carrie Lee, and Richard M. Moore, "Hypersonic Missile Nonproliferation: Hindering the Spread of a New Class of Weapons", RAND Corporation, September 27, 2017, at https://www.rand.org/pubs/research_reports/RR2137.html.

capabilities (Table IV). It has developed the Shaurya surface-to-surface ballistic missile (land version of K-15 missile), which can reach a speed of Mach 7.5, ranging from 700 km to 1000 km.[100] It is also jointly developing with Russia a hypersonic version of the cruise missile BrahMos, which can possibly be a variant of one of the hypersonic anti-ship missiles of Russia.[101] The DRDO has recently tested the prototype of its air-breathing scramjet technology, the Hypersonic Technology Demonstrator Vehicle (HSTDV), in 2020, which travelled at six times the speed of sound.[102] A lesser-known fact is the work of an Indian start-up, HTNP industries, developing India's first HGV, HGV-202F, with an altitude of 44–100 km, with the speed range of upper hypersonic.[103] Its prototype was also displayed at Aero India held in February 2021.[104] There has been little publicly available information on development of the countermeasures.

Table IV: India's Development of Hypersonic Systems

Name of System	Range/Speed/Altitude	Status
Shaurya Hypersonic Missile (K-15 variant)	Speed: Mach 7.5 Range: 700-1000 km	Tested and Deployed
BrahMos II HCM	Range: 600-1000 km Speed: Mach 7-Mach 8	Underdevelopment
Hypersonic Technology Demonstrator Vehicle (HSTDV)	Speed: Mach 6	Tested and Under Further Trials
HGV-202 F (HTNP Industries)	Altitude: 44-100 km Speed: Upper Hypersonic	Underdevelopment

Source: Author's compilation from various online sources.

100. "India Successfully Test-Fires New Version of Nuclear-Capable Shaurya Missile", The Economic Times, October 3, 2020, at https://economictimes.indiatimes.com/news/defence/india-successfully-test-fires-new-version-of-nuclear-capable-shaurya-missile/articleshow/78460487.cms?from=mdr.
101. V. K. Saxena, "Hypersonic Weapons - An Analysis", Vivekananda International Foundation, April 10, 2019 at https://www.vifindia.org/article/2019/april/hypersonic-weapons-an-analysis.
102. "DRDO Successfully Flight Tests Hypersonic Technology Demonstrator Vehicle", Press Information Bureau, September 7, 2020, at https://pib.gov.in/PressReleasePage.aspx?PRID=1651956.
103. "HGV-202F", Home, at https://htnp-industries.yolasite.com/. Accessed June 5, 2021.
104. "HGV-202F: Private Firm Shows of Its Hypersonic Boost-Glide Vehicle at Aero India 2021", Indian Defence Research Wing, February 8, 2021, at https://idrw.org/hgv-202f-private-firm-shows-of-its-hypersonic-boost-glide-vehicle-at-aero-india-2021/.

As a result, this demonstrates India's determination to leave no stone unturned in developing hypersonic capabilities. India must equip itself with the right technology to counter China that re-establishes mutually assured destruction (MAD) and nuclear deterrence. Nevertheless, India must not indulge in an expensive arms race that hampers current military modernisation and look for suitable opportunities to hold dialogue with China on nuclear weapons and hypersonics. It must pursue arms control and ensure greater regional stability while avoiding spiralling effects on other countries.

CONCLUSION

This paper has examined the current developments in hypersonic delivery systems, whether HGV or HCM, with their features of speed, manoeuvrability and ability to evade missile defences. Despite their advantages, they face technical challenges, such as thermal management, gas dynamics, and flight controls, which can impact their target accuracy. It is necessary to note that there are speculations on the utility and targets of such systems, as well as whether they are game-changers or just an evolution in technology. Their actual utility, however, can only be known once they are incorporated into the military doctrines. Until then, the ambiguities will continue to foster misperceptions and arms races.

Today, China is among the leaders in hypersonic technology. Its developments are focused on primarily countering the US threat, increasing the survivability and penetrability of its nuclear forces, and protecting its national interest to give China an edge in future conflicts. However, the continuous R&D and deployment point out that, despite the calls for arms control, China will not restrain from developing hypersonic systems anytime soon. Increasing Chinese capabilities, hence, will have implications for strategic stability with India. If China deploys them against India, it will make India's nuclear assets and command and control vulnerable, compel it to lower the nuclear threshold, amplify misperceptions and increase the chances of an arms race at a trade-off with current military modernisation.

While India's capabilities in hypersonic systems are limited, it has been developing them indigenously and with Russian assistance for military and civilian use. It must continue to develop the hypersonic capabilities, like major powers, to ensure MAD and nuclear deterrence. However, India must avoid an action-reaction cycle of an arms race and seek opportunities to pursue arms control and dialogue with China on nuclear weapons to ensure greater strategic stability in the region. Thus, it must tread carefully to counter the Chinese threat.