HYPERSONIC WEAPONS IN JOINT WAR FIGHTING

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Abstract

Hypersonic weapons which have speeds in excess of 5 Mach have caught every one's imagination. The popular thinking is that hypersonic weapons are gamechangers in battle and that they give a nation a winning edge. Whilst that may be so, it might not be true fully. Hypersonic weapons do have tremendous advantages but have problems also. Being high-tech they are very costly. Further, many in the strategic community discuss hypersonic weapons very glibly without understanding what they are. In this context there is a need to understand 'Hypersonic Weapons' better in order to make an informed judgement and assessment on their utility and employment in various circumstances. This article attempts to do so.

Introduction

On 1 October 2019, the DF 17 missile was paraded during China's National Day.[1] The DF17 had been under development since 2014. It was the first and only hypersonic missile, on a mobile platform to enter active service in the world. Even USA and Russia did not have it at that time. The DF 17, equipped with a with hypersonic glide vehicle (HGV), was designed with a speed above Mach 5. Two years later, around Jul-Aug 2021, China tested two hypersonic weapons where, 'a payload was sent into low-Earth orbit, which travelled partially around the globe and released a HGV that travelled through the atmosphere to a target site in Chinese territory'.[2] These two events made everyone sit up. They marked

the onset of the hypersonic age. Ever since then, hypersonic weapons have caught every one's imagination. Current day popular thinking is that hypersonic weapons give a nation a winning edge and that they are gamechangers in battle. In this context there is a need to understand 'Hypersonic Weapons' better in order to make a judgement one way or the other on them. The understanding will enable the defence planners to look at these emerging options in context with Joint Warfighting.

China's Hypersonic Future, Missile Threat
Source : https://missilethreat.csis.org/chinas-hypersonic-future/

Hypersonic Missile - Basics

Technically, "Hypersonic" implies speeds above Mach 5 but also 'within the Earth's atmosphere.'[3] The trajectory of a hypersonic missile is therefore mostly inside the earth's atmosphere. A hypersonic missile uses aerodynamic forces to execute its manoeuvre. Hence the missile has aerodynamic control surfaces such as wings or tail fins to manoeuvre while gliding. It is very similar to an aircraft in flight. Air resistance and density are necessary for its control surfaces to generate lift. Overall, a hypersonic missile manoeuvres within the earth's atmosphere. This is unlike ballistic missiles which spend a considerable part of their flight in space. Ballistic missiles use a combination of aerodynamics and astrodynamics for manoeuvre unlike hypersonic weapon which rely on aerodynamics alone.

A hypersonic missile could be a cruise missile, a boost glide missile, or a boost glide missile based on a fractional orbit bombardment system. A hypersonic cruise missile is based on a SCRAMJET (supersonic combustion ramjet) which accelerates it to the desired Mach speed number. The missile is powered throughout its flight and flies at about 30-40 kms above the earth well within the atmosphere. It manoeuvres to its target like any other cruise missile. The maximum altitude for a hypersonic flight could be up to100 kms. Beyond that earth's atmosphere ceases to exist and one enters into space. A hypersonic missile combines high speed, low altitude trajectory and manoeuvrability to overwhelm air defences[4].

In a boost-glide system, the missile contains a glide vehicle with a warhead. It is initially propelled by a rocket motor to a high speed. It commences on a ballistic trajectory but is either not allowed to escape the atmosphere or is made to turn back into the atmosphere early. Hypersonic missiles mostly fly at suborbital altitudes and are generally not allowed to go out of the earth's atmosphere. The HGV is detached at some point and made to coast and manoeuvre at high speeds within the atmosphere to hit the target. The HGV uses its kinetic and potential energy, as well as lift generated by its movement through the air to coast at high speeds to the target.

In a hypersonic boost glide missile, based on a fractional orbit bombardment system, the missile is fired into a low-Earth orbit and made to travel around or partially around the globe. At a designated time and point, it releases a hypersonic glide vehicle that re-enters the atmosphere and travels through it to a target like a normal boost glide system as described above. In the terminal phase, the glider can release another missile on to the target as attempted by China.

The question which often comes to mind is that how does a hypersonic system differ from a ballistic missile. In essence, a ballistic missile consists of a warhead mounted on a propulsion system with a control and guidance arrangement. Depending upon the range to be achieved, the propulsion system of a ballistic missile could be single or multistage system. Normally, a long range ballistic missile is propelled into space at high speeds. Once the missile reaches space, the motor is shut off and jettisoned. The unpowered warhead

then follows a ballistic path to the target with the help of some thrusters to keep it on the trajectory. Control and guidance are minimal once the main rocket motor is ejected out. Manoeuvre is minimal except in the case of manoeuvrable re-entry vehicles. However, their speeds remain high being in space. Once they re-enter the atmosphere, they gather speed due to gravity. On the other hand, hypersonic missiles possess the high speeds associated with ballistic missiles along with the manoeuvrability and lower-altitude flight of cruise missiles. These characteristics stress early warning and defence mechanisms of adversaries.

When hypersonic weapons are compared with ballistic missiles, or subsonic cruise missiles certain issues emerge. Generally, hypersonic weapons which fly in the atmosphere are likely to have better chance at overcoming long-range missile defences rather than ballistic missiles which operate in space for a considerable part of time of their trajectory. Their detection and interception will be difficult due to their hyper velocities and below the horizon flight trajectories. Their low trajectories make detection late and thus gives very little reaction time to an adversary to intercept them. Their speed and manoeuvre capability makes them unpredictable. It can confuse the adversary of the intended target as compared to a ballistic missile which is quite predictable. They are likely to have better midcourse survivability against ballistic missile defence systems. However, hypersonic missiles lose speed as they glide towards their targets. They are likely to be traveling with lesser terminal speeds as compared to re-entry vehicles which can maintain their speeds closer to the target. Therefore, their vulnerability against terminal defences increases. However, both missiles can carry out manoeuvres near their targets to make interception difficult. A major point of consideration is that hypersonic technology is still maturing as compared with all other missile technologies. Further, hypersonic boost-glide missiles are costlier by about 1/3rd as compared to equivalent range ballistic or cruise missiles. A fractional orbital bombardment system with a glide vehicle is costlier and more complicated. From available literature, it is not accurate enough to be considered as a fully deployable weapon and is still in the process of evaluation. A holistic comparison between ballistic missiles, subsonic cruise missiles and hypersonic boost glide vehicles is very well illustrated in the Fig 1.[5]

Fig.1: A holistic comparison between ballistic missiles, subsonic cruise missiles and hypersonic boost glide (Source :- U.S. Congressional Budget Office (https://www.cbo.gov/publication/58924)

The operational implication of all missile systems described hitherto fore is best understood from the Fig 2. When a ballistic missile is fired at a target, its trajectory stands exposed for the best part of its flight as can be seen in the graphic above. It can be detected and dealt with at almost any stage of its flight. On the other hand, a hypersonic cruise missile (HCM) or a HGV can be kept under the radar horizon and evade detection for the best part of their flights. A Manoeuvrable Re-entry Vehicle is a via media compromise between the almost complete exposure of a ballistic missile and the complete undetectability of hypersonic systems. The fractional orbit bombardment system with a HGV is different in the sense that it drops down on an unsuspecting target at greater speed with a near vertical approach. It achieves surprise and leaves a target with very little reaction capability. Hypersonic weapons are visualised to be employed against distant, time-sensitive, or well defended targets.[6] Their high speeds compress engagement times drastically compared to ballistic missiles. Their low trajectories enable them to evade missile defences.

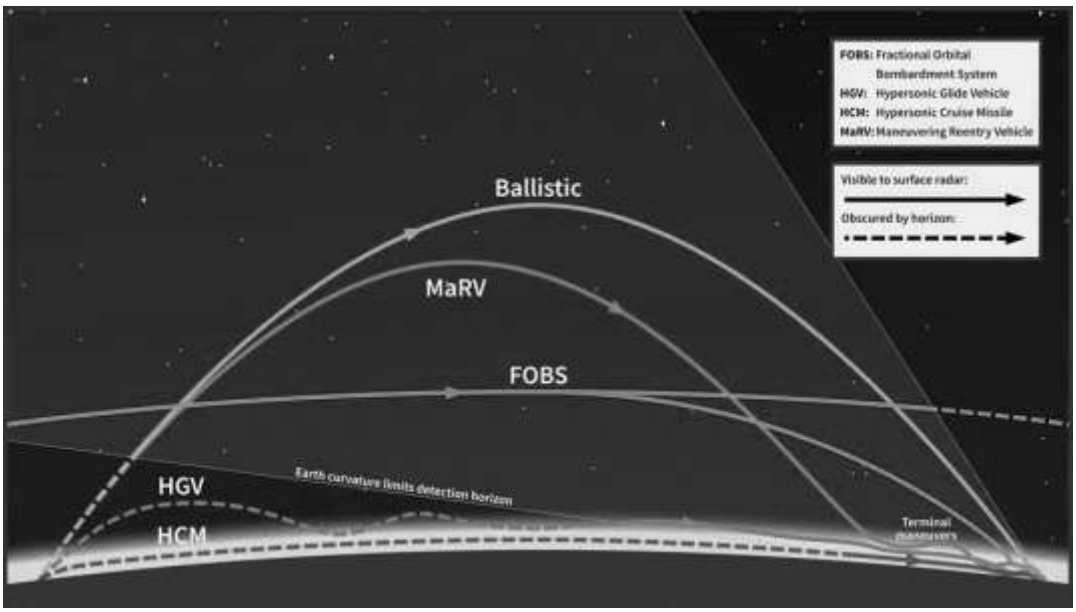

Fig 2: Operational Implication Of All Missile Systems
Source : https://missilethreat.csis.org/wp-content/uploads/2022/02/220207_Karako_Complex_AirDefense.pdf

Hypersonic Technology

Technology which differentiates a normal missile and a hypersonic missile revolves around two issues. Firstly, the propulsion system must be able to propel the missile to Mach 5 and above. Secondly, the Glide vehicle must be able to withstand the effects of high speeds and reach the target intact and in working condition to perform its task.

Propulsion systems of normal rockets/missiles use liquid, solid, or even gaseous propellants which contain an oxidiser.[7] These are ignited in the rocket motor to produce thrust. On the other hand, Hypersonic missiles are based on air-breathing engines which carry only fuel rich propellants in their tank. These engines 'breathe in' pressurised oxygen required for combustion from the air during flight through well designed air intakes. The oxygen gets forcefully pressurised into the rocket motor due to the relative motion of the high speed of the missile and air. When air intake is at subsonic speeds it is called a Ramjet. When the air intake is at supersonic speeds, it is called a Scramjet. Airflow

in a scramjet engine is kept supersonic throughout the entire engine. This ensures that the Scramjet can theoretically operate efficiently even at speeds between Mach 12 and Mach 24[8]. In practice, a Scramjet engine enables a missile to achieve speeds beyond Mach 5. Hypersonic missiles are therefore based completely on Scramjet engines. This technology is currently available with a few countries only. Scramjet engine is shown in Fig 3 for reference. A major point to be noted is that a Scramjet engine has to be taken up to a speed of Mach 1.5 or more through a booster engine before it can function. Hence a Hypersonic missile is invariable always a two stage propulsion system.

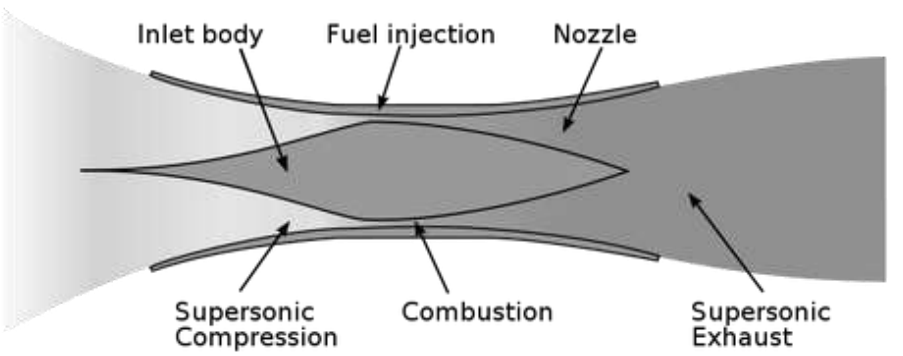

Fig 3: Scramjet Engine

A glide vehicle is essentially a remotely/autonomously piloted air craft which is flying at very high speeds in a very challenging environment. The design of the glide vehicle is therefore cutting edge technology. When a missile transits from supersonic conditions into the hypersonic environment, the external aerodynamic flows and forces on the surface of the glider are dominated by severe aerothermal heating. The high speeds at which a hypersonic missile flies creates a superheated atmosphere due to sheer air friction. This results in extreme thermal gradients and high pressures which stresses any material to fatigue point at accelerated rates as operational Mach numbers increase. This will invariably lead to material failures. Hence the material used is of utmost importance. The material is usually a combination of refractory metals, composites and ceramics. The design of the hypersonic vehicle is equally critical. It involves design of the aeroshell/primary structure, leading edges, control surfaces, thermal protection of exposed

surfaces, propulsion, and guidance systems to perform satisfactorily under such extreme conditions. Existing materials are not resilient in such extreme environments. Design of such materials and structure involves cutting-edge research.[9]

Employment in Battle

Hypersonic weapons were employed for the first time in battle by Russia against Ukraine in their ongoing conflict.[10] Russia targeted an underground ammunition dump and a fuel depot in March 2022. Russia used the air launched Kh-47M2 Kinzhal hypersonic missile to strike targets in Ukraine on multiple occasions.[11] Russia has also demonstrated a ship launched hypersonic cruise missile named Zircon. In April 2024, President Putin stated that the Zircon was used in battle[12] and that it would be impossible to defend against it since the missile has a speed of Mach 8. These two episodes give us a basis on which one can visualise the likely employment of Hypersonic weapons in battle.

Hypersonic systems would be used against high value time specific targets at long ranges (from a hundred to a thousands of km). They would be employed where there is a requirement of high accuracy while attacking a pinpoint target. For instance, the Chinese have made much of the DF 17 being a 'carrier killer' [13]; implying that their hypersonic weapons have the capability of pinpoint accuracy against a fast moving and well protected target like an aircraft carrier. This also implies that hypersonic missiles will be used to overwhelm and penetrate the air defences of the adversary through their sheer speed. The manoeuvrability of hypersonic missiles gives them the advantage of creating uncertainty about their final target. This also enables to spread and stretch the adversary's air defence system. Hypersonic missiles could also be equipped with nuclear or conventional warheads. This creates ambiguity in the opponent's mind.

It must also be realised that hypersonic weapons are 'niche' by nature and are far costlier than ballistic missiles.[14] Nations will only have a limited number in their kitty. Hence, they need to be employed with care. More importantly they cannot be employed everywhere. Further, a missile can hit only one target with a given warhead. To that extent they can be game changers only when used with care. Hence ISR of a very high order as also a thorough target analysis will be necessary. Reconnaissance strike integration will have to

be through a dedicated command and control system. In such an environment, there will also be a necessity of space-based inputs through a global positioning system combined with wide spread ground stations to provide control inputs to the missile once launched. On the whole executing a hypersonic strike in a dense AD environment against a target moving at about 30-40 miles per hour will be a complicated, challenging task which needs detailed planning and coordination.

From all available sources it is pretty apparent that the Russian use of hypersonic missiles have really not been a game a changer in battle. In fact, if Russia had not announced that it had employed its hypersonic weapons, it would not have been even known. Russia has used its hypersonic systems for conveying a strategic message as part of its deterrence plan to keep NATO out of battle. From all available analysis, it has achieved its aim of keeping NATO out of the contest not only by use of a hypersonic missile but by employing an implicit nuclear threat. Overall whether a hypersonic weapon is actually used against a high value target or used demonstratively against any other target, its employment has geostrategic ramifications. This is a factor one must be cognisant of.

Defending Against Hypersonic Weapons

The rationale of a hypersonic weapon is that its high speed and low trajectory makes defence against it very difficult. It is supposed to be impervious to even advanced air defence systems. However, it is to be noted that "Ukraine has announced that the Ukrainian Air Force shot down a Kinzhal hypersonic missile using the Patriot PAC-3 air defence missile system on May 4, 2023."[15] Hence hypersonic missiles can be detected and intercepted.

Defending against a Hypersonic attack hinges on disrupting its 'kill chain'. A kill chain consists of surveillance systems to locate targets, communications networks to relay targeting information to weapons launchers followed by actual launch of a missile. Once launched, the missile needs to home on to its target. Each step in the 'kill chain' is vulnerable to interdiction or disruption. Very often the effort is to discern and home on to the weakest links in the chain. It is axiomatic that defending against a hypersonic threat

will involve a detailed analysis of the threat and how it can manifest. This would lead to a plan to defeat the threat.

One of the basic methods is to put in a passive missile defence. Passive methods include dispersion, deception and hardening. Dispersion of asset bases and personnel across the battle field in sync with the terrain and environmental conditions is a time tested method. It ensures that the detractive impact of a missile attack is limited and strike effectiveness is reduced while retaining own combat potential. Missiles can also be deceived by presenting them with false targets either physically or electronically. One can resort to an elaborate system of decoys or flood the enemy information system with false targets. The alternative is of course to camouflage the likely targets either physically or electronically. Likely missile targets can be hardened and made resilient so that they can withstand a missile attack and bounce back. This could be through a system of having adequate reserves or through good repair and recovery methodology.

There would also have to be a surveillance system in place to effectively monitor hides and launch sites of the weapon so as to actively disrupt its deployment in the first place. Alternately, the weapon/missile can be tracked throughout its flight, either through over the horizon or space based capability. Invariably it would have to be a combination of the two. The weapon can be disrupted either electronically or physically on launch, in mid-flight or in its terminal phase. Hence a layered surveillance and air defence capability must be put in place. The current thought process is to shoot incoming missiles down through down kinetic interception. It could be done by direct collision or blast-fragmentation interceptors that explode at close distance, spraying shrapnel into the hypersonic vehicle. In future use of lasers, high-powered microwaves, rail guns, or particle clouds designed to disrupt hypersonic weapons in flight will invariably be devised. These could be space or land based.

However, this is easier said than done since 'Hypersonic weapons are extremely difficult to detect and counter given the weapons' speed and manoeuvrability, low flight paths and unpredictable trajectories.[16] The entire concept of a countering and defending against a

hypersonic system is a work in progress. As days go by better and more holistic counter hypersonic systems will evolve.

China's Thought Process on Hypersonic Weapons

It is well known that China possesses 'the most significant ground-based missile force on Earth.'[17]. It is also the largest and most diverse missile arsenal in the world.[18] An important component of China's rocket force is its hypersonic weapon capability. The Chinese opine that hypersonic weapons give it the capability to 'fight and win wars against a strong enemy (United States), counter an intervention by a third party, and project power globally'. China places faith in its rocket force to threaten U S Forces with a barrage of long range precision guided missiles. They believe that such a tactic will force the US military to keep a safe distance away from its shores/area of operations. As explained by one Pentagon official when the Chinese can deploy [a] tactical or regional hypersonic system, they hold at risk our carrier battle groups. They hold our entire surface fleet at risk. They hold at risk our forward-deployed forces and land-based forces. The Chinese also aim to paralyze or incapacitate US military capability in the initial phases of any future battle. In Chinese thinking, hypersonic weapons will help immensely in disintegration of US force capability. They also feel that China can also pose a new threat to mainland USA if their hypersonic weapons are deployed as part of naval task forces operating from forward bases in the Pacific.

China, at this point of time sees itself as being far ahead of its peer competitors in Hypersonic technologies and weapons. Hypersonic missiles with conventional warheads could provide China with better escalation controls and capability to deter USA from intervening in a regional conflict specially in a Taiwan scenario. Against this backdrop, in 2019, China deployed its first operational hypersonic system, the DF-17 hypersonic glide vehicle (HGV) capable medium-range ballistic missile (MRBM).[19] In a regional conflict in the Western Pacific, it is estimated that China will have the advantage of being able to fight from its territory. This implies that while its own forces can be dispersed yet be logistically well disposed, the forces of its adversaries would be stretched logistically and be forced to

operate in a concentrated manner from specific bases only. This gives China's rocket force and its plethora of hypersonic weapons a huge advantage.

Employment of Hypersonic Missiles in Joint Warfighting in India

It is evident from the above discussion that if the hypersonic missile system have to be weaponised by India in the Tri-services construct, these have to be produced in adequate numbers and that too indigenously. Proper selection of targets has to be done to get value for the cists invested. Like nuclear arsenal, these also have the huge potential of strategic signalling which has successfully attempted by Russia. Since, China has taken the lead in this field, India needs to galvanise the R&D, manufacturing and employment.

Conclusion

The ability to deploy and employ high manoeuvre hypersonic weapons with long ranges is a major strategic advantage for any country since they can evade current defence systems and be effective on their targets with great effect. However these weapons are not game changers unless reconnaissance strike integration of a high order is in place. Presently it is only China and Russia which have these weapons in their inventory. The US is in an advanced stage of testing them. North Korea has also carried out some tests of hypersonic weapons. Australia, India, France, Germany and Japan have the capability and technology to develop them and are in the process of doing so. In addition, Iran, Israel and South Korea are also carrying out some research in this field. As Hypersonic weapons are being developed, there is also a parallel development in defence against these systems. All in all, as the hypersonic system technology matures, these weapons will continue to dominate strategic thinking in years to come.

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