CENJOWS

ISSUE BRIEF

SPACE FRONTIERS FOR BUILDING COUNTER HYPERSONIC CAPABILITIES

LT GEN (DR) V K SAXENA, PVSM, AVSM, VSM (RETD)

www.cenjows.in

CENTRE FOR JOINT WARFARE STUDIES

CENJOWS

SPACE FRONTIERS FOR BUILDING COUNTER HYPERSONIC CAPABILITIES

Lt Gen (Dr) VK Saxena, PVSM, AVSM, VSM (Retd), former Director General Air Defence, Indian Army.

Abstract

The professional body today has moved far beyond the debate as to why there is so much buzz about the hypersonic weapons. The talk in the defender's camp today is to challenge the tag of 'un-stoppable' attached to the hypersonic weapons.

This work looks at the challenge of building the counter- hypersonic capabilities as it relates to our scenario and in that, how the domain of space can be optimally utilized.

BUILDING THE PERSPECTIVE

The three combat virtues

Basically three combat virtues constitute the 'challenge package' in the hypersonic weapons. These are briefly captured[1]:-

- **Speed is the first virtue**. While the qualifying standard to be designated as hypersonic is merely Mach 5 (6174 km/h). The real hypersonic weapons are far more menacing in speed. Sample these:-
    - Zircon Hypersonic Cruise Missile or HCM (Russia) - Mach 8 (9878 km/h)
    - DF 27 hypersonic IRBM (China) - Mach 8.6- 10 (10,619km/h).
    - KH 47 M2 kinzhal HCM (Russia) Mach 12 (14817.6 km/h).
    - DF 41 HCM (China) and Avanguard Hypersonic Glide Vehicle or HGV (Russia) - Mach 27 (33339.6 km/h)

- At these speeds many things happen:-

    - The incoming weapons totally rout the OODA cycle of detection-interception-destruction which the conventional air defence missiles and anti-missile systems must go through to counter the threat. Hence the tag ‘UNSTOPPABLE’.

    - Speed is the new stealth as the menacing weapons flying in the far hypersonic domain give no chance (implying time) for the conventional surveillance or the missile guidance radars to detect the incoming threat.

    - The virtue of speed also grants a great degree of unpredictability to hypersonic weapons as these can change course suddenly. This also enables them to keep huge swaths of area under their threat footprint forcing the defender to commit disproportionate resources for defence.

    - Higher the speed, higher is the kinetic catastrophic effect at the target end. By one count, for the same weight of warhead a hypersonic weapon at just Mach 5 will have some 36 times higher kinetic kill effect than a normal conventional missile. Imagine at Mach 12/20/27?

    - Threat vehicles at such incredible speeds smash the air molecules around them which break up into positively charged ions and negatively charged electrons and cover the weapon with a sheath of plasma. This plasma has a capability to block the radar waves making detection that much difficult. It also blocks the radio waves making two way communications with the threat vehicle a very big challenge.

- **The second virtue is maneuverability**. Unlike a pure ballistic missile whose trajectory is governed by the force of gravity and is highly predictable, hypersonic trajectories are unpredictable as the threat vehicles being all-the-way powered can manoeuvre and have an unpredictable trajectory.

- **The third virtue is altitude**. HCMs fly low and normally remain under the radar shadow thus making detection a big challenge. The plasma sheath surrounding the vehicle’s immediate environment adds to the degree of difficulty. HGVs normally exploit the near space environment (60-80Km) where these threat vehicles skip along at the end of the atmosphere at incredible speeds. This is one area of space that poses a great detection challenge the sensors on ground, air and space.

HYPERSONIC THREAT IS NOT A FLIGHT OF FANCY

The hypersonic threat is very much real from our northern neighbour. Some salient points are briefly captured:-

- While the run-up preparation to build the hypersonic capability in China started way back on 2010-11, the prototype for tests started to appear sometime in 2017-18.

- For instance in May 2018, China tested an HGV boosted by a solid fuelled MRBM called DF 17 having a range of 1800-2500km. The vehicle flew for about 1400km and hit its intended target in Xinjiang province[2]

- Soon thereafter in Aug 2018, China tested a hypersonic aircraft (Xingkong -2 also called Starry Sky -2). This HCM achieved 5.5 to 6 Mach, it flew for 10 min achieving an altitude of 30 km.[3]

- In the years that followed number of various scaled down hypersonic aircraft models were tested (DF 18-1S, DF18-2S, DF18-3S).[4]

- In Jul 2021, the Long March rocket (the one that carried the lunar probe Change-5) boosted an HGV that actually went over the South Pole thus achieving a capability of threating the US missile defences from the southern and SE direction. This HGV also did something unprecedented. It fired an Air-to-Air Missile (AAM) towards the end of its flight. A hypersonic AAM designed to kill a missile defence warhead or may be a satellite killer? [5,6,7,8]

- As recent as Feb 2023 China launched an HGV (DF ZF) boosted by the DF 27 IRBM (range 800 km). The HGV flew for 12 min to a range of 2500 km achieving Mach 10 and rose to an altitude of 30.48 km[9].

All the above and more indicate that China does have a hypersonic threat capability. It will also be reasonable to assume that the associated command and control structures required to operationally use the hypersonic warheads are in place/fast catching up.
Two other points based on the sense of the author are also worth mentioning here:-

(1) It is still a few years before the hypersonic threat from China actually becomes 'battle-ready'.
(2) It is a common knowledge that China has more of US on its cross-wires than India. That of course gives no room for complacency knowing the treacherous ways of our hostile neighbour. Also, where capability exists intent exists; period!

OFFENCE IS THE BEST DEFENCE

In line with the above truism, building a hypersonic strike capability is the best form of defence against them. Why?

- Firstly, building a defensive capability against the hypersonic threat is a many notches more difficult task than to build an offensive capability.

- Secondly the deterrent value obtained by having operational hypersonic weapons will force the adversary to think twice before taking up the misadventure.

As of date the offensive hypersonic capability is the purview of only a handful of nations – Russia, China leading in that order, US playing the catch up not yet there, India, Israel, Iran and South Korea- development stage) .
As regards India following points are stated:-

- India's hypersonic journey began way back in 2004 when the DRDO took up a conceptual design for a hypersonic air frame.

- In 2008, the then Chief of DRDO, Dr. V K Saraswat indicated a possible dual use of hypersonic technology being used for Low Cost Satellite Launch Vehicles also making up for the HCMs.

- In the period 2010-2016, wind tunnels (one imported from IAI Israel and the other provided by National Aerospace Laboratory) were used to test various hypersonic related technologies.

- On 12 Jun 2019 the DRDO tested the Hypersonic Technology Demonstration Vehicle (HSTDV) boosted by an Agni 1 missile[10].

- This test was only a partial success. The ballistic carrier vehicle did not complete its mission since its booster went into an uncontrolled mode and could not achieve the desired altitude.

- The second test followed on 07 Sep 2020. Though the booster behaved this time and the vehicle did fly for 20 sec achieving the speed of 6 Mach, the overall result was again a partial success only[11].

- The latest test took place on 27 Jan 2023. The success rate was better than the previous two tests but still not quite there. This is indicative of the huge degree of difficulty in achieving a proven hypersonic offensive capability[12].

- That notwithstanding, the trio of tests have got us somewhere. In that the following stands proven:-

    - Aerodynamic configuration for a hypersonic manoeuvre.

    - Boost technology to achieve speeds so as to set up the wave-rider phenomenon (a point where the shock waves generated by the boost flight starts acting as lifting surfaces hugely increasing the lift to drag ratio and enabling the HGV to detach from the carrier and takeoff on a hypersonic maneuver.

- Setting up of scramjet propulsion (engines using atmospheric oxygen to combust air+fuel mixture at supersonic speeds and propelling the vehicles at many a Mach speeds).

- Successful development of materials (titanium alloy for airframe, niobium alloy for engine and mnemonic alloy for outer surfaces) that can withstand surface temperatures in hypersonic domain (2000-2500^{0}C).

- Communication and connectivity with hypersonic vehicle despite the plasma sheath challenge.

- Along with all the above, in Dec 2022 ISRO in coordination with the Joint Services Innovation and Indigenization Centre (JSIIC) under HQ IDS, developed an Hypersonic Air Breathing Vehicle with Air Integration System (HAVA). The current focus of the project us to test and prove critical technologies.[13]

All this is clearly a WIP (work in progress) with many challenges yet to be overcome. The ambitious aim is to achieve a 600 sec controlled, sustained and powered flight achieving a range of at least 1500 km with a capability of taking 300-400 kg of conventional and special warhead – a huge challenge.

BUILDING COUNTER HYPERSONIC CAPABILITY

This is still a bigger challenge which is configured on three main verticals:-

1. The Detection Challenge.
2. The kill Challenge
3. The BMC2 challenge.

THE DETECTION CHALLENGE

As explained earlier the tag of ‘unstoppable’ is derived by hypersonic threat vehicles from their unique strength that these cannot be detected (hence killed) by conventional air defence sensors. A quick recap of the challenges:-

- HCM remain low and avoid radar detection by mostly flying in the radar shadow.

- HGVs skip along the upper end of the atmosphere- a region where both the ground sensor as well as satellite based sensor are week in detection.

- The ‘speed’ as it is gives no time for any conventional sensor to go through the paces.

The solution to the above seemingly insurmountable challenges lies in having a ‘global look-see’ capability in the target area of interest through a distributed architecture of sensors. This is briefly enumerated:-

- The concept of distributed sensor architecture is to extend the sensor arm all the way from ground (and sea) to air to space with a capability of detection from low-levels to near space (end of atmosphere) – the domain of HGVs.

- This will demand the ground sensor uplinked to air/ hi-altitude drone based sensors on to sensors based in the low earth orbiting satellites.

- This is a monumental challenge which is easier said than done.

- The emerging trend in the aerial sensors is to employ pseudo high-altitude satellites also called the HAPS or High Altitude Platform Systems. HAPS are platforms located in the stratosphere at altitudes from 20km to 80 km.

- These stable platforms carry on board state-of the art sensors such as imaging radars, Synthetic Aperture Radars (SARs) along with an array of Electro-optical and Infrared sensors. SARs incorporate the Ground Moving Target Indicator (GMTI) function enabling such radars to pick up moving targets over static terrains.

- HAPs provide tremendous coverage. An HAPS at just 20 km altitude has a radio horizon of 580 km and an optical horizon of 500 km meaning thereby, a that a few HAPs placed appropriately, can cover a very huge swaths of area.

- The hypersonic vehicles are ‘heat-bombs’. The sure way to detect them is to track their heat signatures. HAPs with high sensitivity IR sensors on board will prove to be invaluable in detecting a hypersonic vehicle instantly.

- Of course the task will become more and more challenging when heat signature of the threat vehicle will need to be distinguished from the heat signature emanating from hot earth surface. GMTI combined with high resolution IR sensor may help.

- What about satellite based surveillance? Orbiting satellites in LEO carrying IR sensors on board is no easy solution as well. A large number of satellites will have to be orbited to keep the surveillance chain active over the target area of interest.

- For instance US, under its programme called HBTSS (Hypersonic and Ballistic Tracking Space Sensor) plans to launch three tranches of satellites:-[14]

    - Tranche 0 – a set of eight missile warning satellites positioned closer to the earth’s surface than the existing Geo-stationary satellites and equipped with Wide Field-of-View (WFOW) Overhead Persistent IR (OPIR) sensors.

  - Trance 1 – a set of 28 satellites (to be launched by 2025) in the LEO orbits to keep the target area under constant surveillance.

- As against the satellite-based surveillance regime, the HAPs platforms will have the following advantages:-

  - Much less costlier.
  - Providing a much closer (hence a clearer) look at the near space being located in the stratosphere.
  - Lower latency rates.
  - Lesser number of near static HAPs platforms proving surveillance and communication capability over huge swaths of area

This is just a small glimpse of the degree of challenge in detection of hypersonic threat vehicles. And also it is just a third of the challenge, the balance two-thirds lies in the other two verticals (kill and BMC2).

Where is India in HAPS?

Open sources reported that HAL in collaboration with a start-up New Space Research and Technologies Private Limited (NRT) are jointly developing a High Altitude Pseudo-Satellite Unmanned Aerial Vehicle. This huge solar powered platform named 'CATS Infinity' with a span of over 50 m will have the capability of providing uninterrupted communication a and surveillance cover for months together. Some points[15]:-

- These are all still baby steps.

- DRDO must come in to tie up with ISRO on providing HAPs based and LEO satellite based surveillance for detection of hypersonic threat vehicles.

- The monumental stature and costs of such strategic projects must be carefully weighed with a host of other factors. Some of these are:-

  - In what time frame will we require such a capability?
  - Offensive vs defensive capability.
  - Reality of the threat becoming critical and in what time?
  - Dual use/ existing capability takeaway/up-gradation of the existing capabilities etc.

THE KILL CHALLENGE

Even if a hypersonic threat gets detected (if at al?) while there are still a few fleeting minutes left to kill it, the conventional air defence and anti-ballistic missile systems will as it is proved ineffective to counter it; simply too fast (read too smart) for them. The weapons that can kill them must out-beat them in speed. These must strike instantly and at lightening speeds

Such arsenal belongs to the category of Directed Energy Weapons or DEW; also called soft-kill weapons. Essentially, these weapons direct a beam(s) of destructive energy on the target to cause immediate catastrophic destruction[16]. These are of three types; Laser, High Power Microwave (HPM) and Charged Particle Beams (CPB) weapons.

DEWs have ranges that are invariably higher than conventional weapons to kill threats beyond the SAMs. These strike at the speed of light thus meeting the response-time challenge of hypersonic weapons. Also, the Soft-kill magazine is unlimited. A powered source can attack, multiple threats in quick succession endlessly.

How DEW will kill hypersonic threats?

- A laser DEW is configured to direct a very high-powered laser beam (15-100+ KW) on the target. Such killer beams with high degree of coherence, directionality and high intensity achieve an instant burn-out and crippling of the electronics and electromagnetics on the target leading to its instant kill. The challenge however is to be able to generate laser beams of adequate power to be effective at required ranges especially when such weapons are deployed at some distance from the threat (ground, sea, HAPS, near space?). Another challenge is the degradation of laser beams on account of such factors as air turbulence, moisture, dust, fog, mist etc.

- An HPM weapon is designed to accelerates an electron beam to very high voltages (200KV+), currents (1-100 kilo amperes) and energy (200+joules/pulse). Such beam in short pulses when directed on to the target causes adiabatic burnout of electronic components and detonation of electro-explosive devices on the target causing an instant kill. The greatest challenge in such weapons is to be able to produce a pulsed beam of such power on a weapon platform.

- CPB weapons achieve its destructive power by accelerating sufficient quantities of sub-atomic particles to velocities near the speed of light (186000m/s). Such a beam develops a penetrative capability akin to a ‘Lightning Bolt’. These when incident on the target instantly cause a catastrophic kill.

As of date laser weapons are a reality, HPM is on the cusp of reality and CPB are in the pipeline.

Where is the world and where is India in DEW?

The world:-

- As stated Laser weapons are a reality today. US Army’s Guardian 50 KW laser system was reported to be operational by Dec 2022.[17] Another US defence giant Lockheed Martin was reported to be demonstrating a 300 KW laser weapon in Jul 2022.[18]. Airborne High Energy Laser (AHEL) is also under development[19]. Frontline countries that have developed laser-kill weapons are Russia (Peresvet

and Zadira Systems) and China (weapons from 50- 300KW capability)[20]. France, Germany UK, Israel, Turkey and Iran are also in DEW domain.[21]

India:-

- Centre for High Energy Systems and Sciences (CHESS) and Laser Science and Technology Centre (LASTEC) under the DRDO are the nodal Centre for developing the DEW.

- India is developing 100 KW DEW called DURGA II (Directionally Unrestricted Ray Gun Array). Its predecessor (DURGA I) was a 1KW weapon with a range of 250 m. DURGA II is a classified project. It is likely to be operational shortly with Army and in other two Services thereafter.

- LASTEC is reported to have developed a 25 KW laser gun that can kill a ballistic missile in its terminal range up to 5 km.[22]

- DRDO with BARC are reported to be developing an HPM weapon since 1989. It is called KALI (Kilo Ampere Linear Injector) or Single Shot Pulsed Gigawatt Electron Accelerator. This DEW will emit powerful pulses of electrons to achieve a soft-kill. Based on increasing electron beam power. Several versions of KALI have been developed (KALI 80, 200, 1000, 5000 and now KALI 10,000). KALI 1000 was reported to be commissioned in 2004. This Project is classified Top Secret.[23]

- LASTEC has developed technologies in the laser domain. This includes Gas dynamic laser (GDL-20KW) and Chemical Oxygen Iodine Laser (COIL -100KW). Its Project Aditya was an experimental Test bed to seed critical DEW technologies[24].

Developing DEW is one issue, deploying them will be a greater challenge. Still a long way to go.

THE BMC2 CHALLENGE

BMC2 is the biggest of all the challenges in building counter hypersonic capability. Here is a small glimpse of what all a typical BMC2 has to achieve:-

- Building near real-time communications and connectivity between hugely dissimilar sensor platforms on ground, sea, air, HAPs and space and tying them all into one huge but instantly responsive loop of a distributed surveillance architecture grid having a global look-see capability focused in the area of interest.

- Maintaining a dynamic threshold air surveillance picture (ASP) by carrying our multi-sensor fusion of dissimilar sensor inputs corrected for duplication.

- Keeping the ASP dynamic across the entire chain of sensors connected to the command infrastructure.

- Instant picking up of hypersonic threats by one/more sensors (radars, EO, IR) across the distributed sensor architecture and passing them in real time to weapon control centres.

- Auto-selection of the most optimally placed DEW and designation of the threat to the same.

- Instant decision to kill followed by the launch of DEW.

- Weapon control of DEW to achieve a catastrophic kill.

All this looks pretty simple when presented in a few bullet points. Each of these is a herculean challenge. This is something with which the world is currently engaged.

It is heartening to note We Are Very Much There.

DISCLAIMER

The paper is author's individual scholastic articulation and does not necessarily reflect the views of CENJOWS. The author certifies that the article is original in content, unpublished and it has not been submitted for publication/ web upload elsewhere and that the facts and figures quoted are duly referenced, as needed and are believed to be correct.

---

[1] "Hypersonic weapons- an analysis," at www.vifindia.org. Accessed on 02 May 2023.
[2] "Advanced hypersonic missile threat", at www.economictimes.indiatimes.com.Accessed on 02 May 2023.
[3] World's first-hypersonic aircraft that can fire nuclear warheads," at www. indiatoday.in. Accessed on 02 May 2023.
[4] "China tests three hypersonic missiles at one go," at www. economictimes.indiatimes.com. Accessed on 03 May 2023.
[5] "China tests new space capability with hypersonic missile," at www.ft.com. Accessed on 03 May 2023.
[6] "China hypersonic missile test showed unprecedented capability," at www.bloomberg.com. Accessed on 04 May 2023.
[7] "Hypersonic: China Hypersonic missile test: All you need to know," at www.timesofindia.indiatimes.com. Accessed on 04 May 2023.
[8] "China launched second missile July hypersonic test, reports say," at www.the guardian.com. Accessed on 04 May 2023.
[9] "China deploys hypersonic IRBM.." at www.firstpost.com. Accessed on 04 May 2023
[10] DRDO successfully tests HSTDV," at www.pib.gov.in. Accessed on 05 May 2023.
[11] DRDO successfully tests HSTDV," at www.pib.gov.in. Accessed on 05 May 2023.
[12] India's march towards achieving hypersonic capability," at www.vifindia.org. accessed on 07 May 2023.

[13] “Air breathing propulsion,” at www.vssc.gov.in. accessed on 07 May 2023.
[14] Hypersonic and Ballistic tracking Space Sensor Satellites, “at www.northropgrumman.com. Accessed on 10 May 2023.
[15] ‘HAL Combat air Teaming System,” at www.en.m.wikipedia.org. Accessed on 10 May 2023.
[16] ‘Directed energy weapon,” at www.en.m.wikipedia.org. Accessed on 10 May 2023.
[17] The US Army laser weapon platoon..,” at www.interesting engineering.com. Accessed on 10 May 2023.
[18] “US Military gets most powerful laser..” at www.eurasian times.com. Accessed on 11 May 2023
[19] “Changing the game..” at www.news18.com. Accessed on 12 May 2023.
[20] ibid
[21] Directed energy ..” at sentinelassam.com. Accessed on 12 May 2023.
[22] 6ibid
[23] “KALI” at www.en.m.wikipedia.org. Accessed on 12 May 2023
[24] “Aditya Project..<” at wwwindiandefencenews.in. Accessed on 13 May 2023.