Centre for Air Power Studies

HYPERSONIC TECHNOLOGY: CHALLENGES AND OPPORTUNITIES

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Introduction

Aerospace technology has been relentless in its breaching of new barriers. Initially aircraft, in the infancy of air power were restricted to speeds of a few tens of kilometres per hour (kmph). By World War-II (WW-II) speeds of up to 600-700 kmph could be achieved.[1] At the time the limitations of airflow around a propeller system were seen to present an upper limit to achievable speeds.[2] Development of the centrifugal flow jet engine followed by the axial flow jet engine overcame this limitation and in a few years the sound barrier has been broken. Thereafter supersonic aircraft capable of speeds of just past Mach[3] 2.0 became commonplace. A few specialised aircraft, the American A-12/SR-71 "Blackbird" and the Soviet MiG-25 "Foxbat", were able to reach speeds of Mack 3.2 and remained the fastest aircraft built by man till recently.[4] Today the cutting edge of research involves building aircraft able to fly at hypersonic speeds. These new technologies, of hypersonic craft, pose fresh challenges while also presenting new opportunities to overcome earlier imitations in capability.

Background

The endeavour to attain hypersonic speeds depends upon a few key technologies. These are development of engines able to maintain steady combustion in a supersonic airflow, materials able to withstand the very high temperatures that a craft at such speeds would be subjected to by air friction, and craft shaping to be able to operate effectively at

such speed regimes with suitable control systems to enable required manoeuvrability.[5] The requirement for engines able to maintain combustion in supersonic airflow could be dispensed with if the craft is designed to glide with every decreasing speed. This could be the case for say a vehicle shaped to operate at hypersonic speeds by virtue of its shape and brought to hypersonic speeds in a long range rocket.

Supersonic flight is considered to commence once the airflow around an aircraft is traveling at a relative speed of beyond the speed of sound or approximately 1,225 kmph or 340.3 meters/second (m/s) at International Standard Atmosphere (ISA) conditions at sea level. The speed of sound reduces to 1,063 kmph or 295.4 m/s at 35,000 feet or 10,668 meters above Mean Sea Level (AMSL).[6] Hypersonic speeds are arbitrarily designated as speeds of flight above Mach 5.0.[7]

The quest for hypersonic speeds stems from two requirements, the more important of which is the ability to penetrate contested airspace successfully. In the current Western air power tradition this capability has been achieved through development of stealthy fifth generation (Gen 5) aircraft such as the F-22, F-35 and B-2 bomber. These craft carry a very high per unit purchase cost ranging from $181 million to $ 2.2 billion from the F-35A to the B-2. Another avenue to achieve the capability is through development of vehicles able to operate at hypersonic speeds. All defensive systems have a limit in the speeds envelope of targets that they can engage effectively due to the detection and tracking capabilities of their sensors as well as the interception projectile's capability to achieve required speeds in short time frames to be able to follow needed interception geometries. Most anti-aircraft weapons available in the world today and even under development lack the ability to engage hypersonic craft as this was a threat that was not in the offing when the design and development or these anti-aircraft weapon systems commenced.[8]

Of the countries that have the capability to field advanced materials able to withstand high thermal stress one can count the US, Russia, a few technologically advanced European countries such as France and Britain, China, and India (which have successfully tested space to earth re-entry vehicles demonstrating this capability).[9] All these countries are known as per open sources to possess the ability to design hypersonic craft, known as

"wave riders", and to have programs to develop supersonic combustion ramjet (scramjet) engines. The US leads in this field having tested its X-43 hypersonic craft in free flight. The Russian, Chinese and Australian programs follow in milestones achieved. The Indian program consists of two separate endeavours by Indian Space Research Organisation (ISRO) and Defence Research and Development Organisation (DRDO) to test scramjet engines and craft powered by these engines. The interest in India by ISRO as well as DRDO appears to stem from the fact that hypersonic technology could be used to produce weapon platforms as well as reusable space access craft. For India hypersonic research presents more opportunities than challenges given India's environment and engineering and scientific abilities as showcased by recent achievements of the country's scientific community.

Implications of Hypersonic Craft

A hypersonic craft using a scramjet engine could achieve global range by default. This craft would be able to reach sub orbital altitudes from where it could glide to almost all parts of the globe through multiple boosts up to these altitudes if required. In addition to this global reach such a vehicle through its high speed operation and ability to carry out even mild manoeuvres could defeat most interception systems thus giving it the kind of invulnerability from attack that stealth is said to deliver. The cost of such scramjet powered craft is not likely to be low in view of the advanced materials and advanced construction techniques that would be required to build them. However, it is more than likely that these would cost much lesser per unit than the current Gen 5 fighters and stealth bombers emerging in the West.

Even if the payload carried by a rocket were to be a craft of wave rider design characteristics without scramjet engines it could provide benefits. Such a craft could be carried aloft by a rocket and on re-entry into the atmosphere could glide at hypersonic speeds till its designated impact point. The interesting thing here is that in case of payloads carried by ballistic missiles such as IRBMs and ICBMs the payload impact points are determined by the ballistic path followed by the rocket from launch onwards. This gives some predictability about the target that is being addressed as well as the path of the

payload itself. Such predictable information assists in chances of a successful intercept by suitable weapons systems. In case the rocket were to carry a payload in a hypersonic glide vehicle it could have the ability to glide well out of the ballistic trajectory that brought it till release point. The cone of possible targets that such a hypersonic glide vehicle could address would lie well outside the projected ballistic path of the rocket that brought it till release point for hypersonic glide. A rocket equipped with such a hypersonic glide enabled payload could release the payload so that the payload flies at hypersonic speeds to much further than what range the same rocket could achieve with a purely ballistic payload. Moreover, the hypersonic glide vehicle would operate at such high speeds that current generation air defence and ballistic missile defence systems would be in all likelihood be unable to achieve intercept geometries on it thus precluding a successful intercept and destruction of the payload. Such a system has the potential to give ballistic missiles the ability to defeat ballistic missile defence (BMD) weapon systems.

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More In Focus

The recent Chinese tests of the Wu-14 hypersonic glide vehicle has stirred fears in the US for these reasons as it heralds an unexpected ability of China's newer ballistic missiles to defeat American BMD systems.[10] It also presages the future emergence of possible hypersonic craft powered by scramjet engines from China's factories.

From the Indian perspective it is prudent for India, especially give the research already undertaken successfully in the country to pursue development of these technologies to make the country's missiles more effective as well as to deliver greater

strike abilities to the Indian air Force (IAF) in the medium term future. From the Indian perspective hypersonic technology could deliver benefits out of proportion to its costs of development and operationalization.

Conclusion

There has been a trend of new technologies driving the ability to aircraft to operate at every higher speed with passage of time. To move from a few hundred kmph to supersonic speeds took almost half a century. Today another half century later we stand poised to achieve hypersonic speeds in practical machines. Hypersonic craft have the potential to deliver assured penetration of hostile defences as well as global reach. Applied to missiles they could expand the reach of ballistic missiles through the ability of the payload to fly further out as well as defeat BMD systems. All these benefits coupled with the level of research and development already done in India make it prudent for the country to look at this technology from a practical point of view.

(Disclaimer: The views and opinions expressed in this article are those of the author and do not necessarily reflect the position of the Centre for Air Power Studies [CAPS])

End Notes

[1] Chuck Hawks, ""The Best Fighter Planes of World War II"", http://www.chuckhawks.com/best_fighter_planes.htm, accessed on 08 Dec 2014.

[2] Lawrence Miller, *The Avro Arrow*, (Toronto: James Lorimer and Company Ltd, 2014), pp 26.

[3] Mach number is a ratio of the speed attained by an aircraft to the local speed of sound. Mach 1.0 indicates that the aircraft is flying at the speed of sound.

[4] "Supersonic! The 10 Fastest Military Airplanes", http://www.livescience.com/39829-fastest-military-airplanes.html, accessed on 08 Dec 2014.

[5] "X-41 Common Aero Vehicle (CAV) Hypersonic Technology Vehicle (HTV)", http://www.globalsecurity.org/space/systems/x-41.htm, accessed on 08 Dec 2014.

[6] "Speed of Sound at Different Altitudes", http://www.fighter-planes.com/jetmach1.htm, accessed on 08 Dec 2014.

[7] "Hypersonic", https://www.princeton.edu/~achaney/tmve/wiki100k/docs/Hypersonic.html, accessed on 08 Dec 2014.

[8] By Jeffrey Lin and Peter W. Singer,"" Secretive D.O.D. Drone Dodges Defences At Hypersonic Speed"", http://www.popsci.com/article/technology/secretive-dod-drone-dodges-defenses-hypersonic-speed, accessed on 08 Dec 2014.

[9] "India's First Hypersonic Demonstrator Vehicle being Tested", http://www.vancouverdesi.com/news/tests-underway-for-hypersonic-technology-demonstrator-vehicle/668036/, accessed on 08 Dec 2014.

[10] Bill Gertz ""Hypersonic arms race: China tests high-speed missile to beat U.S. defences"", http://www.washingtontimes.com/news/2014/jan/13/hypersonic-arms-race-china-tests-high-speed-missil/?page=all, accessed on 08 Dec 2014.