



INDIA'S SCRAM JET TEST AND IMPLICATIONS FOR FUTURE SPACE TRANSPORTATION

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Background:

On August 28 at around 1800 hrs, an Advanced Technology Vehicle (ATV), sounding rocket with a solid booster carrying advanced Scramjet (Supersonic Combustion Ramjet Engine) engines, was successfully flight-tested from the launch pad of the Sathish Dhawan Space Centre. The scramjet engine designed by ISRO uses hydrogen as fuel and the oxygen from the atmospheric air as the oxidiser. This was the first experimental mission of its kind and was aimed at the realisation of an Air Breathing Propulsion System which uses hydrogen as fuel and oxygen from the atmosphere air as the oxidiser. The test flight was the maiden short duration experimental test of ISRO's scramjet engine with a hypersonic flight at Mach 6.

The Scram Jet Test

The ATV vehicle, which touched down in the Bay of Bengal approximately 320 km from

Sriharikota after a flight of 300 seconds, was successfully tracked during its flight from the ground stations at Sriharikota. With this, the ISRO had successfully demonstrated its capabilities in critical technologies like ignition of air breathing engines at supersonic speed, air intake mechanism and fuel injection systems. Manifest in the test were a variety of challenges including the design and development of hypersonic engine air intake, the supersonic combustor, proper thermal management and ground testing of the engines etc. During the test, all the important flight-events like the burn out of booster rocket stage and functioning of scramjet engines for 5 seconds followed by burn out of the second stage took place exactly as planned. With this, India became the fourth country to demonstrate the flight testing of a scramjet engines. This mission is a milestone for ISRO's future space transportation system causing the ISRO Chairman to declare that

“Today’s experiment of doing a scramjet engine test is a very significant development. We are the fourth country to do such a thing; the test (scramjet engine) was very successful.”¹ The test has done the country proud and it kindles hope for more commercial and social gain to the country in keeping with the unique civil development goal of Dr Vikram Sarabhai.

Putting the issue in its overall context was the remark of K Sivan, Director, Vikram Sarabhai Space Centre (VSSC) *“This is a baby step for us. It will take more than a decade to develop an engine to power a rocket. Currently no other country flies its rocket powered by a scramjet engine”*. He further added that the testing of the scramjet engine is part of India’s Make in India programme and Indian Space Research Organisation (ISRO) has developed several technologies like a reusable launch vehicle and others as a part of this scheme. He also clarified that actual employment of the technology would come after several more steps: *“The engine that was tested today was burnt only for five seconds. But in a rocket, the engine has to burn for over 1,000 seconds. The speed at which it has to burn would also vary. We have to conduct various tests for that before getting ready an engine that can fly a rocket,”* He said currently Indian rockets carry a huge quantity of oxygen — say 200 tons in a geosynchronous satellite launch vehicle (GSLV) — which gets burnt during the atmospheric flight phase of the rocket. *“The scramjet engine will suck the atmospheric oxygen and use that to*

burn the fuel. As a result the weight of the rocket will come down drastically which in turn can be used to increase the rocket’s carrying capacity. The cost of rocket will also come down,”². According to him, the total cost of developing this technology is estimated at Rs 35 crore. He said the scramjet engine can be used to augment ISRO’s reusable launch vehicle.

The Implications for the Future

For future, reusable space transportation systems, as well as for hypersonic flight vehicles, the main design problem is to reliably sustain operation in supersonic combustion mode. A scramjet propulsion system is very likely to offer an economic alternative to classical, expendable and hence expensive rocket driven systems and is one of the key technologies for hypersonic flight.

Hypersonics using rocket propulsion is a staple of the space age, but hypersonics using air-breathing aircraft engines is something altogether more challenging. Such technology involves aircraft designed to traverse the atmosphere at speeds at least 5 times that of sound or approximately 6000 kmph. The key to making it happen are scramjets (supersonic combustion ramjet engines), which allow for supersonic airflow through the engine’s combustion chamber. The critical challenge is the aero-heating, caused by the friction of air rushing over the vehicle’s solid surface at extreme speeds. Aero-heating dominates every aspect of

hypersonic vehicle design: materials, vehicle shape, and internal heat management. It's generally not a significant problem at speeds less than or equal to Mach 2. But at hypersonic speeds [aero-heating] can cause extremely dangerous temperatures of up to two to three thousand degrees Fahrenheit. That can melt aluminium and even titanium. Temperatures like that are a threat to the vehicle and anything inside it. This requirement of thermal management also affects overall vehicle layout.

The achievement is indeed significant considering that over the past few decades, a variety of agencies across the world have put in efforts to develop an air breathing propulsion system, based on scramjet technology, for flight in the hypersonic velocity regime. As a matter of fact, conceptually Scramjets have been in vogue since the 1950s, they were lab-tested by NASA in the 1960s and NASA holds the scramjet speed record for its X-43a experimental aircraft which achieved Mach 9.68 on November 16, 2004.

On the one hand, complete scramjet powered hypersonic flight vehicles can be used with a two-stage propulsion system. The first stage, a conventional rocket, is required to reach scramjet operation conditions. After stage-separation and ignition of the scramjet, the vehicle performs a self-powered aerodynamic flight. This concept has successfully been tested within the NASA Hyper-X program. Furthermore such a concept is the basic idea of the European

LEA testing program and the Japanese research activities at JAXA. On the other hand, single scramjet demonstrators have been used. Examples include the Russian KHOLOD hypersonic flight lab, a combination of a rotationally symmetric scramjet and a rocket. Here, the rocket permanently produces thrust, even during the operation of the scramjet. Another type of flying test bed consists of a scramjet demonstrator placed as a payload on the top of a rocket. Here, the rocket boosts the demonstrator to the apogee of its trajectory. Under the influence of gravity, the demonstrator accelerates and falls back towards the Earth's surface. When operational conditions are reached, the engine is ignited. Considering that the finer details of ISRO's launch are yet to be made public, it would be difficult to undertake a clear analysis and arrive at any conclusive judgment on the functional principle of the scramjet.

However, when viewed in the backdrop of India's quest for a Reusable Launch Vehicle, the feat is enormously significant. Since the scramjet engine is, used only during the atmospheric phase of the rocket's flight, it will help in bringing down the launch cost by reducing the amount of oxidiser to be carried along with the fuel. This reduction makes the launch vehicle lighter and automatically enables more payloads to be put into orbit. Launching in the Low Earth Orbit becomes far more flexible and economical than ever before. Many more payloads both domestic

and foreign can be launched thereby increasing the national revenue and enhancing civil developmental goals.

Conclusion

Considering that ISRO launch rates are amongst the cheapest in the world and that it boasts of a very high reliability rate, it would be reasonable to expect the commercial meter to rise significantly. All-in-all, the launch augurs very well for the developmental vision of Vikram Sarabhai as also the contemporary vision of Make in India.

(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])

Notes

¹ Express Web Desk, "We are the Fourth Nation to conduct a Scram Jet Test", *The Indian Express*, 28 Aug 2016 at <http://indianexpress.com/article/technology/science/isro-successfully-test-launches-scramjet-engine-from-sriharikota-3000016/>, accessed on 28 Aug 2016

² G Ravikiran, "ISRO successfully test-fires Scramjet Engine", *The Hindu*, 28 Aug 2016 at <http://www.thehindu.com/news/national/isro-successfully-testfires-scramjet-rocket-engine/article9042486.ece> accessed on 29 Aug 2016.