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Hypersonic Flight future of space and defense

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ABSTRACT: What if the economics and technical challenges of hypersonic flight were conquered and the once exclusive world of Concorde-style travel was replaced with hypersonic possibilities?

Imagine the possibilities of an aircraft capable of sustained flight at Mach 5.5 and beyond at altitudes above 60,000 feet on the very edge of space. The speed of hypersonic flight would mean that I could have breakfast in London, fly to Singapore in time for a dinner meeting in Dempsey Road and then fly back to India in time.

In this report we are talking about basic introduction and development of hypersonic in world and also share basic ideas through my thoughts

KEYWORDS: Hypersonic, Scramjet, Aerospace, Space, Defence.

I. INTRODUCTION

Hypersonic systems are highly maneuverable, travel many times the speed of sound, and allow for the destruction & travel at any point anywhere in the world in less than an hour. Hypersonic flights are a growing and extremely complex threat to our national interests. Currently, 23 nations have demonstrated varying degrees of expertise in hypersonic technology...a number that continues to grow daily. Hypersonic is really about industrialization, not about science...Are we technically prepared?

If you've been following defense or aerospace news in recent years, you may have noticed that there's been significant buzz about hypersonics. The USA, China, Russia, Germany, Britain, India, Australia, and even Indonesia have been conducting research into various aspects and problems of flying at Mach 5 (3,800 mph, 6,125 km/h) and above.

Now before go further let first know the basics.

Hypersonic in world:-

Hypersonic is flight through the atmosphere below about 90 km height and at min. speeds above Mach 5, at this speed dissociation of air begins to become significant and high heat and pressure loads at which mostly material changes its physical properties. At this speed the air flows around object forms a shock waves which deflects the air from the stagnation point and insulates the flight body from the atmosphere. And the Power of these shock waves can calculate by that there is a book name shock waves was published by the world bank group in Climate Change and Development Series.

But still There are numerous projects are running in the world some of which are:-

Hypersonic aircraft:-United States Aerojet General X-8, United States North American X-15, United States, Lockheed X-17, United States NASA X-43 , United States Boeing X-51 , China DF-ZF , Russia Avangard , India HSTDV

Spaceplanes:- United States Space Shuttle orbiter, Soviet Union Buran , India RLV-TD , United States Boeing X-37 , China Shenlong , Soviet Union BOR-4 ,United States Martin X-23 PRIME and X-24, United States ASSET , Japan HYFLEX

There are huge numerous potential advantages of hypersonic flight , including reduced travel times, improved space access and also cutting down the cost of space programs. And as today's we can see lots of defence reports for hypersonic flight. These reports should worry military analysts is fairly obvious because at the moment, defense systems operate at supersonic speeds and below. Fighter planes, bombers, missiles, anti-missiles, and artillery shells all fly at less than Mach 5. Even the fastest manned jet plane ever built, the now-retired SR-71, could only manage Mach 3.5. The only weapons that do count as hypersonic are ballistic missiles that fly out into space before returning to Earth,



which makes them a very special case and same for the space programs we use huge rockets which took a high amount of resources and money in form of fuel.

As on current situation The United States, Russia, and China are leading the race to develop hypersonic missiles, with France and India close behind. Japan, Australia, and Europe are all developing the component technologies, in some cases for ostensibly civilian purposes. Within ten years, hypersonic missiles are likely to be deployed and potentially offered on the international market.

In fact, it is in the interests of the world to reduce their exposure to this new threat. Russia in particular has been vocal regarding the dangers of hypersonic missiles, perhaps due to a fear that NATO could mount a devastating hypersonic attack. Further, China can be expected to oppose both Japanese and Indian acquisition of such weapons or in short we can say that hypersonic is the second biggest threat after nuclear weapons.

But still there is lots of potential to be developed that's why world and many engineering expertise are working for that. From all these potential we have one is hypersonic glide vehicles can travel higher Compared to a ballistic (parabolic) trajectory, Hypersonic cruise missiles, which are powered by scramjet, are restricted below 100,000 feet but a hypersonic vehicle would be capable of large-angle deviations from a parabolic trajectory.

For example of ballistic missile a joint Russian-Indian company has started the development of a cruise missile capable of flying at Mach 5, which will make it 'impossible to intercept'. BrahMos-2 will be the next generation of the highly successful the BrahMos missile already used by Indian military. And some of hypersonic ballistic missile in all over world are as follows:-

United States AGM-183A air launched rapid response weapon (ARRW, pronounced "arrow")

Russia Kinzhal

China DF-41

As for that first step of glide vehicle as a testing we will develop a Hypersonic cruise missile which can Launches from an aircraft and uses a scramjet engine which turns on at hypersonic speeds to power the weapon. And for that there are multiple options one of them is Indian missile Astra which can carry 15kg war head at max. Speed of mach 4.7 and most importantly can launch from many aircrafts. After this we will develop intercontinental missile systems. Basic idea made by me is written further as a Idea 1.

Then after completing first step we could step further for space launching using structural and technology from hypersonic cruise missile design and development. At this step we will boost our main glide vehicle will gain a speed above mach 4 or 5 through a solid booster rocket. Using that we can reduce around 50% resources which is used in form of fuel and also can make space flight reusable and also reduce space garbage. Basic idea for that made by me is written further as a Idea 2.

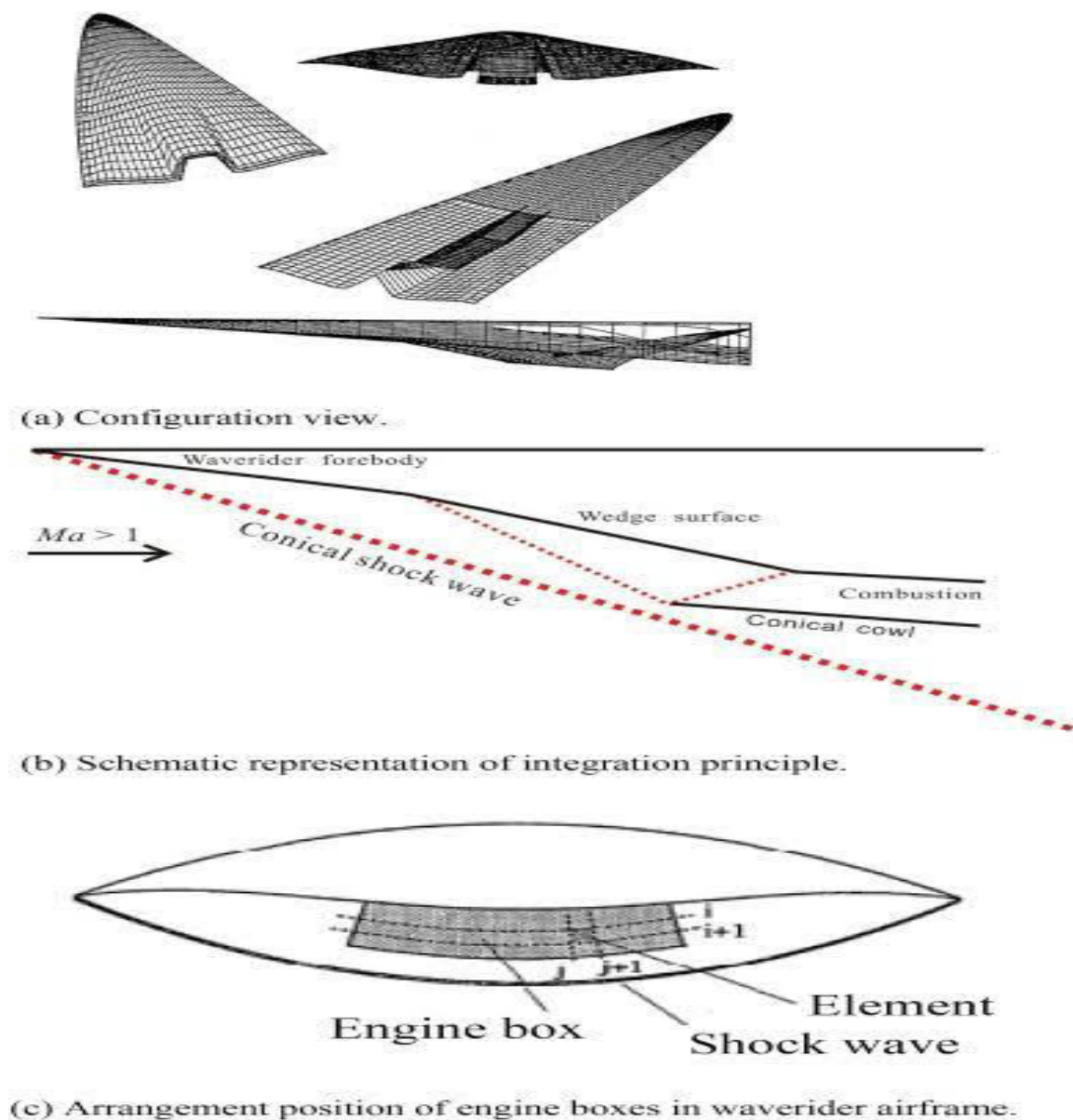
Whole world expertise in engineering complex systems is working to realise these benefits and trying to fasten the life of world and technology but hypersonic technology itself offers hope, as it is extremely difficult to master. Igniting the engine of a hypersonic cruise missile has been compared to lighting a match in a 2,000-mile-per-hour wind. Moreover, the shape of the missile changes under the rigors of hypersonic flight, creating great challenges for flight control.

Everyone is demonstrating our capability in flight vehicle design and testing, and creating technologies to overcome from each other and to overcome from the many technical challenges associated with hypersonic flight. Mainly friction from the atmosphere exposes the air frame to extreme temperatures. And for that need materials and strategies to cope with the high temperature, which threaten to melt and warp the structure / design. And to counter drag, we seek propulsion systems that are efficient and effective at high speed. We currently rely on traditional rocket engines to provide thrust above Mach 3 to 4. These are generally unsophisticated and inefficient and less acceleration.

Designer of an efficient supersonic aircraft must take shock waves into account, and will generally select a sharp geometry, such as that of Concorde, which keeps the shock waves as weaker as possible. At hypersonic speeds it is even more important to control the strength of shock waves, and this leads to a requirement of different design philosophy for hypersonic aircraft compared with their more conventional cousins. Behind a hypersonic shock wave the temperature is also the leading edge of a hypersonic craft scales inversely with the square root of its radius of

curvature. In other words, the sharper the leading edge of the vehicle, the hotter it will get. This is why spacecraft are designed with rounded noses and very blunt wings – characteristics that also increase the drag force. Air-breathing hypersonic or to be says glider vehicles are not able to tolerate this added drag, and so they will be built with sharp leading edges instead.

But apart from all this when we incorporating the sharp aerodynamic configurations of hypersonic flight into an aircraft means adopting a whole new design. Instead of fighting the shock wave, need to use it to our best advantage. One very promising and proven design is the so-called waverider airfoil, which actually rides on top of its own shock wave for highly efficient flight. The University of Maryland have designed waverider wing and body combinations that have very high lift, low drag and offer plenty of volume for holding payloads and fuel which all are main requirements. Moreover, the shapes are well integrated with the engine system. These sleek designs – which range from missiles to space launchers – have been tested in wind tunnels and in computer simulations and practically project by Boeing X51A is running from last 7 years and many more.

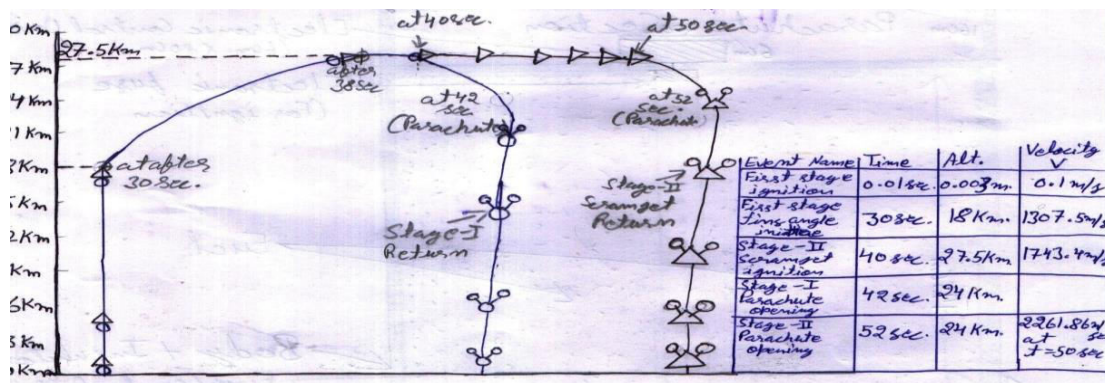


II. RELATED WORK

Idea 1

Basic Idea for testing of Scramjet model (glide vehicle) :-

In this testing we are using a sounding rocket (astra missile) which have weight of 158 Kg. Which achieve proper mach number 4.5 for stage II scramjet model and also used to obtain a certain altitude (27.5 Km) with testing project weight 15 Kg. After reaching at mach 4.5 let suppose at time $t=40$ sec. our scramjet stage II will release and start free fall for 2 seconds and because of that free fall it achieve mach 5.5 to 5.81 speed at $t=42$ seconds.



During testing our stage II will start let suppose at or after $t=42$ second and runs for next 10 seconds and achieve Mach number 7.4 to 7.6 from Mach number 5.6 using 1.3 Kg of liquid Hydrogen fuel.

Total height of model will be 1.21 meter

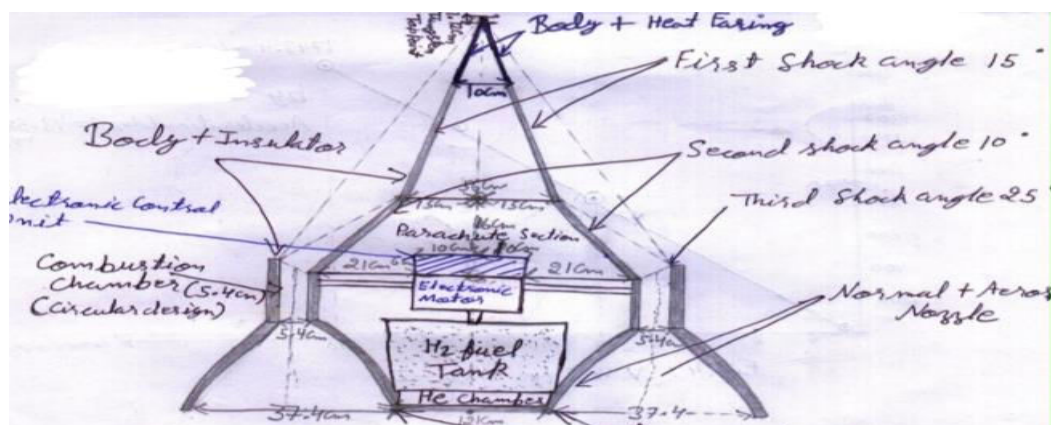
Total height of project will be $3.5 + 1.21 = 4.71$ meter

Diameter of model will be 127 mm and Diameter of missile will be 178mm.

Basic design and performance of stage II Scramjet model:-

For it's whole body we use material PBN (polymer Boron Nitride) as it's basic design and we use both kinds of w-BN and c-BN at a time for heat fearing over silica aero gel and make nanolayer sandwich design where silica aerogel is located between both kind of BN. Thin spray of this heat fearing material will provide high heat and pressure performance with no melting point and also provide higher conductivity with rapid cooling property at lower the cost compared to other materials.

As insulation we use combination of rubber + EPDM + Boron oxide which provides a high heat resistance and also protect our body to react with air and other gases.



In this design we used a Advance design for air mixing as on figure we can see two side waveriders air frames which allow us to use two scramjet at a time which will gives us a higher trust and more controllability over model. And also as we saw a aerospike structure which have 2 advantages first it will reduce the effects of shock wave at back of our model and also we will use to generate a low pressure region which is useful us to generate power to our turbine system which pressured He (helium) and that will pressures our fuel tank and then a electric motor separate equal fuel in both combustion Chambers.

And as we increase Mach number exit nozzle pressure is also increase which increase our pressure on fuel tank and so on extra fuel is delivered to combustion Chambers and this process continues till fuel tank empty.

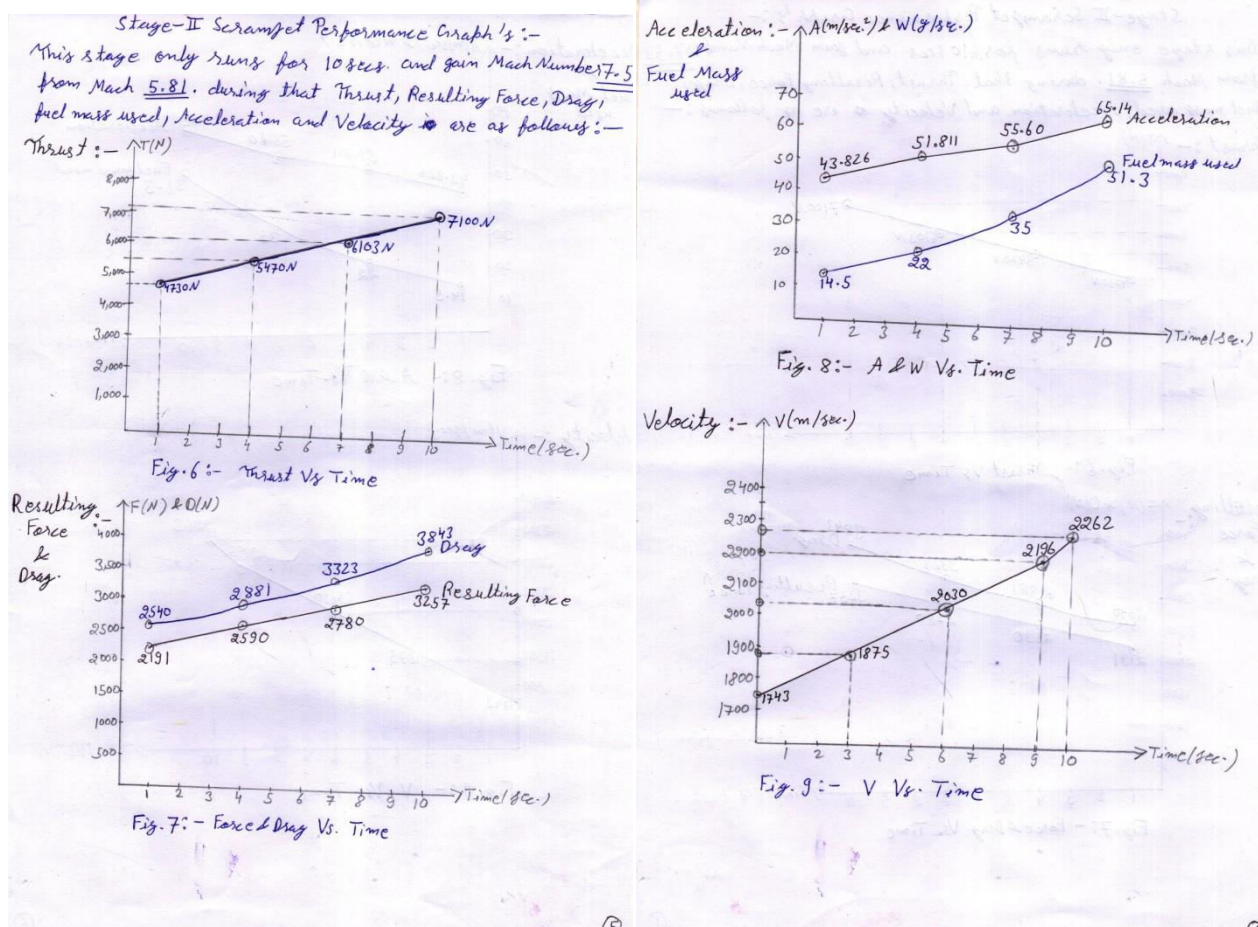


Figure:- Mathematical calculated performance of scramjet for 10sec.

Idea 2

As we go further in our research and in our studies in space and communication sector. we required new devices and as per NASA we have thousands of objects in our orbit and most of them are space junk and we are continues that but what if we can made such satellites which can do multiple works at a time and can change their own working as per future requirements. Then an idea steps in mind of world that we can use scramjet engines for launching. But till today this idea is look like a dream and there is few knowledge for this available and only few people's in world have a Idea for that.

But still I made a simple rough idea for launching through using scramjet (whichs rough notes are attach) which I named RAL (reusable advance launching) and during calculation I took weight same for all time in stage 2a just for rough calculations.

Calculations example can look from this link:-

<https://drive.google.com/file/d/1QrpLrPP8YmE9MVBBrj--gi7LN-OYurf0f/view?usp=drivesdk>

Basic structural and functional:-

Total height of project :- 50.192 m ; Biggest diameter of project:- 8.4 m

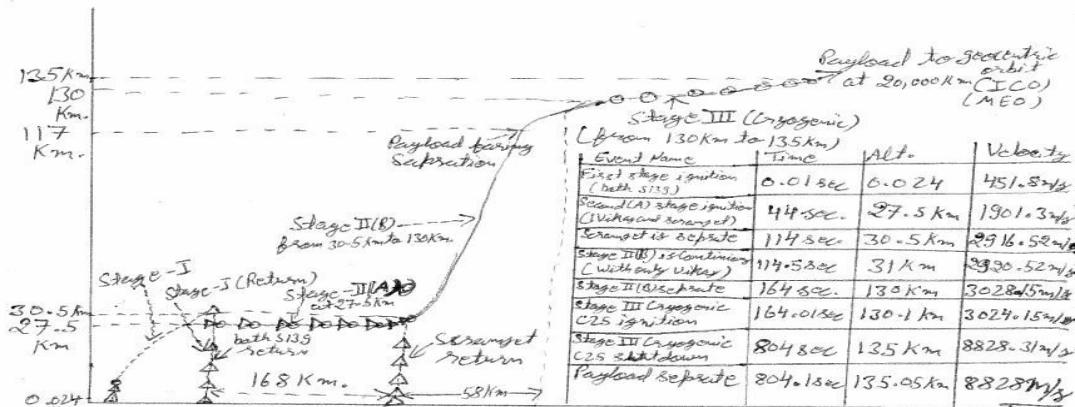
Total lift off mass :- 269 Ton

Payload capacity (to GCO) :- 4 Ton

Basic operation / functional idea:-

EVENT NAME	TIME	ALTITUDE	VELOCITY
First stage ignition(launching)	0.01 sec.	0.024	451.8 m/s earth's velocity
Second stage ignition (scramjet)	44 sec.	27.5 km.	1901.3 m/s
Scramjet separation stage II	114 sec.	30.5 km.	2916 m/s
Stage II (vikas shutdown final separation)	164 sec.	130 km.	3028 m/s
Stage III cryogenic ignition	164.01 sec	130.1 km	3024 m/s
Stage III cryogenic C25 shutdown	804 sec	135 km.	8828 m/s
Payload separation	804.01 sec.	135.05 km	8828 m/s

*Reusable Advance Launches (RAL)
(for GCS satellite using scramjet technology)*



Reusable Advance Launcher (RAL) Specifications =>

Height : 50.192 m & Diameter : 8.4 m
 Heat shield diameter : 5.0 m
 (on payload fairing)
 Heat shield diameter : 3.0 m (as on Square pyramid design)
 (on Scramjet Nose)
 Lift off Mass : 269 tonnes
 Payload to (GCO) or (MEO) : 4 tonnes
 (GCO) at 20,000 km

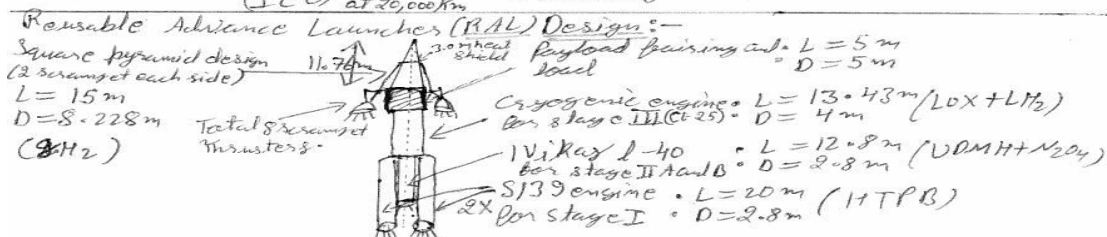


Image:- Basic structural and operations idea

Basic idea of stages

Stage I :- In this stage we use two S139 engine for given the required thrust to lift off 269 tonne. Each of S139 have power to generate 4800KN thrust during flight of stage I till 0 sec to 44 sec. And 280 KN during return while returning we control return thrust for at least 60 sec .

Total fuel used by S139 for stage I is ==> $62.5 \times 2 = 125$ ton

Structural weight of both S139 (basically used by ISRO is ==> 57 ton

Total weight by both S139 in project is ==> 182 ton

As on ignition of stage I velocity gain because of earth rotation is 451.8m/s and after working of both S139 we achieved velocity of 1901.3 m/s before separation and returning of both S139. Just after separation our stage II started at altitude of 27.5 Km.

During returning minimum thrust required by both S139 (for stable returning) is ==> $9.81 \times 28.5 = 279.59$ KN

For for safety we try to maintain returning thrust between 280-- 282 KN and this returning takes 60 sec. To land back safely.

Stage II (Scramjet and one vikas L-40) :- In this stage we have two sub parts A and B which will be explained ahead. In this stage we use 1 vikas L-40 engine and 8 scramjet engines as a add on for providing required thrust to project and help to lift off 87 tonne at gain a high impulse specific because while any project flying at higher velocity a huge amount of drag push it downwards and also make a huge amount of friction on project and this make project uncontrollable so make this issue minimum we use high number of medium size scramjet engines which are controlled by AI which is designed to control flight path of project and also provide stable lift off to project.

In this stage vikas L-40 engine works for 120 sec. For both sub parts A and B. Here our stage II A works for 70 sec and stage II B works for 50 sec. During stage II vikas L-40 engine generates 719KN and each of our 8 scramjet engines have capacity to generate minimum 50KN to maximum 150 KN . But because of high thrust impulse specific we use Scramjets only for 70sec till stage II A ended and after it scramjet are returning back and that's why we design this to use in multiple projects and that will reduce our cost of launching and because of this I named this project reusable advance launching vehicle (RALV).

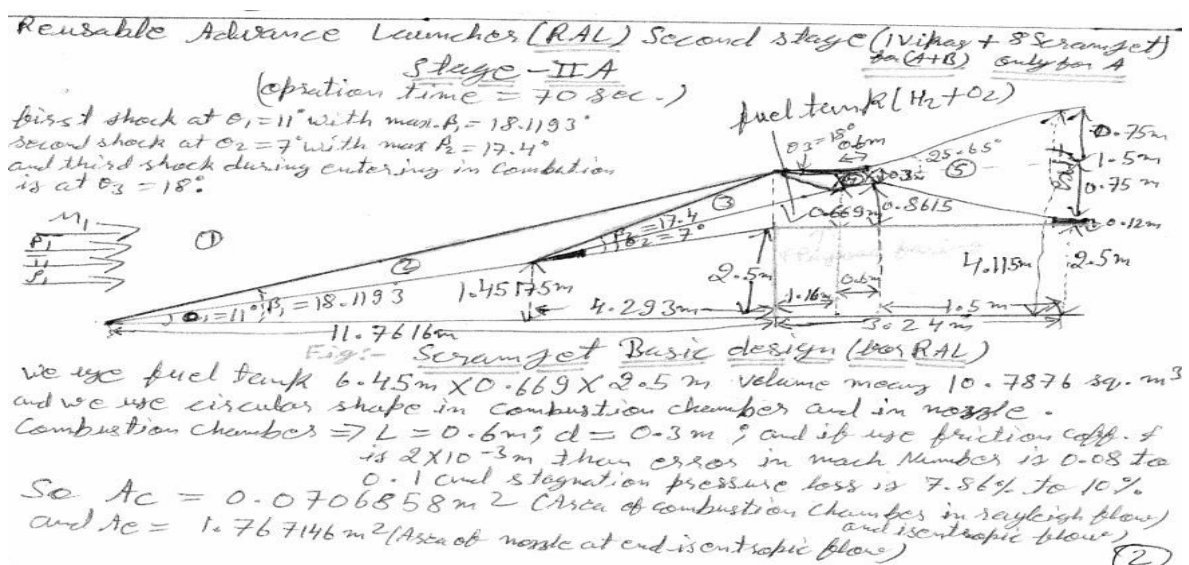


Image :- basic scramjet design stage II

Total fuel used by vikas L-40 ==> 21.7778 ton during part A + 15.222ton during part B = 37 tonne



Structural weight of vikas L-40 is ≈ 5.6 tonne

Total fuel used by 8 scramjet $\Rightarrow [34 \text{ Kg H}^2 \text{ for 70 sec.} + 16 \text{ H}^2 \text{ for returning} + 48 \text{ Kg O}^2 \text{ for returning}] \times 8 = 784 \text{ Kg.} = 0.8 \text{ ton}$

Structural weight of scramjets with heat fearing ≈ 8 ton

Total weight of stage II in project is ≈ 51.4 tonne

As on initial of stage II velocity is 1901.3m/s and after stage II A ended (after 70 sec) velocity achieved is 2916.53m/s then scramjets are separated at altitude of 30.5Km. and in stage II B (for 50 sec) only one vikas L-40 is provided required thrust to gain altitude climbing at 130Km. And after stage II velocity of project is 3028.15 m/s and after this our stage III cryogenic C25 ignite.

During returning only scramjets are returned vikas L-40 didn't return.

Minimum thrust required by each 2 scramjet (one side of square pyramid structural) is $\approx 9.81 \times 2 = 19.62 \text{ KN}$.

So we use 20KN controlled vertical thrust by scramjet pairs just before 15 sec of touching down the ground this helps for smooth landing.

Stage III :- In this stage we use cryogenic C25 engine for given the required thrust to accelerate last 35 tonne of project. C25 engine works for 640 sec and generate a steady thrust of 200KN.

Total fuel used by cryogenic C25 engine is ≈ 28 ton

Structural weight of C25 is ≈ 3 ton

Final payload is ≈ 4 Ton

Before ignition cryogenic C25 engine we already gain velocity of 3024.15m/s and after 640 sec of cryogenic C25 engine we achieved velocity of 8828.31m/s than after 640 sec our payload of 4 tonne separates at altitude of 135Km.

III. CONCLUSION

In this report we studies about hypersonic flight and share some ideas about hypersonic flight in this study we look current situation and development of hypersonic flight in world and also we look an example of double side inlet waverider design and also computation flow calculations of this design.

Here we introduced a basic idea for design and discussed both uses of this design in defense and space. This design is most promising design for future because this will increase stability and efficiency of hypersonic flights. This will also increase Controlability of projects during higher mach numbers.

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