Research Inventy: International Journal of Engineering And Science
Vol.6, Issue 4 (April 2016), PP -71-77
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Skylon Space Plane

[1]Jude Joseph Davy, [2]Nithin Thimothy, [3]Noble Joy, [4]Shijo Tom
[1,3,4] Under Graduate Student, Mechanical Engineering Department, Jyothy Engineering College, University Of Calicut,Kerala
[2] Under Graduate Student, Mechanical Engineering Department ,Thejus Engineering College, University Of Calicut,Kerala

***Abstract**: We are living in a vast universe that contains tremendous unknown knowledge. Human space exploration helps to address the fundamental questions about our place in the universe. In this the development of spacecrafts is remarkable. SKYLON is space plane that can be a replacement for the current scenario of space travel by its reliability, ease of operation and economic friendly nature. It's a single stage to orbit hypersonic space plane. That uses horizontal take off and landing like a conventional aircraft. It could reach up to the low earth orbit (LEO) with a payload of about 15 tons. This system use combined cycle engine commonly known as synergistic air breathing rocket engine (SABRE).That works both in air breathing and pure rocket mode. This permits the vehicle to cruise at hypersonic speed (around Mach 5.5) within earth atmosphere. SKYLON is the future of aviation and space industry, which may ease many missions from earth surface to space. Further modification in the engine may lead not only to the orbit but also far away from that .its low fuel consumption lower weight and reduced risk factor increases the performance and makes possible space tourism for people belongs to any community*

***Key Words:** SKYLON, Space Craft, Mach Number , Hypersonic.*

I. Introduction

Our universe is huge that contains approximately 300 sextillion stars (3 x 10^{23}) and more than 100 billion (10^{11}) galaxies. The sun is one of those stars that contained in a galaxy known as Milky way. The earth is a small planet that revolves around the sun where we live. Since the beginning of history, man has dreamed of flying to the stars – always fearing, however, that the dream was an impossible one. Actually, flying to the stars still is impossible for us; but journeying to the moon and the planets is not.indeed, manmade packages have already flown to the moon and beyond.It is now a ffact that men have learned to launch sizable vehicles with sufficient speed and accuracy to attain satelite orbits around the earth, and even to escape the earth's gravitational field altogether.

This is surely one of the greatest human accomplishments of all time.mysteries of interplanetary space presents problems which will challenges mens's ingenuity and add to their knowledge for generation, for centuries, to come. Human space exploration helps to address the fundamental questions about our place in the universe. In this venture the development of spacecraft is remarkable.

II. Current Access To The Space

The launchers derived from cold war military technologies have been the faithful friends enabling the birth of space age and returning services and knowledge. The main technical issues encountered on the current systems are, Only vertical take off is possible, Bulkier design, High fuel consumption, High cost, Less payload carrying capacity, Multi-stage launch vehicles use tons of propellant, Need to carry huge amount of oxidizer, Chances of technical failures etc.

III. History

The origins of SKYLON lie in the early 1980s,when two british engineers (Alan Bond and Bob Parkinson) speculated that there was a revolutionary path to access to space that could transform an industry in its infancy into an established and enabling transportation sector capable of supporting current markets and enabling institutional and commercial ventures that would otherwise be impossible.

In the mid 1980s British Aerospace and Rolls Royce adopted the SSTO concept and technology, and rolls Royce started design work on Bond's engine, naming it the RB545.British aerospace employed it's space, military and civil aircraft divisions and integrated the engine into HOTOL (acronym for Horizontal Take Off and Landing) with both government and industry funding. Despite enormous technical challenges the project eventually achieved a technically feasible design, however, the international cooperation that would have been necessary for project development was not forthcoming as other nations were by then pursuing their own national programs . (NASP,Sanger,Hermes,etc.).

Their incapability in overcoming the challenges within time undesirable effect on the project development. Due to this the program was cancelled by the U.K govt. and Rolls Royce withdrew their support. But the details and patents regarding the HOTOL was kept as a top secret so Alan and his team was incapable of continue with the project. To ensure the continuation of the concept Alan Bond and his colleagues founded Reaction Engines Limited. And continued the airframe work with SKYLON and its propulsion system SABRE

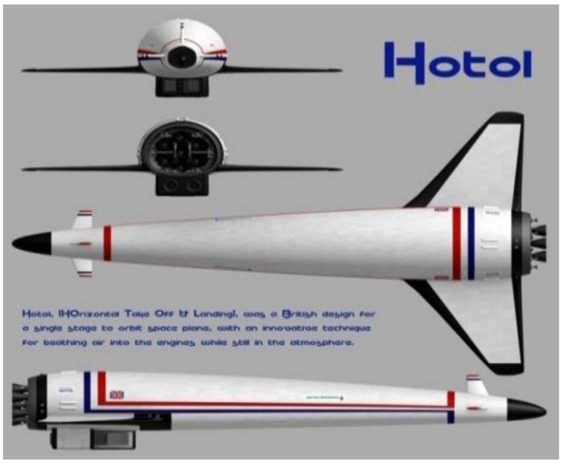

Fig1. HOTOL Space Plane Concept

IV. Skylon

SKYLON is a single stage to orbit(SSTO) hypersonic space plane. That uses horizontal take off and landing like a conventional aircraft. It could reach up to the low earth orbit (LEO) with a payload of about 15 tons. This system use combined cycle engine commonly known as synergistic air breathing rocket engine(SABRE). That works both in air breathing and pure rocket mode. This permits the vehicle to cruise at hypersonic speed (around Mach 5.5) within earth atmosphere.

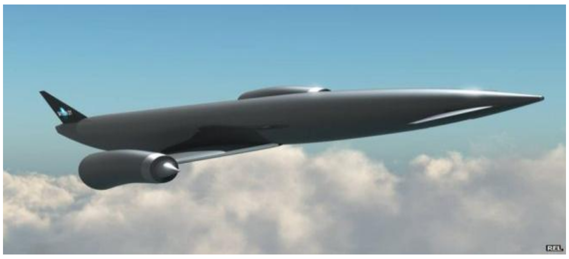

Fig.2. SKYLON

SKYLON is an aircraft like "space plane" that will take off from a runway, fly into orbit, perform missions such as launch satellites, or deliver crew and supplies to space stations, before re-entering the Earth's atmosphere and gliding to a runway landing. Unlike all current launch systems, SKYLON will be fully reusable, being capable of 200 operational flights. SKYLON is the last completed design configuration. This is 84 m long, with 25 m wing span and weighs 275 tonnes at take off. The nominal payload into a 300 km circular low Earth orbit is 12 tonnes. The system is designed to be recoverable over a wide range of in-flight failure modes during powered ascent via a continuous spectrum of abort trajectories.

V. MAIN PARTS OF SKYLON

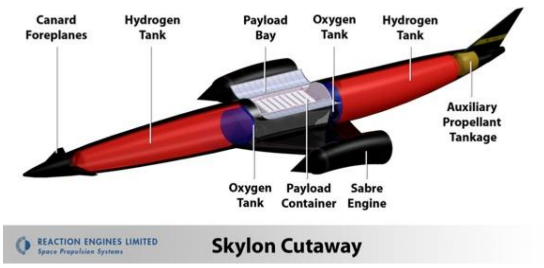

Fig.3. Parts of SKYLON

1) *SABRE Engines*:-SKYLON uses SABRE engines in air-breathing mode to accelerate from take-off to Mach 5.5 which allows 1,250 tonnes of atmospheric air to be captured and used in the engines, of which 250 tonnes is oxygen which therefore does not have to be carried in propellant tanks. At Mach 5.5 and 25 kilometres altitude the SABRE engine transitions to its rocket engine mode, using liquid oxygen stored on board SKYLON, to complete its ascent to orbit at a speed of Mach 25. In this space access application, SABRE engines need an operational life of only 55 hours to achieve 200 flights, significantly less than the 10,000s of hours needed for conventional jet engines

2) *Body Material*:-SKYLON's fuselage and wing load bearing structure is made from carbon fibre reinforced plastic and consists of stringers, frames, ribs and spars built as warren girder structures. The aluminium propellant tankage is suspended within this, free to move under thermal and pressurisation displacements. The external shell (the aeroshell) is made from a fibre reinforced ceramic and carries only aerodynamic pressure loads which are transmitted to the fuselage structure through flexible suspension points. This shell is thin (0.5mm) and corrugated for stiffness. It is free to move under thermal expansion especially during the latter stages of the aerodynamic ascent and re-entry.

3) *Propellant:*-At the start of the take-off roll the vehicle weighs 275 tonnes, whilst maximum landing weight is 55 tonnes. At take-off the vehicle carries approximately 66 tonnes of liquid hydrogen and approximately 150 tonnes of liquid oxygen for the ascent. The ground handling operations will be carried out using a standard aircraft tractor and a bonded goods cargo building permitting overhead loading and protection from the elements. For safety and operational simplicity the cryogenic propellants are loaded subcooled without venting of vapour. Cryogen loading is automatic through services connecting in the undercarriage wells whilst the vehicle is stood on the fuelling apron.

4) *Payload Bay*:-In the SKYLON configuration presented here, the SKYLON payload bay is 4.6m diameter and 12.3m long. It has been designed to be compatible with expendable launcher payloads but in addition to accept standard aero transport containers which are 8 foot square in cross section and 10, 20, 30 or 40 feet long. It is anticipated that cargo containerization will be an important step forward in space transport operations, enabling the "clean" payload bay to be dispensed with. The design target for the SKYLON vehicle was 12 tones to a 300km equatorial orbit, 10.5 tones to a 460km equatorial space station or 9.5 tones to a 460km x 28.5 deg space station when operating from an equatorial site. The updated SKYLON configuration has a payload of 15 tones to a 300km equatorial orbit. Although essentially a cargo carrier the payload bay can accommodate tankage for propellant supply to orbit based operations, upper stages for orbit transfer operations and, once endurance certification is achieved, a cabin module for 30 passenger.

VI. Main Components Of Sabre

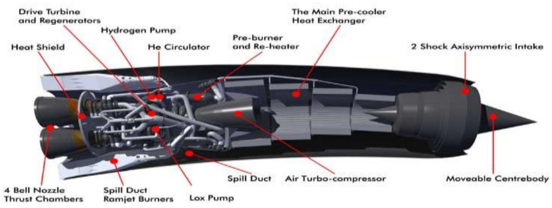

Fig.4. Engine Schematic

1)*Pre-cooler*:-Due to compression effects sucked environmental air at supersonic/ hypersonic speed becomes very hot. Conventionally, in jet engines this high temperature is dealt using heavy Nickel (Ni) or Copper (Cu) based material, by reducing the pressure ratio and by strangling back the engine at higher airspeed to elude melting. But in SSTO vehicles, heavy materials are useless due to weight problems and throttling is not done to get maximum thrust out of it for orbital insertion and to escape earth's gravity earliest to minimise gravity losses. SABRE design is emerged from Liquid-Air Cycle Engine (LAC) concept. LACE utilizes the cooling capability of cryogenic liquid hydrogen(LH2) to liquefy incoming environmental air before pumping, but regrettably liquefied air needs high fuel flow. The stated problem is solved in SABRE by cooling down the air to the vapor boundary (from 1000°C to -150 °C in 0.01 sec), avoiding liquefaction eliminating blocking by freezing of liquid vapor as well as cooling requirement and LH2 flow, using heat exchanger in pre-cooler and endorse the need of a relatively traditional turbo compressor. For cooling in pre-cooler is achieved by Hitself cooled by liquid hydrogen. For prevention of ice formation, a methanol-injecting 3D-printed dicer is implemented to prevent ice formation .

2)*Compressor***:-**In the air breathing mode of engine air cooled by the pre-cooler passes into redesigned TC similar to conventional jet engines' turbo compressor but operating abnormally at high pressure ratio, facilitated by the low temperature of the precooled air. Precooled air compressed by the compressor at high pressure of 140 atmospheres leads to the rocket combustion chamber to combust with stocked liquid hydrogen (LH2). Instead of powered by combustion gases like jet engine, TC is powered by a gas turbine operating on waste heat collected by a HE loop.

3)*Helium Loop***:-**The hot HE from the precooler is reprocessed by cooling it in a heat exchanger with the LH2, heat absorbed by HE from incoming air is 74utilized to power various parts of engine developing a self-starting Brayton cycle based engine.

4)*Nozzle***:-**SABRE engine operates a single array of nozzle, rather using multi stage concept like traditional rockets. RE performed several experiments on an expansion-deflection nozzle, named STERN, to swamp the non-dynamic exhaust expansion problem, and found the 80% bell nozzle design as optimal solution.

5*)Engine***:-**Static thrust potential of SEBRE engine, makes aerospace vehicle capable to take off in air breathing mode like conventional jet engines. With increasing altitude escalation pressure decreases and suck more and more air into the compressor as the effectiveness of ram compression decreases with pressure drop. As the aerospace vehicle climb, outside air pressure varies with altitude change and more and plenty more amount of air is sucked into the compressor to maintain the performance of the ram compression and makes jets capable to function efficiently at much higher altitude than an aerospace vehicle with conventional technique. Air-breathing system becomes incompetent and powered down beyond Mach 5.5, and substituted by on board stocked oxygen as fuel in rocket mode, allows the engine to operate at much higher velocity needed to accelerate the aerospace vehicle to much higher orbital velocities (about Mach 25).

VII. Working

During airbreathing mode air is drawn in through the intake and decelerated using a simple two-shock conical intake system. The decelerated air, which at Mach 5 has a stagnation temperature in excess of 950ıC, then splits into two flows. Part of the flow is directed through the pre-cooler into the core engine whilst the remaining flow passes into the surrounding spill duct by-passing the core engine.

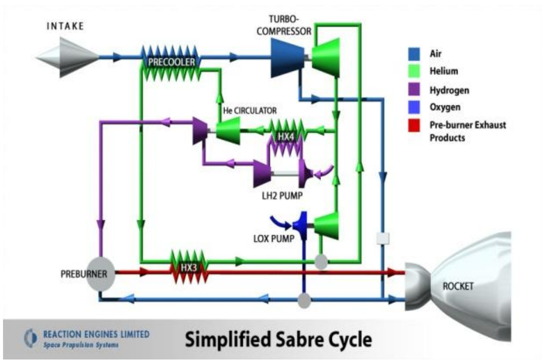

Fig.5. SABRE Working Cycle

A very high pressure ratio air turbo-compressor (around 150:1) is used to supply the rocket combustion chamber with compressed air. In order to minimise the power requirement and also to achieve reasonable compressor outlet temperatures it is necessary to cool the incoming air flow, particularly at high Mach numbers. This cooling is performed in the pre-cooler and is achievable because of the very low temperature and the high specific heat of the hydrogen fuel.

In the SABRE engine an intermediate helium loop is introduced between the 'hot' air flow and the 'cold' hydrogen flow allowing efficient temperature matching whilst eliminating hydrogen embrittlement from the pre-cooler. In operation the air will be cooled to around -130°C on exit from the pre-cooler. In this cycle the quantity of heat rejected to the hydrogen flow is reduced by converting part of the incoming air enthalpy to work thus reducing the amount of hydrogen required for cooling. This is achieved by using the helium flow to power the turbine driving the air turbo-compressor. The use of helium also enables the intermediate loop pressure ratio to be minimised by virtue of its high ratio of specific heats. Above Mach 5 the operation of the engine changes from air-breathing mode to pure rocket mode. However, although the air intake and pre-cooler are no longer used, the helium cycle still operates and the engine becomes, in effect, a closed-cycle hydrogen-oxygen rocket engine, albeit one with an unusual thermodynamic configuration.

VIII. Comparison With Other Engines

SABRE engine have a thrust to weight ratio(TWR) of 14 ,a higher value than jet engines with TWR 5 and 2 for scramjet. This is achieved by denser and cooled air requires less compression and low temperature allows the use of lighter alloys in engines. The installed specific impulse and thrust/weight ratio of the SABRE engine are shown in

Figure with the other engine candidates shown for comparison

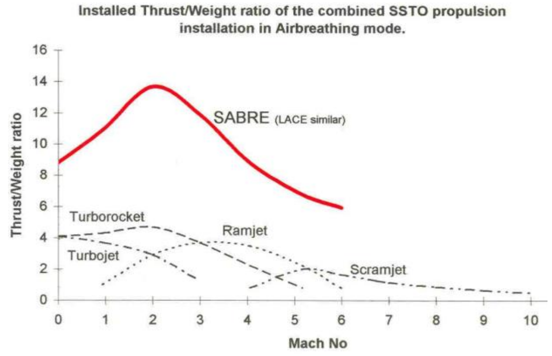

Fig.6..Installed Thrust/Weight Ratio To The Mach Number

It is important to note that all the candidates have been assessed using broadly extant materials and aerothermodynamic technology. These figures show that with turborockets whilst simultaneously attaining installed thrust/ weight ratios similar to LACE engines.

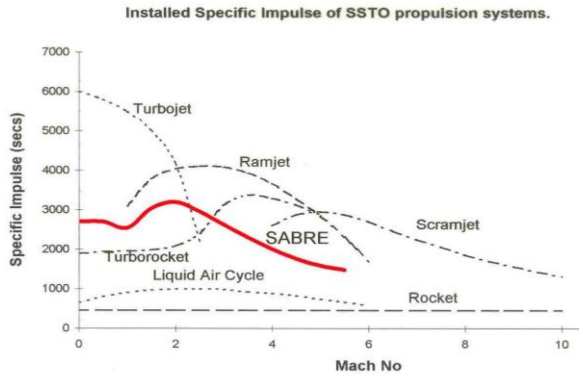

Fig .7 Installed specific impulse of SSTO propulsion systems

It is this com bination of moderate specific impulse with low installed weight that makes precooled hybrid engines uniquely suitable for SSTO launch vehicles. The application of the SABRE engine is described in which also covers the design of a suitable airframe (SKYLON) which properly harnesses the full potential and unique characteristics of this engine type. The final SABRE/SKYLON combination is capable of placing a 12 tonne payload into an equatorial low Earth orbit at a gross takeoff mass of 275 tonnes (payload fraction 4.36%).

IX. Applications

1)*Telecom Application*:- SKYLON can deliver payloads to low Earth orbit (LEO) which have an upper stage attached to propel them to Geo-stationary orbit (GSO). This allows SKYLON to cater for telecoms and other markets which require GSO satellite launches. Once used it would be possible to collect the upper stage for reuse on a future mission.

Fig 8. Telecom Application

2)*Personal And Cargo Application*:- Although essentially a cargo carrier the payload bay can accommodate tankage for propellant supply to orbit based operations, upper stages for orbit transfer operations and, once endurance certification is achieved, a cabin module for 30 passengers. SKYLON provides no payload support being purely a transport system

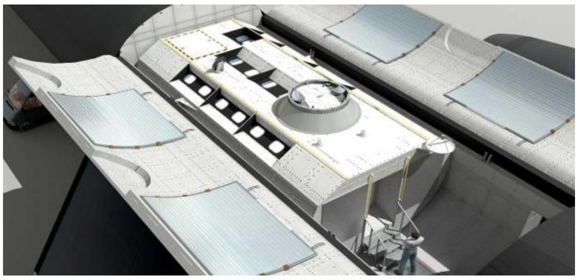

Fig.9. Personal And Cargos Carrying

3) *Space station supplies*:- SKYLON can link to space stations using a specially designed interface allowing passengers and supplies to be delivered. The fulfillment of requirements may be a difficult task for the current space vehicles.that can be easily achived by skylon .

Fig.10. Space Station Supplies

4)*Future Exploration Module*:-SKYLON would be able to launch elements on in-orbit infrastructure such as modules for future space stations, for space telescopes, for planetary missions and for large satellites.

Fig.11. Future Exploration Module

X. Conclusions

SKYLON is the future of aviation and space industry ,which may ease many missions from earth surface to space. Further modification in the engine may lead not only to the orbit but also far away from that. SKYLON reduces the technical risk and increase the performance, which consequently reduces the specific launch cost. This makes possible space tourism for people belongs to any community.

XI. References

[1]. Alan Bond, "The SKYLON project" Roger Longstaff, Reaction Engines Ltd, Building D5,Culham Science Centre, Abingdon Oxon,OX14 3DB United Kingdom,2011

[2]. Richard Varvill And Alan Bond, "The Sylon spaceplane :Process to Realisation" Reaction Engine Ltd.,Culham Science Centre,Abingdon,Oxon,OX14 3DB,UK,2008

[3]. Mark Hempsell, "Progress On Skylon and SABRE" Reaction Engines Limited, U.K ,2014

Authors	
	**Mr. Jude Joseph Davy** is doing his B.Tech degree (2012-2016) in mechanical engineering at Jyothi Engineering College, Thrissur -679531 ,Kerala Under University of Calicut, Kerala, India.
	**Mr. Nithin Thimothy** is doing his B.tech degree (2012-2016) in mechanical engineering at Thejus Engineering College,Thrissur -680584, Kerala Under University of Calicut, Kerala, India.
	**Mr. Noble Joy** is doing his B.Tech degree (2012-2016) in mechanical engineering at Jyothi Engineering College, Thrissur -679531 ,Kerala Under University of Calicut, Kerala, India.
	**Mr. Shijo Tom** is doing his B.Tech degree (2012-2016) in mechanical engineering at Jyothi Engineering College, Thrissur -679531 ,Kerala Under University of Calicut, Kerala, India.