SABRE Engine a New Frontier in Aerospace Engineering

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Abstract: ***The SABRE engine is similar to the RB545, a Rolls - Royce engine with the horizontal takeoff and landing idea (HOTOL). SBARE is a cross between an air - breathing engine and a rocket engine. This article provides a quick overview of the SABRE engine and explains and simplifies its operation. The article examines the engine components and provides a brief overview of the SKYLON aircraft. This article also explains the complicated engineering behind the SABRE engine, providing readers a high - level overview of the SABRE engine***

Keywords: Aerospace, aviation, engineering, air - breathing engine, skylon

1. Introduction

The SABRE engine was first developed in the early/mid 1990s as one of Alan Bond's air - breathing engines; this idea was then utilised to the aerospace vehicle SKYLON for space tourism and providing payloads to celestial bodies in their separate orbits. SABRE (Synergetic Air - breathing Rocket Engine) is a hybrid engine (air - breathing engine and rocket engine) that collects and liquifies atmospheric oxygen and utilises it as an oxidizer for combustion reactions at higher altitudes, thereby acting as both an air - breathing engine and a rocket engine.

Air - breathing engines are one of the most challenging projects to develop, but if successful, they might aid in future space exploration by lowering the weight of the ship and improving the overall flight trajectory of an aerospace vehicle on its voyage. In the early 2000s, a British firm called Reaction engines ltd adapted the concept of air - breathing engines like SABRE to an aeronautical vehicle in the shape of an aircraft. . Fig.1 shows Skylon

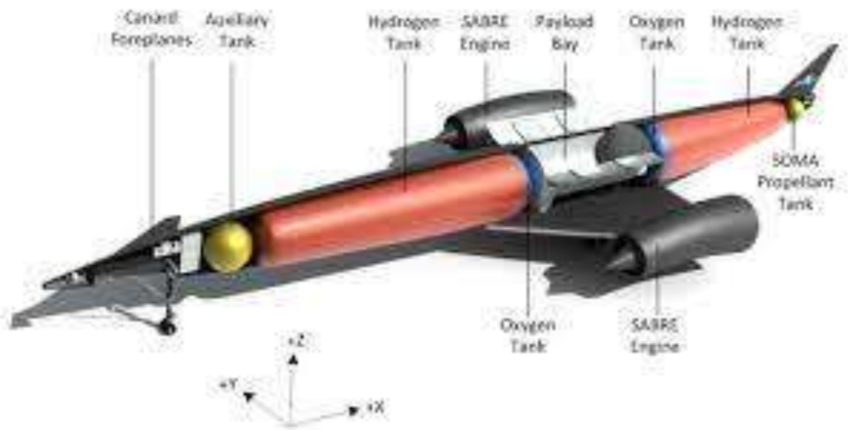


Figure 1: Skylon

The sabre engine's flight route differs from that of the model rocket engine. Given that the Sabre engine will be attached to some aerospace vehicle here Skylon, during take - off, the plane will consume fuel in the form of liquified hydrogen present on either front of the spacecraft, while the Sabre's air - breathing system will also be accumulating environmental air and liquifying atmospheric oxygen with the help of liquid hydrogen. The liquid oxygen reaches the oxygen storage unit and is utilised as an oxidiser when the spacecraft gains altitude.

System Components
1) Air - intake
2) Pre - cooler
3) Turbo - compressor
4) By - pass duct
5) Rocket nozzle/ exhaust

Having a understanding of jet engine would make the process of learning about SABRE engine a lot more easier. The figure below shows schematic of a jet engine

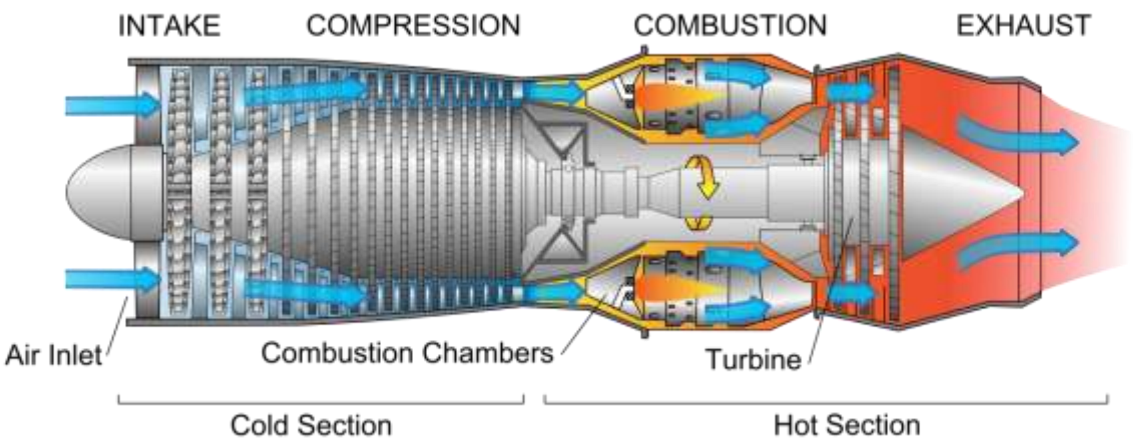


Figure 2: Jet engine

The concept of a jet engine is very simple: the engine attached to either side of the aircraft sucks in a large volume of atmospheric air and then compresses it to increase the pressure of the accumulated air before passing it through the combustion chamber and carrying out a combustion reaction. The exhaust or the air coming out of the jet engine has extreme temperatures that when flows out.

Remember here the aircraft is flying at altitude wherein there is oxygen supply for carrying out combustion reaction with fuel which is essential for producing the hot air

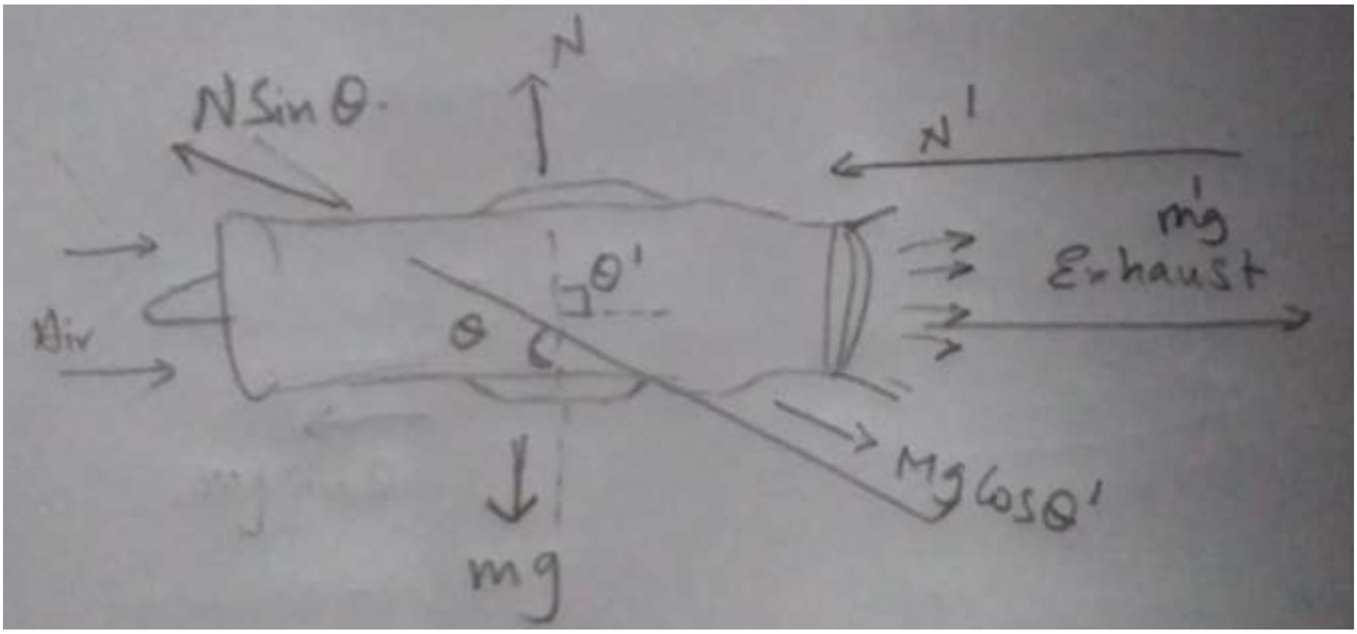


Figure 2.1: Free - body diagram of a jet engine

However, there is no oxygen supply in the outer space meaning there must be slight advancements made in current jet - engine technology to make it possible for the engine to accumulate the oxygen store it as liquified oxygen and then use it as oxidizer.

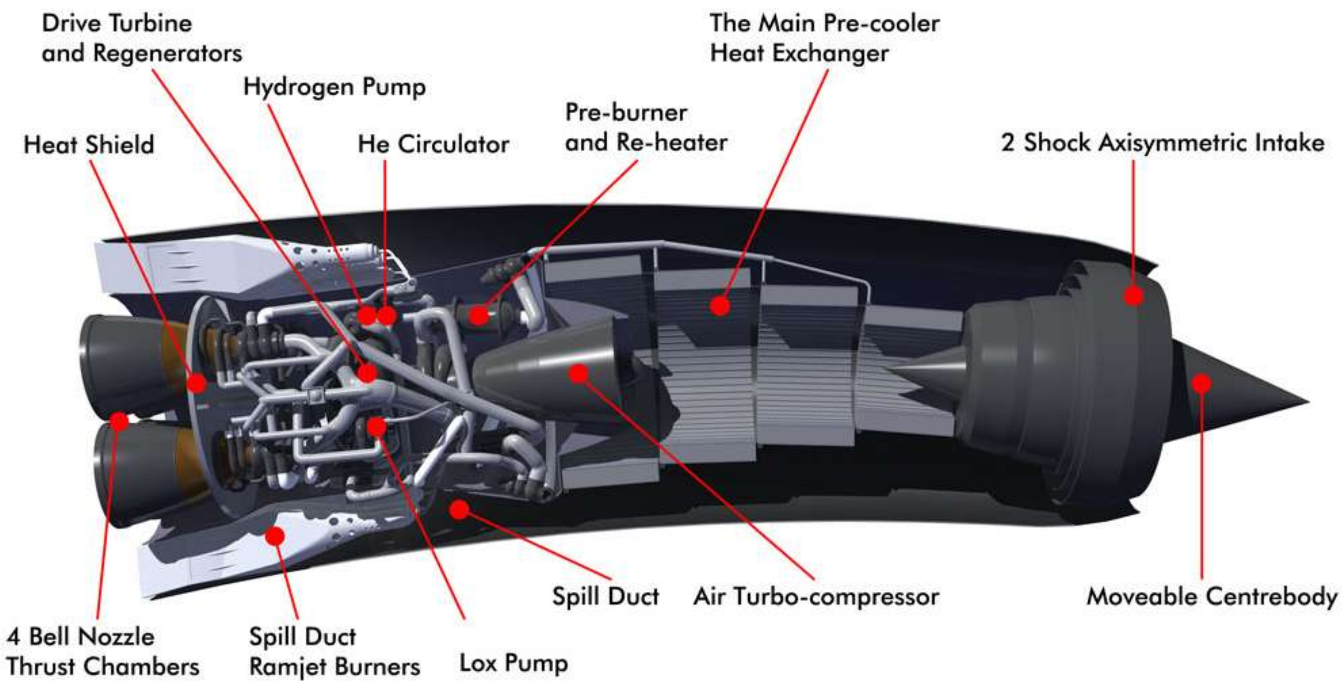


Figure 3: SABRE engine

The above shown diagram depicts SABRE engine and its components which would help us understand about working principles and working of engine.

2. Components of SABRE Engine

Shock Axisymmetric inlet:
The shock cone axisymmetric inlet in front, slows down the sucked environmental air to subsonic speed by two shock reflections, some part of the sucked atmospheric air passes radically through pre - cooler into central core, with leftover passes through ringlets of bypass ramjets.

Turbo - compressor:
The central core of SABRE after pre - cooler system is turbo - compressor [TC] which also operates on helium [He] loop and Brayton cycle that compresses air and leads to combustion chamber. At rocket mode of SABRE [High altitudes] oxygen is used is as oxidizer and passed through the combustion chamber. The turbo compressor compresses the incoming environmental air and increases the pressure per meter cube this gas will be again passed through the pre - cooler system and liquify the air and extract the liquefied oxygen and store it in the storage unit and the remaining unwanted gases are exerted out through spill duct.

Pre - cooler system:
Due to compression effect sucked environmental air at supersonic speed becomes very hot, to solve this problem in jet engines is dealt by using heavy nickel [Ni] and copper [Cu] based material, by reducing the pressure ratio and by strangling back the engine at higher air speed to elude melting. But however, using heavy metals won't help as it would just increase the weight of the aerospace vehicle and throttling is not done to get maximum thrust out of it for orbital application and to escape earth's gravity earliest to minimize gravity losses. As the idea of SABRE engine is derived from LACE [liquid - air cycle engine] it utilizes cooling capability of cryogenic liquid hydrogen [H2] to liquify incoming environmental air to vapor boundary [from 1000c to - 150c in 0.01 sec]. Avoiding liquefaction eliminating blocking by freezing of liquid vapor as well as cooling requirements flow, by using heat - exchanger in pre - cooler. For cooling of incoming air in pre - cooler is achieved by [He] itself is cooled by liquid hydrogen. For preventing of ice formation, a method injecting 3D - printed dicer is implemented. As the hot sucked air travels axially across it some of the flow is caught radically inside it and crosses a number changed pipes filled with [He], results in conversion of that air into cool air

As shown in the figure, inlet slows down the incoming environmental air and guides to outer fringes, which flows inwards through the pre - cooler and lead to compressor.

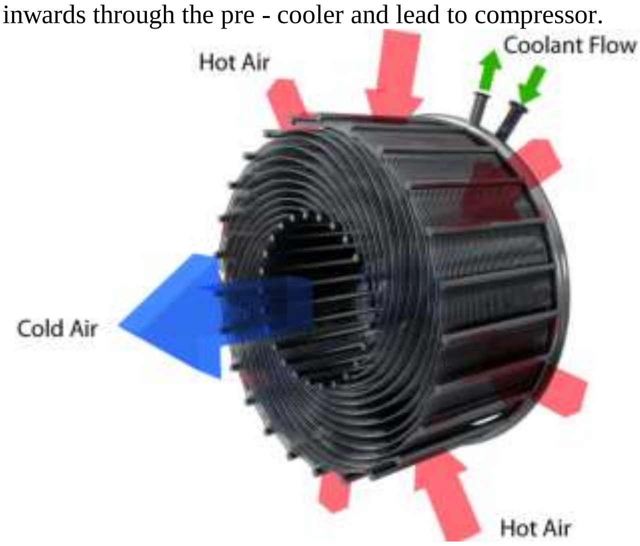


Figure 4: SABRE engine pre - cooler.

Compressor/ turbo - compressor:
In air breathing mode of engine air cooled by the pre - cooler passes into realigned turbo - compressor similar to

conventional jet engine, turbo - compressor operate abnormally at high pressure ratio, facilitated by low temperature of pre - cooled air. Pre - cooled air at pressure of 40 atmospheric pressure leads to the rocket combustion chamber to combust with stocked liquid hydrogen [H2], instead of being powered by combustion gases like jet engine TC is powered by a gas turbine operating on waste heat collected by [He] loop. In order to liquify oxygen the pressure required is around 49 atm. To liquify the gas into liquid we must follow rules of thermodynamics and adjust the temperature according to critical temperature of oxygen so that oxygen gas can turn into liquified oxygen.

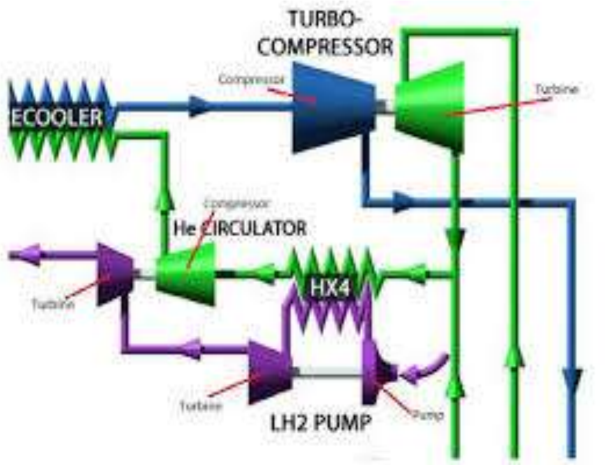


Figure 5: Machinery of SABRE engine.

Helium loop:
The hot [He] from the pre - cooler is reprocessed by cooling in heat exchanger with liquid hydrogen, heat absorbed by the incoming environmental air is utilized to provide power to various parts of the engine developing an self - starting Brayton cycle based engine.

Bypass thrusters:
Avoiding liquification by using heat exchanger in pe- cooler generating less entropy. This results in improved engine efficiency and boils off less amount of liquid hydrogen when compared to amount required for artlessly cooling the air with that can be used to burn the engine core, excess environmental gases not required in combustion reaction are declined with series of spill duct ramjet burners arranged as ring around central core, fed with air that bypass the pre - cooler, is formed to minimize the undesirable effect of drag due to air that passes into the intake but not fed into the main rocket engine rather than generating thrust. At low speed the volume of air that compressor supply to combustion chamber is at its peak, requiring to accelerate the bypassed air to retain of these low speeds
Engines:

Static thrust potential of SABRE engine makes aerospace vehicle capable to take off in air - breathing mode like conventional jet engines, with increasing altitude escalation pressure decreases and sucks more and more air into the compressor as the effectiveness of ram compressor decreases with pressure drop. As the air - craft climbs outside, air pressure varies with change in altitude more and more plenty more amount of air is sucked into the compressor to maintain the performance of compression and wake jets capable to function efficiently at much higher altitude than aerospace vehicle with conventional techniques.

Nozzle:
SABRE engine operates a single array of nozzle, rather using multistage concepts like traditional rockets. Several experiments performed indicated on expansion deflection nozzle, named stern to swamp the non - dynamic exhaust expansion problem and found that 80% of bell nozzles design as optional solution.

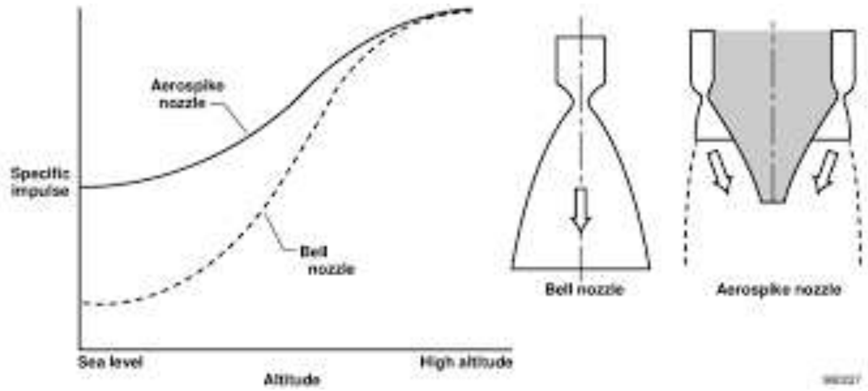


Figure 6: Bell nozzles

The below diagram shows the schematic diagram of SABRE engine.

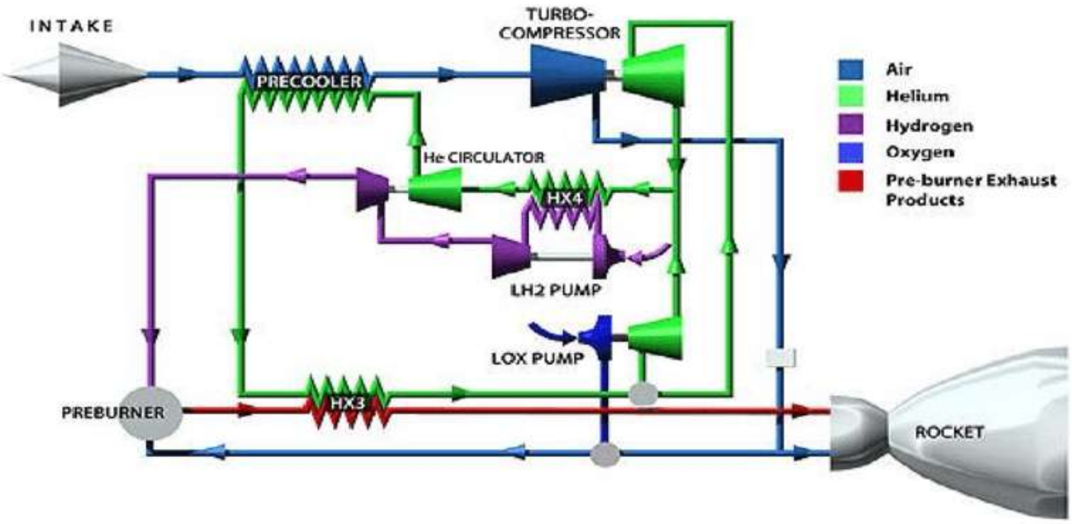


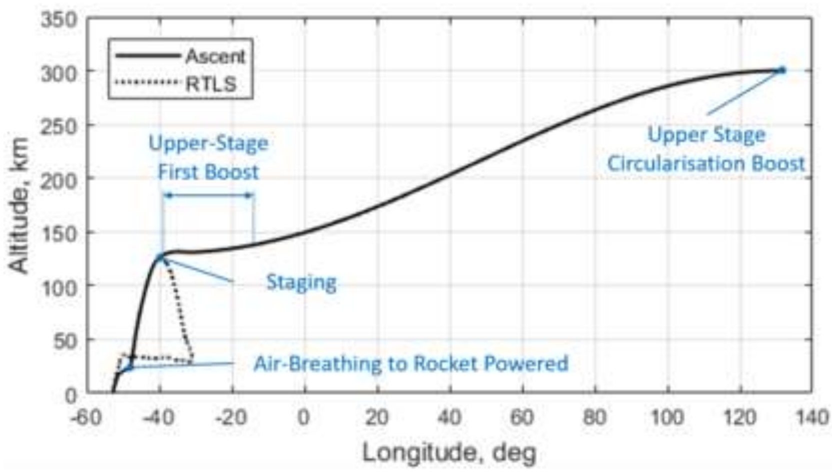
Figure7: Schematic diagram of SABRE engine

3. Title, Authors, Body Paragraphs, Sections Headings and References

3.1 Title and authors

Title of the paper is SABRE engine a new frontier in aerospace engineering, it is written by author: Sheikh Kolimi Abdul Ahad

3.2 Figures and Tables



4. Equations

$$x = y\tan(\theta) - \frac{gx^2}{2v^2\cos(\theta)^2}$$

=> trajectory equation.

$$F = mV_e + (P_e - P_o)A_e$$

=> equation of thrust produced by engine

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Author Profile

Sheikh Kolimi Abdul Ahad is a junior high school student, he has this unimaginable love for space and technology, he is also self - taught python programmer he has done many jobs till now and have been trained under world's second youngest astronaut trainee Akshat Mohite. He has also been invited to NASA - AMES space settlement contest in 2019 and was awarded top 50 award in whole world. He aims on creating a better world for human beings with appropriate use of technology and bring ease in day - to - day life. He is also the person who made the first machine which has the potential to grow plants and vegetables on the ISS with application of Aeroponics.