An Overview on Recent Green Aviation Technologies

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Abstract

As both civil and military aviation expands, environmental aspects and fuel savings are becoming increasingly important. The volume of passengers and cargo transported by air continues to grow worldwide. With this growth environmental impacts are increasing both local and global. At present, the most significant impacts are noise around airports and emissions which are responsible to change the global climate and greenhouse effect. So the environmental advisers are always forcing to find out alternative technology in aviation to reduce the environmental impacts. Looking at the prospect of alternative fuels, synthetic kerosene, alcohol can be more feasible and offers environmental benefits in the short run, whereas hydrogen seems to be the more attractive alternative in the long run. Though there are also various techniques to reduce environmental impacts like air to air refueling, advanced air traffic control management which reduces the fuel consumption, new engine development is the most important as by changing the design both noise and emissions can be reduced. In this paper will start to discuss the environmental impacts of aviation especially noise and emissions generates by the aircraft. Then try to find an appropriate alternative environmentally friendly fuel by analysis the previous researches comparing to the current fuel used in aviation. Besides an alternative fuel consuming engine will
introduce here. Also discuss various recent green aviation technologies specially focusing the recent aero engines proposed by various recognized manufacturers and researchers and try to focus the best technology by analyzing the environmental factors. And finally give a recommendation for the future green aviation to reduce the environmental impacts.

1.0 Introduction

People around the world are going to the skies in increasing numbers. In 2009 Asia hosted more travelers than America, while 704 million passengers are flown by carriers

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in the United States, a number forecast to reach 1.21 billion by 2030 [4]. Next 20 years global passenger aviation traffic is expected to grow averaging around 5.3% annually. To accommodate such growth will require new aircraft, more flights, new runways and airports. The likely consequences are a significant to increase the harmful jet engine emissions and noise around the airports. The continuing growth in air traffic and increasing public awareness have made environmental considerations one of the most critical aspects of commercial aviation today. On the other hand the anticipated air traffic growth raises the demand of stored fossil oil resources. In 2000 the United States Geographical Survey estimated that the ultimate recoverable world oil recourses would supply an expansion of 2% per annum through 2025, reaching around 125 million barrels per day. So it is necessary to find out alternative fuel before finishing the stored recourses. Moreover the greenhouse effect generated by emissions produced by burning fuel, particularly carbon dioxide has become an increased concern. The majority of scientists today are in agreement that discharging greenhouse gases and particulates into the atmosphere has an impact on the global climate. So is therefore essential to find environmentally responsible green aviation technologies which may introduce an alternative fuel, reduce the emissions and noise level.

2.0 GOALS OF THIS PAPER

The main goal of this paper is to give a clear concept about the negative impacts of aviation on environment and find a solution to mitigate these impacts by discussing various alternative fuels and corresponding effects of these fuels. It also compares various recent green engines with conventional aero engines and their challenges.

3.0 ENVIRONMENTAL IMPACTS OF AVIATION

Environment impacts of aviation are ranging in scale from the local to the global and with lifetimes from minutes to centuries. There are mainly three types of impacts of aviation-The effect of noise near the airports, the air quality degradation due to aircraft emissions and finally the effect of aircraft emissions at atmosphere and on regional and global climate.

The formation of contrails and cirrus clouds also contributes to aviation’s climate impact. Each of these impacts has different causes, consequences and mitigation opportunities. There are also other environmental impacts, including land and water pollution due to chemicals used in de-icing; treatment of waste generated by airport activities; land take and local development associated with the airport; and impacts associated with surface access to airports. Here only two major types are discussed – noise and emissions.

3.1 NOISE

Noise can disrupt communities near airports, having health and social impacts. The main source of noise near airports is aircraft movements. During take-off and climb, aircraft noise comes mainly from the engine; for approach and landing the airframe is also significant. Other airport noise sources include auxiliary power units (used to supply power for lighting, air conditioning and other electrical systems); ground support vehicles and systems; and site access traffic for both passengers and staff.

Aircraft noise exposure has been linked to health impacts, including an increase in vitality-related conditions like headache and tiredness and increased use of medication and sedatives. In schools, high levels of aircraft noise can be a barrier to communication, impairing children's development of reading comprehension.

Aircraft noise is also linked to economic impacts, and particularly to a reduction in land prices, especially for housing. However, it can be difficult to statistically separate noise exposure effects from other factors governing land prices, and to accurately balance the economic effects associated with employment and accessibility offered by proximity to the airport [8].

Time of day of exposure is significant, with most measures of aircraft noise incorporating a weighting for night flights to account for the additional problems associated with sleep disturbance. Some residents have also expressed a higher willingness to pay to reduce air traffic movements in early morning and the evening on weekdays

Aircraft noise remains a significant problem and it is anticipated to grow. In 2000, approximately 0.5 million people in the United States lived in areas with noise levels above 65dB DNL. In 2000, approximately 5 million people in the United States lived in areas with noise levels above 55dB DNL. There has been a further 10% reduction in the number of people impacted since 2000 due to the earlier than expected retirement of certain aircraft in light of the economic downturn and the events of 9/11, and the continuing reduced traffic in the U.S. system compared to 2000.

3.2 EMISSIONS

Aviation emissions have come under scrutiny in recent years due to the rapid growth in air transport, which has been increasing at an annual rate of about 5% throughout the last two decades. The aviation emissions consist mainly of carbon dioxide (71%), water vapor (28%) and nitrogen oxides on the atmosphere. It is widely recognized that emission at high altitudes are more environmentally damaging than those at ground level, due to increased interaction with gases in the atmosphere. The release of exhaust gasses in the atmosphere is the major environmental issue associated with commercial airliners. The world fleet releases approximately 13% of CO2 emissions from all transportation sources, or 2% of all anthropogenic sources. The expected doubling of the fleet in the next twenty years will certainly exacerbate the issue: the contribution of aviation is expected to increase by a factor of 1.6 to 10, depending on the fuel use scenario. Conscious of this problem, engine manufacturers have developed low-emission combustors, and made them available as options. These combustors have been adopted by airlines operating in European airports with strict emissions controls, in Sweden and Switzerland, for example. Current emissions regulations have focused on local air quality in the vicinity of airports. Emissions released during cruise in the upper atmosphere are recognized as an important issue with potentially severe long-term environmental consequences, and ICAO is actively seeking support for regulating them as well. However, political and diplomatic considerations compound the difficulty of reaching an agreement on emissions levels in international airspace. Current statistics shows that fuel consumed by the U.S. commercial air carriers and the military releases more than 250 million tons of carbon dioxide (CO2) into the atmosphere each year. CO2 is a greenhouse gas and a contributor to global warming. Other major emissions are nitric oxide (NO) and nitrogen oxide (NO2), which together are called NOx and contribute to ozone creation; sulfur oxides (SO2); and particulates (often referred to as soot). Forty of the top 50 U.S. airports are in areas that do not meet Environmental Protection Agency local air quality standards for particulate matter and ozone. Reducing NOX emissions also reduces SOX emissions. Reducing the amount of fuel burned reduces CO2 emissions [4]. Figure 1 describes the carbon di oxide emission from various alternative sources of global aviation over time.

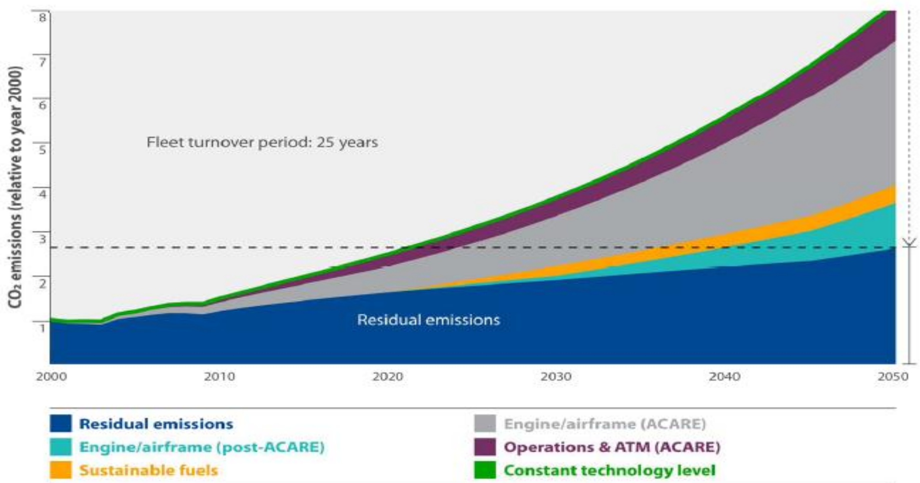

Figure 1: CO_2 emission from the global aviation [4].

4.0 GREEN AVIATION TECHNOLOGIES:

Various organizations are working to reduce the environmental impact of aviation. NASA is more concern about this issue. Now research begins at an elementary level in the laboratory about green aviation technology. The main goals of all the researches are to achieve technological capabilities to reduce noise and emissions and fuel consumption and increased mobility through a faster means of transportation. They have raised some new ideas about this topic where the most perfectible technologies are introducing alternative fuel, advanced aero engine design, changing the aircraft design, air to air refueling plant, advance traffic control management etc.

5.0 ALTERNATIVE FUEL FOR AIRCRAFT:

At Aviation Week & Space Technology's Green Aviation Management Forum in Madrid in September 2008, representatives and researchers from Boeing, Airbus, the FAA, Air France, and KLM spoke at length about what they expect to be the future of alternative energy in aviation [9]. They concluded that the starting point for evaluating alternative fuels is to establish a set of rules by which to judge each fuel's suitability. The participants agreed on these criteria

- It cannot be a food stock.
- It must be scalable.
- There must be a stable supply of it.
- It must be a proven solution.
- It must work with the existing jet fuel infrastructure.
- It must at a minimum meet current jet fuel performance standards.
- It must be cost efficient.
- It must not cause a net harm to the environment.

Researchers have investigated a host of different sources, including coal to liquid (CTL), gas to liquid (GTL), and biomass to liquid (BTL). But considering the above criteria CLT technology fails as it emits CO2 which is harmful for environment.

5.1 LIQUID HYDROGEN

Liquid hydrogen is an environmentally suitable fuel compare to the used kerosene. The main difference between kerosene and Liquid hydrogen is the fuel density. In order to carry the same amount of energy, when comparing two aircraft for the same mission, the mass of the fuel is 2·8 times less for liquid hydrogen, whereas the volume is four times larger which may allow for a higher payload or longer range compared with an equivalent kerosene-fuelled aircraft. The main benefits is when hydrogen is burnt the emissions consist of only water vapor (H2O) and oxides of nitrogen (NOx). All emissions containing carbon and sulphur are eliminated. However it requires a new aircraft design, provided with roughly four times larger fuel tanks compared with conventional aero planes. Engines must be re-designed for the new fuel, particularly with respect to minimization of NOx emissions. The fuel system will be completely new, and its components will need dedicated technology development.

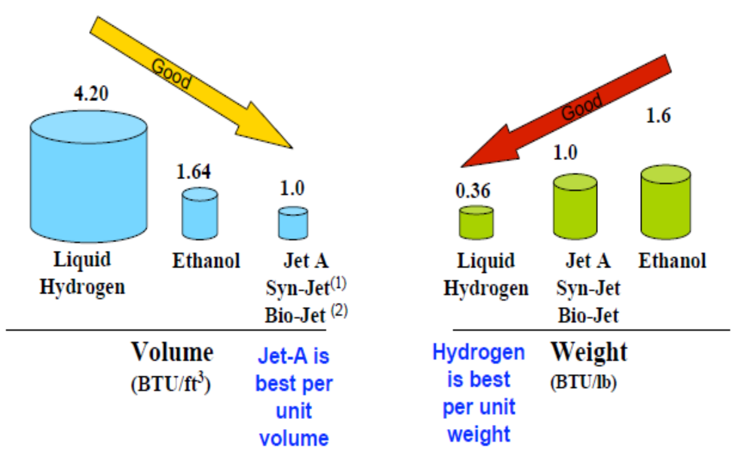

Figure 2: Relative comparisons of different types of alternative fuel [2]

5.2 ALCOHOL

Another alternative fuel concept is alcohols, such as, ethanol and methanol, liquid methane and synthetic kerosene. Alcohols offer environmental benefits as they are renewable energy sources, and since they are liquid fuels, they do not impose any major infrastructure changes at airports. Moreover, an experimental study of ethanol blended Jet-A fuels indicates marked reductions in carbon dioxide, oxides of nitrogen and soot formation with increasing blend rates. But the main drawback is at low power condition the combustion of alcohols produces organic acids and aldehydes, with attendant health hazards to ground support personnel. To produce alcohol it requires a large amount of hydrocarbon. The overall disadvantage however, with alcohols, which make them a less attractive substitute to kerosene, is their very low heat contents, both in terms of mass and volume, thus imposing significant penalties in aircraft range and/or payload capacity.[4]

5.3 SYNTHETIC KEROSENE

Another alternative fuel is synthetic kerosene. The efficiency for producing the fuel is about the same as for producing liquid hydrogen. It is a liquid fuel with about the same energy content as kerosene, and would therefore impose the smallest required changes in aircraft and fuel systems compared with the other alternative fuels discussed here. Due to a small content of hydrocarbons in synthetic kerosene, it is less unhealthy to handle and produces less toxic unburned hydrocarbons emissions when burnt than conventional kerosene. Again, the low content of hydrocarbons reduces the NOx and other emissions it has also no chance to produce organic acids or aldehydes like alcohol. However, synthetic kerosene seems to be a less attractive alternative to kerosene than hydrogen, as its production requires large quantities of one single energy source, namely, biomass. In order to mitigate the climate impacts of the greenhouse effect it would be reasonable to increase CO2 absorbing sources, of which the biosphere is one of the most important, rather than decrease or keep them at a constant level.

5.4 LIQUID HYDROGEN ENGINE TECHNOLOGY

As for the aero engine, the cycle and combustion chamber design need careful attention to secure a safe and reliable operation, as well as to exploit fully the favorable properties offered by using hydrogen for aero gas turbines. The engine could be designed either by making a minimum number of hardware changes or by employing unconventional cycles, which exploit the cryogenic properties of hydrogen, in order to improve the performance

5.4.1 POLLUTANT EMISSIONS

Given that liquid hydrogen is produced from renewable energy sources, the emissions are reduced to water vapor (H2O) (which increases by a factor of about 2·6) and small quantities of oxides of nitrogen (NOx) when burning hydrogen. All emissions containing carbon and sulphur are eliminated. In order to achieve satisfactory emission characteristics, the challenge is to minimize the NOx emissions while preserving or reducing the SFC. Performing research focused on reducing NOx emissions of gas turbines is highly important, since the effects of these emissions upon the environment and on human health are considerable.

5.4.2 EFFECTS ON NOX EMISSIONS BY USING HYDROGEN

In order to address properly the issue of NOx production of hydrogen combustion compared with kerosene combustion, several different combustion characteristics of these fuels need to be considered. The engine load in a gas turbine is controlled by varying the TET, which is determined by the overall fuel-air ratio in the combustion chamber. When a conventional kerosene-fuelled combustor is operating at full power, the primary zone operates at roughly stoichiometric fuel-air mixtures, where the flame temperature is highest and the chemical reactions are fastest. At low power idle conditions, the fuel-air ratio is essentially leaner and the primary zone fuel-air ratio has to be maintained above the flame-out limit with a sufficient margin. Hence, in order to minimize the NOx emissions, it is desirable to modify the fuel-air ratio in the combustor primary zone in a way that lean combustion is achieved at all engine load conditions without suffering a flame-out . In figure 3 the flame temperature of kerosene and hydrogen combustion versus primary zone equivalence ratio is shown where it shows that using hydrogen has greater flame temperature than kerosene.

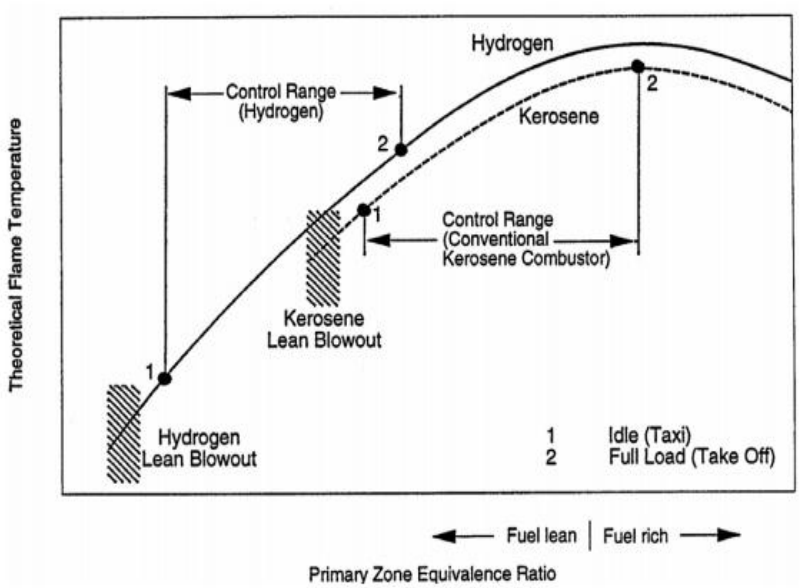

Figure 3: Comparative Temperature characteristics graph of two alternate fuels kerosene and hydrogen [7].

6.0 ADVANCED AERO ENGINE TECHNOLOGIES

For green aviation it is necessary to redesign the aircraft engine to reduce noise, emissions, and increase the fuel efficiency. The National Aeronautics and Space Administration (NASA) is leading the green aerospace charge among American aircraft manufacturers. It may be new engine which can absorb alternate fuels like liquid hydrogen or alcohols efficiently. Already various concepts have already been raised about this topic like open rotor engine, ultra high by pass ratio turbofan, MTU engine. Some company has already developed few engines which may be environmentally convenient like PW1500G BY Pratt & Whitney, ADVENT by U.S. Air Force, and E3E by Rolls Royce. Figure 4 shows some example of recent green aero engines.

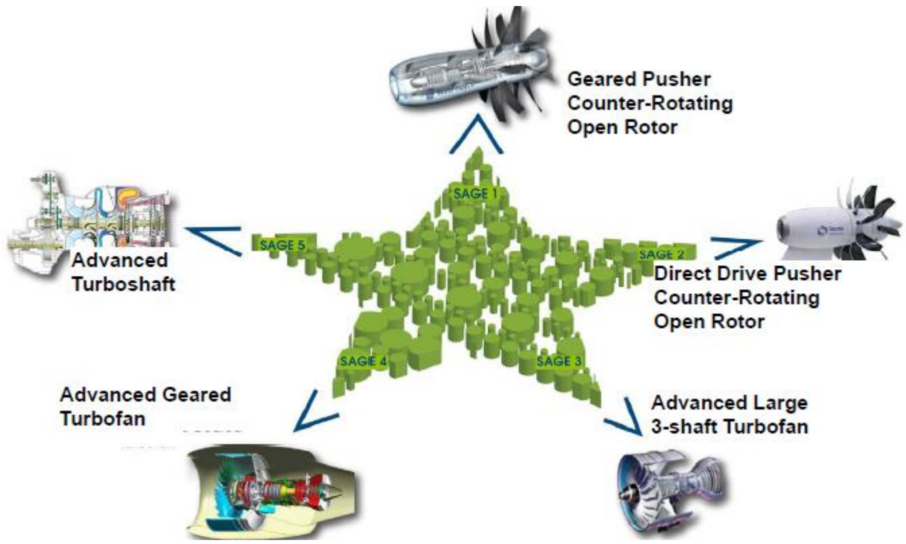

Figure 4: Recent green aero engines proposed by Rolls Royes [3].

6.1 GEARED TURBOFAN ENGINE (GTF)

The geared turbofan features a new engine concept, aiming at very high Bypass ratios and OPRs. Since more than 15 years, Pratt and Whitney America (P&WA), Pratt & Whitney Canada (P&WC), Fiat Avio and MTU are jointly working on the development of geared turbofan engine technologies for small and large thrust class applications. In 1992 the partners successfully run the Advanced Ducted Prop fan (ADP) demonstrator engine for bypass ratios up to 14 to demonstrate the technology for fuel efficient long range applications. More recently they introduced the Advanced Technology Fan Integrator (ATFI) representative to smaller thrust class engines. Latest Efforts aim at a new PW6000 based GTF demonstrator to support the development of 20- 30 klb new engine generation for regional aircraft.

The GTF bears the advantage to separate the low speed Fan component from the LPC and the LPT. Thus both component categories, i.e. Fan on the one side and LPC/LPT on the other side can run at their optimum speeds allowing uncompromised maximum benefit in terms of component efficiencies, stage count (weight, cost) and noise (low fan speed for minimum noise) (figure 5). So far, geared systems were confined to demonstrator applications only, but within the scope of new challenges from environmental and commercial constraints, studies have confirmed that the GTF will become a highly attractive alternative for the new generation of aircraft. The emerging demonstrator program will demonstrate this to the public.

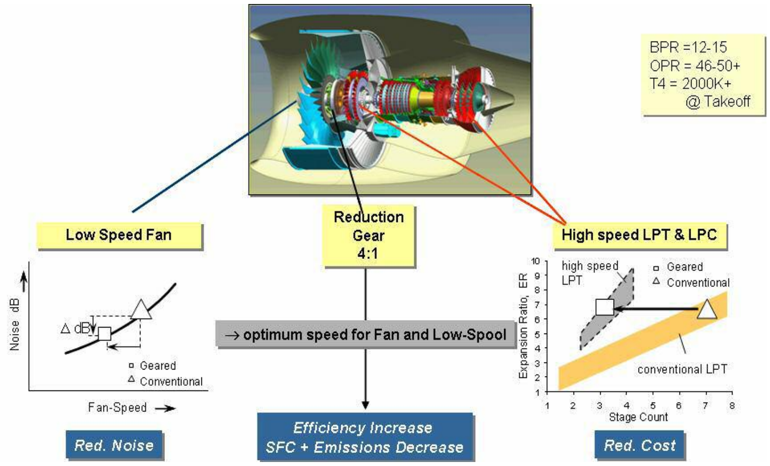

Figure 5: The Geared Turbofan for maximum propulsive efficiency and minimum noise [1].

GTF has various environmental benefits comparing the conventional technologies. It requires lower fuel than other engines like turbojet or turbo fan. As a result it emits lower CO_2, NOx or other harmful gases and has lower cost as well. Figure 6 describes this clearly.

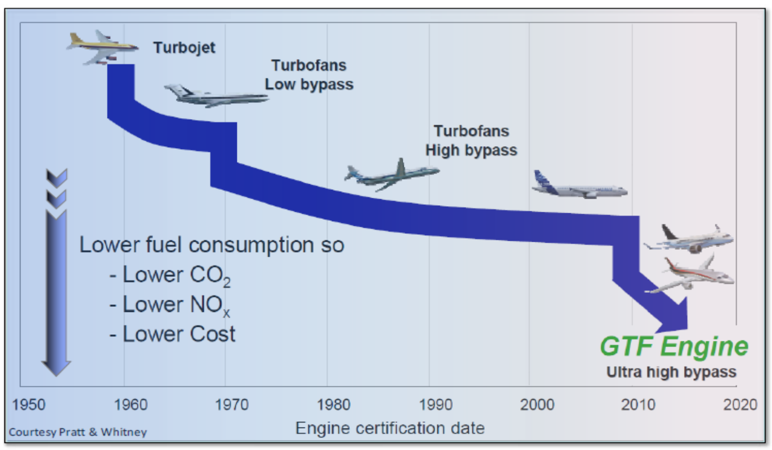

Figure 6: Environmental benefits by GTF engine [10].

6.2 E3E ENGINE BY ROLLS ROYCE

For instance, engineers at Rolls-Royce are developing a new two-shaft jet engine that promises to be fuel-efficient and environmentally friendly called the E3E (figure 7) which states for Environment, Efficiency and Economy. It uses cutting-edge technology to increase engine temperature, pressure ratio and component efficiencies. It has a 25 percent better thrust-to-weight ratio than existing engines. It reduces fuel consumption up to 20 % and CO_2 emissions by 15 percent, and noise up to 12 DB compared to similar engines, currently in service [5].

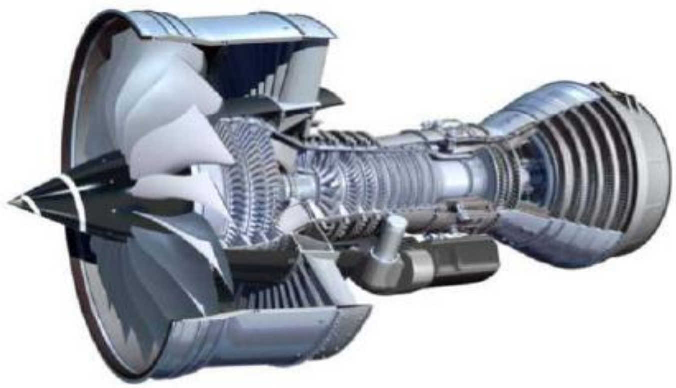

Figure 7: Two shaft E3E engine

6.3 ADVENT TECHNOLOGY BY U.S AIR FORCE

The U.S. Air Force Research Laboratory recently announced Phase II funding for GE Aviation's demonstrator engine core and critical components for the ADaptive Versatile ENgine Technology (ADVENT) program. It is developing a variable engine cycle, greater component efficiencies, and new materials to provide future military and commercial aircraft with far greater range and mission flexibility.

For the past two years, GE engineers have been engaged in Phase I of ADVENT, which involved preliminary and detailed design, analysis and risk-deduction activities. The development work involved running a full annular combustor rig, component and rig tests using ceramic matrix composite materials, and testing of a full core engine consisting of the compressor, combustor and high-pressure turbine. "Several key technologies will be demonstrated in Phase II, including a hot section featuring ceramic matrix composites, a high-pressure ratio core and an advanced variable pressure ratio fan, and GE's next-generation cooled turbine," says Jeff Martin, general manager for the ADVENT program. These technologies, if successfully demonstrated, will find home on (future 8) GE jet engines.

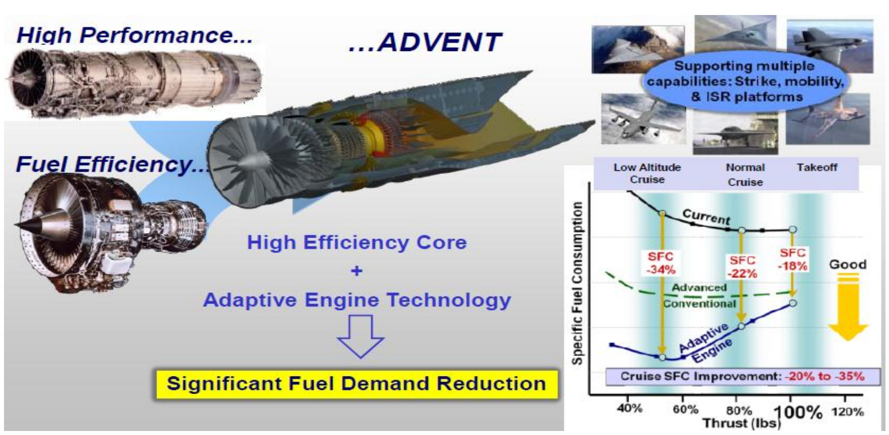

Figure 8: Benefits of ADVENT technology [11].

6.4 Open Rotor technology by GE:

General Electric is also working with NASA's Glenn Research Center to develop a new generation of open-rotor aircraft engines, which feature two high-speed propellers on the outside. The unique shape and design of the propellers allow airplanes to fly at speeds much closer to aircraft using traditional jet engines. It reduces fuel consumption by 30 %, CO_2 by 30 %, emissions by 50% and quieter comparing the traditional aircraft (figure 9). NASA's goal is to validate noise reduction with an open-rotor system while still getting a good fuel-burn performance metric. But here technical challenge is quieting the noise to make open rotors acceptable to the flying public.

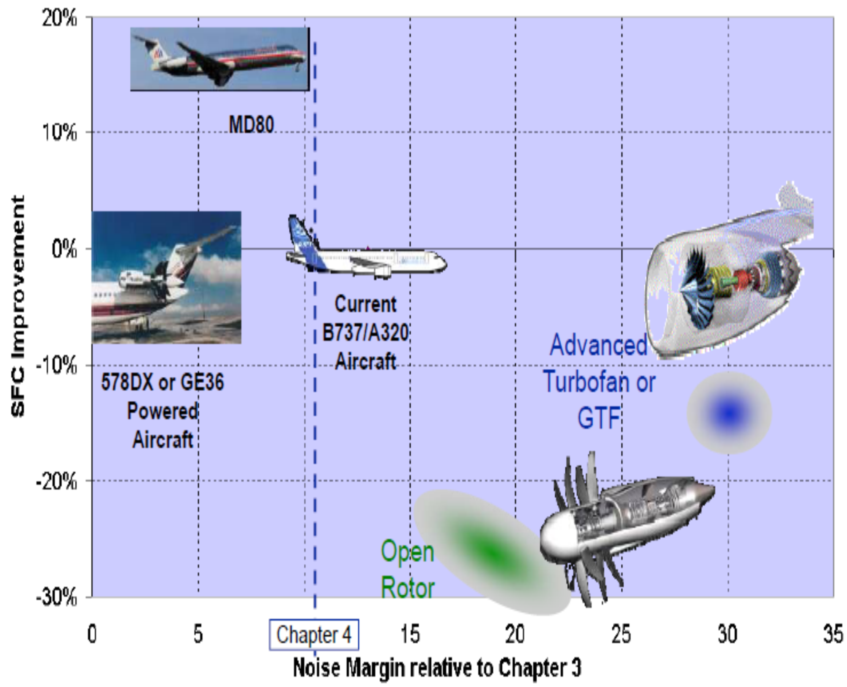

Figure 9: Noise and fuel burn improvement in open rotor engine comparing to other engines [7].

6.5 HIGHLY EFFICIENT EMBEDDED TURBINE ENGINE (HEETE)

HEETE is a highly fuel efficient turbine engine which can reduce the fuel consumption by 35% that's why it is environmentally helpful engine. It provides subsonic propulsion that supports future ISR, UAVs, Tankers and mobility extreme endurance and range. It has ultra-efficient cores with adaptive features and advanced thermal management. That's why it reduces the emissions and noise and increases power extraction. It also increases the payload (figure 9).

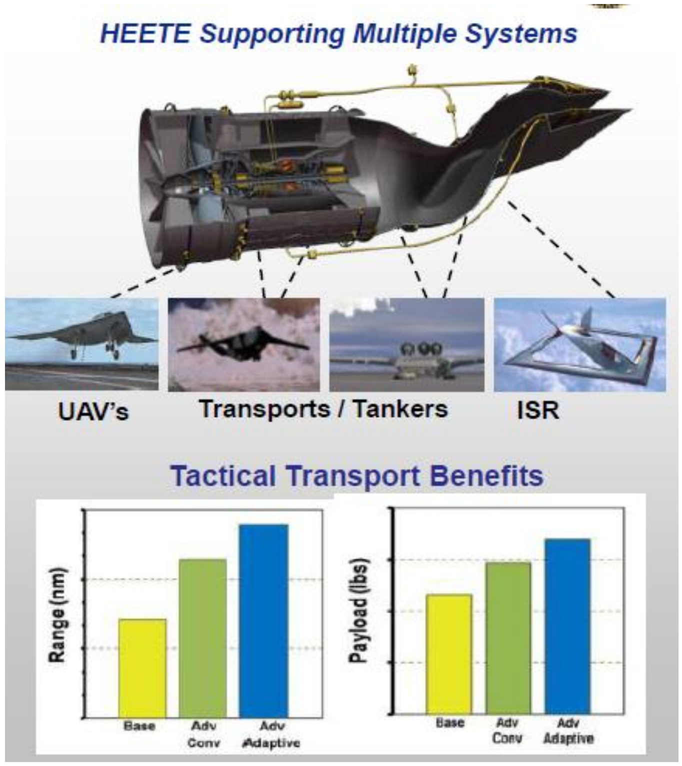

Figure 9: Benefits of using HEETE engine [11].

7.0 SOLAR ENERGY TECHNOLOGY

Some of the latest green achievements have come in the form of solar-powered aircraft. For instance, QinetiQ engineers recently set a world record with their unmanned Zephyr, which features a 22.5-meter wingspan. The hand-launched aircraft stayed aloft for more than 14 days, despite constantly changing weather conditions, during a recently stayed aloft for more than 26 test in Arizona. A team of Swiss aviators plan to fly around the world in a solar-powered aircraft. The Solar Impulse features a 64-meter wingspan. It recently stayed aloft for more than 26 hours during a test flight in Switzerland More than 10,700 solar cells cover the plane's wings, which contain four electric engines.

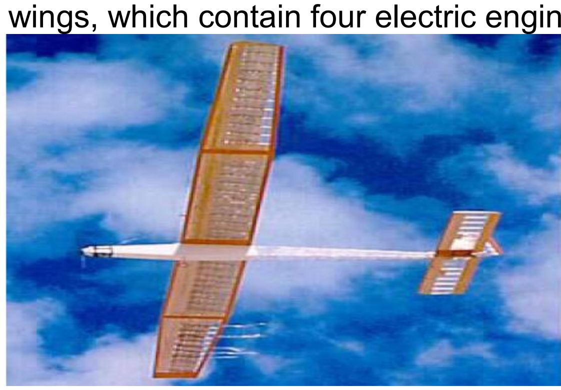

Figure 10: First solar driven aircraft flown on November 4, 1974 at Fort Irwin, California [6].

Boeing engineers have been experimenting with a wide variety of fuel cell technologies. In fact, Boeing Research & Technology Europe flew the world's first hydrogen-powered manned airplane two years ago. A hybrid system consisting of a proton-exchange membrane fuel cell and lithium-ion batteries powered an electric motor coupled to a conventional propeller in the two-seat motor glider. Despite those successful applications, many observers believe that fuel cells and solar panels will primarily be used as secondary power-generating systems on aircraft, such as auxiliary power units for large commercial airliners, rather than as primary power units.

8.0 AIR TO AIR REFUELING TECHNOLOGY

Recent studies have shown that air-to-air-refueling (AAR), well established in military circles, introduced to civil aircraft operations would provide fuel savings of the order of 30% – 40% (figure 11). AAR will allow smaller (3,000nm range), more efficient (greener) aircraft, operating from shorter runways, to fulfill long-range route requirements. In addition, the 'safety-net' afforded by the availability of AAR will enable a host of hitherto borderline technologies to be accepted and utilized in future aircraft designs. Laminar flow will provide fuel savings and increased efficiency in its own right provided it is enabled within a civil AAR environment. Similarly, supersonic transport becomes an acceptable economic option.

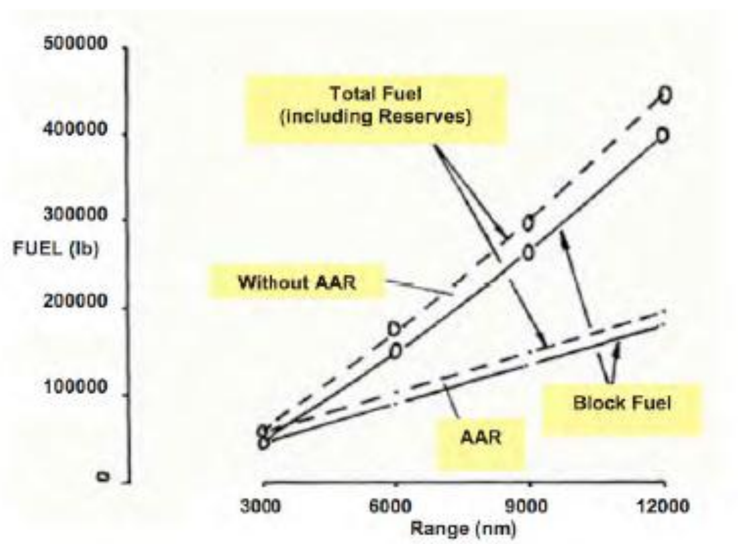

Figure 11: Effect of AAR on fuel consumption [2].

AAR would reduce the need for larger long-range aircraft. The consequent noise reductions would reduce or even remove night flying restrictions. The problems caused by take-off and landing shed vortices at airports would also reduce, allowing increased frequency.

9.0 CONCLUSION

Significant fuel burn, noise, emission and maintenance cost reduction will be required for engines for the next generation of regional aircraft. In order to achieve this targets a further improvement of existing engine types will not be satisfactory. A big technology step has to be done with new engine concepts and considerable advanced component technologies for compressors turbines and combustors. The geared turbofan features a new engine concept, aiming at very high bypass ratios and overall pressure ratios. By separating the low speed fan from the LPC and LPT each component can run in their optimum speed. That results in best component efficiencies (fuel burn), low stage count (weight, cost) and low noise (low fan speed for minimum noise).

10.0 ACKNOWLEDGEMENT

The authors would like to acknowledge the sustained works of V. Williams, R. B. Noland, Florham Park, NJ Eric Kronenberg, Justin White, Robert J. Boucher, Ric Parker, for their outstanding publications which have been used here as references.

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