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A Review on Strategies to Reduce Fuel Consumption in Different Phases of Flight

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Abstract: ***Fuel consumption is a critical aspect of aviation that directly impacts the cost, safety, and environmental impact of air travel. Aircraft require significant amounts of fuel to power their engines and maintain their altitude and speed during flight. Therefore, optimizing fuel consumption is a key priority for airlines, pilots, and aviation engineers. By understanding the factors that affect fuel consumption airlines can develop fuel-efficient flight plans and operational procedures that reduce costs and minimize the environmental impact of air travel. Research on ways to reduce fuel consumption are ongoing and lots of investment and research is required to improve the efficiency and sustainability of air transportation. In this review paper we will be discussing the ways airlines can reduce overall fuel burn in different phases of flight by using certain methods and procedures.***
Keywords: Aviation, Fuel, Flight operations, cost, airline, Strategies.

I. INTRODUCTION

Phases of flight refer to the different stages that an aircraft goes through during a flight, from takeoff to landing. Understanding these phases is crucial for pilots, air traffic controllers, and other aviation professionals to ensure safe and efficient operations.

The phases of flight typically include-

1) *Taxi:* It is the movement of the Aircraft on the surface of an airport using its own power.
2) *Takeoff:* It is the phase of flight where the aircraft leaves the ground and becomes airborne.
3) *Climb:* It is the operation where the altitude of the aircraft increases. It is following takeoff phase and preceding cruise.
4) *Cruise:* It is the phase after climb where the aircraft levels off and maintains that altitude until it begins to descend for landing.
5) *Descent:* Operation of flight where the altitude of the aircraft decreases. It is following the cruise phase.
6) *Approach:* The phase of flight starting when an aircraft under the control of the flight crew descends with the intention to conduct an approach and ending when the aircraft crosses the approach end of the landing runway.
7) *Landing:* The phase of flight starting when an aircraft under the control of the flight crew crosses the approach end of the landing runway (runway threshold) and ending when the aircraft safely vacates the landing runway.

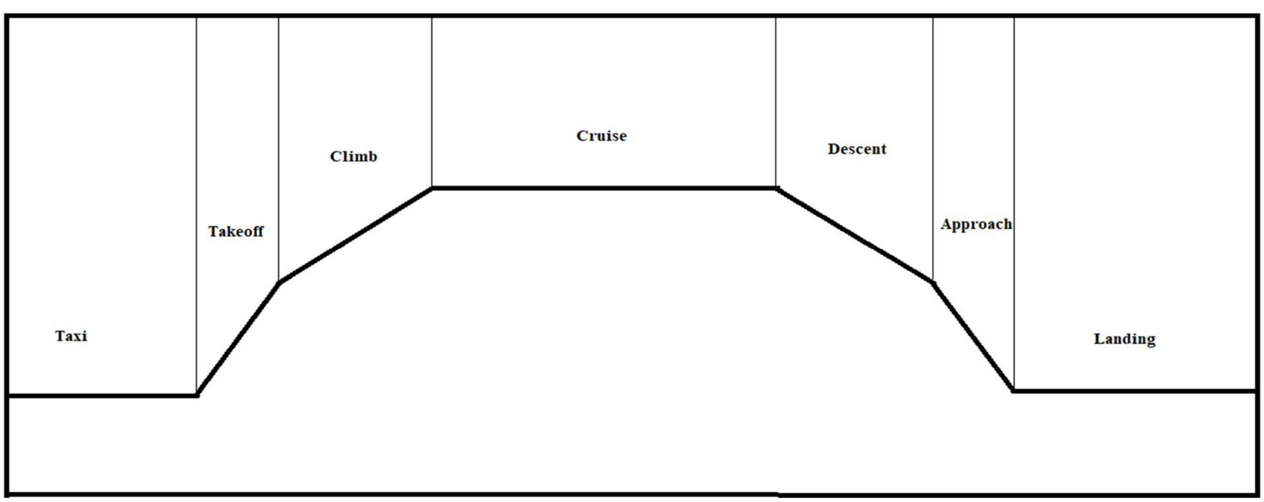


Figure 1 shows the different phases of flight

II. METHODS THAT CAN BE IMPLEMENTED

A. *Using GPU instead of APU*

When an aircraft is parked at the gate with its engines shut down, pilots have the option to use a Ground Power Unit (GPU) instead of the Auxiliary Power Unit (APU) to provide power to the aircraft. The advantage of using a GPU is that it consumes significantly less fuel compared to an APU. For instance, United Continental has reported that an APU can consume anywhere from 120 to 400 kg of fuel per hour, while a GPU provided by the airport typically uses less than 20 kg of fuel per hour.

B. *Single engine Taxi*

In this phase of operation, the aircraft moves from the terminal towards the runway on its own power. During this the aircraft can taxi using only one engine while keeping the other engine off which leads to saving of fuel. The operating engine must be capable of providing sufficient power for the aircraft's weight, and the pilot must monitor the engine's performance during taxing. Typically, the taxi period various from 5 minutes at smaller airports to as much as 30 minutes at larger airports. Using this strategy not only helps in reducing the fuel consumption but as the same time reduces the amount of emission that would have been emitted by two engines. Below is the data table showing the amount of fuel that can be saved using this method. This can be implemented both during taxi-out (before takeoff) and taxi-in (after landing) given that warm-up and cooldown time for engines are taken into account.

Aircraft type	Fuel saved (Kg/min)
B737	5
B777	13

Table 1 shows fuel saved by different aircraft types by using single engine taxi method.

C. *Derated Takeoff*

A derated takeoff is a technique used in aviation to reduce the wear and tear on an aircraft's engines while also saving fuel during takeoff. During a derated takeoff, the engine's thrust output is intentionally reduced from its maximum level to a lower level than what it is capable of producing. By doing so, the engine operates at a lower temperature and pressure, which results in reduced stress and wear on its components, leading to longer engine life and lower maintenance costs. Derated takeoffs are usually performed on flights where the aircraft is not fully loaded or when the runway length is longer than necessary, allowing the aircraft to take off with less power than it would typically require. The reduced thrust output during takeoff also leads to lower fuel consumption, resulting in cost savings for the airline. Pilots must follow specific procedures during a derated takeoff to ensure the aircraft's safety and performance. These procedures may include adjusting the aircraft's weight, selecting the appropriate takeoff power setting, and monitoring the aircraft's performance during takeoff. The aircraft's computer systems may also need to be programmed to account for the derated takeoff conditions.

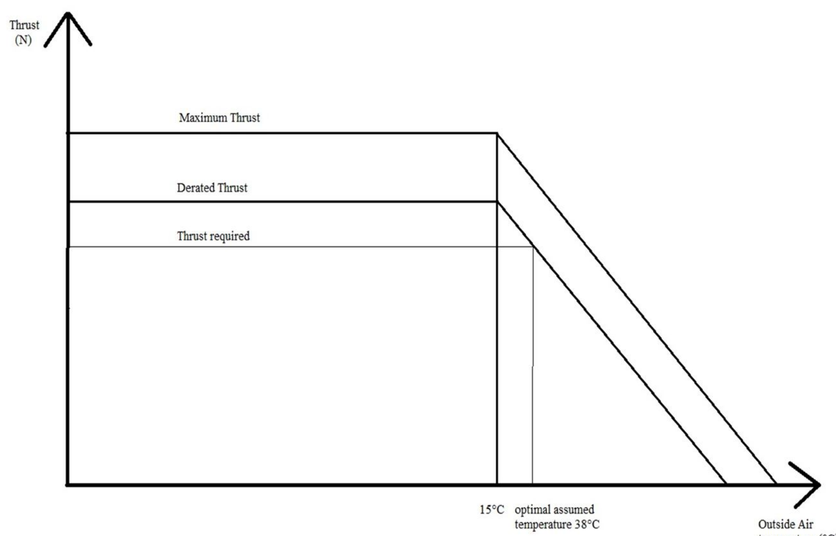


Figure 2 shows the comparison between maximum thrust, thrust required and derated thrust.

D. Using lower Flap setting

Flaps help in increasing lift produced by the wings at lower speeds by increasing the camber. But this comes at a cost of drag. The drag significantly increases. Hence using lower flap setting on takeoff helps in reducing the fuel consumed during takeoff and initial climb-out. But using lower flaps setting leads to increase in runway length required for takeoff hence this can be implemented where sufficient runway length is available for takeoff. As we can see from the figure below higher flap setting leads to more fuel being consumed as compared to lower flap settings during takeoff. This method can also be implemented during landing.

Aircraft type	Takeoff Flap setting	Gross weight (Kg)	Fuel Used (Kg)	Fuel differential (Kg)
737	5 10 15	72,575	578 586 588	0 8 10
777	5 10 20	249,476	1635 1668 1692	0 33 57

Table 2 shows the fuel consumption for different aircraft types using various flap settings

E. Using Different climb modes

Generally, most commercial aircraft are equipped with FMC (flight management computer) in which the pilot can chose between different modes of climb. On the climb page the pilot can select the mode of climb as per the requirements. MCL here is the maximum thrust that can be used for climbing and CLB 1 and 2 are modes where lesser thrust is used while climbing. The values shown in the figure are approximate values and it varies with weight of the aircraft, outside temperature, pressure and several other factors.

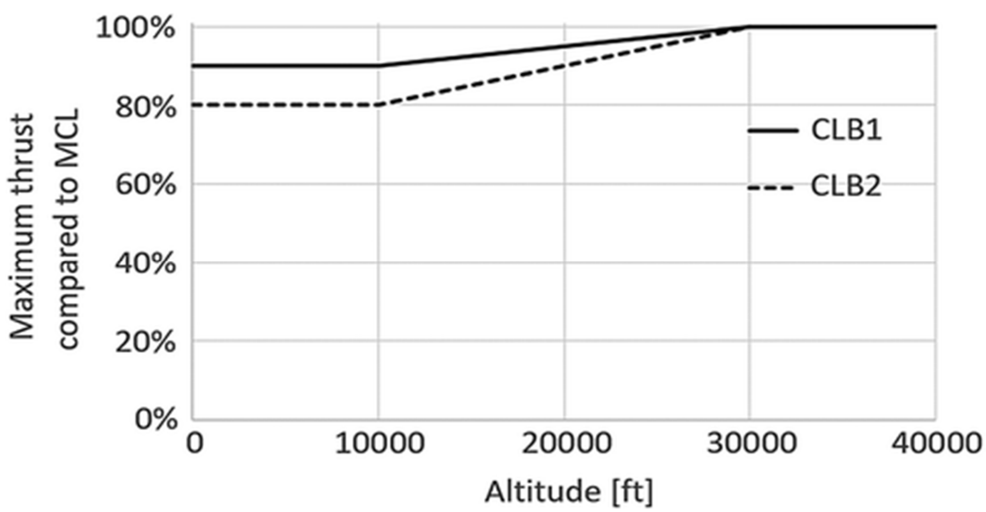


Figure 3 shows the comparison between MCL, CLB1 and CLB2

F. Using lower CI (cost index)

The CI is the ratio of the time-related cost of an airplane operation to cost of fuel.

$$CI = \frac{\text{Time related costs}}{\text{Fuel cost}}$$

Using lower cost index leads to aircraft consuming less fuel but at the same time increases the duration of flight. Aircrafts using lower cost index tend to fly at slower speeds to save fuel. Given below is the data from a B767-300ER aircraft performing flight from a European hub to a southeast Asian hub. As we can see from the data using lower cost index leads to increase in flight time but at the same time less fuel is burned.

Cost Index	Flight Time (minutes)	Fuel used (Kg)
136	739	58257
79	754	56931
38	765	56375

Table 3 shows the variation of flight time and fuel used with respect to cost index

G. Cruising at higher Altitudes

As the altitude goes on increasing the density of air goes on decreasing and less thrust is required by the aircraft.Hence this leads to saving of fuel.Given below is the chart for a 737-800 where the fuel flow varies with altitude.

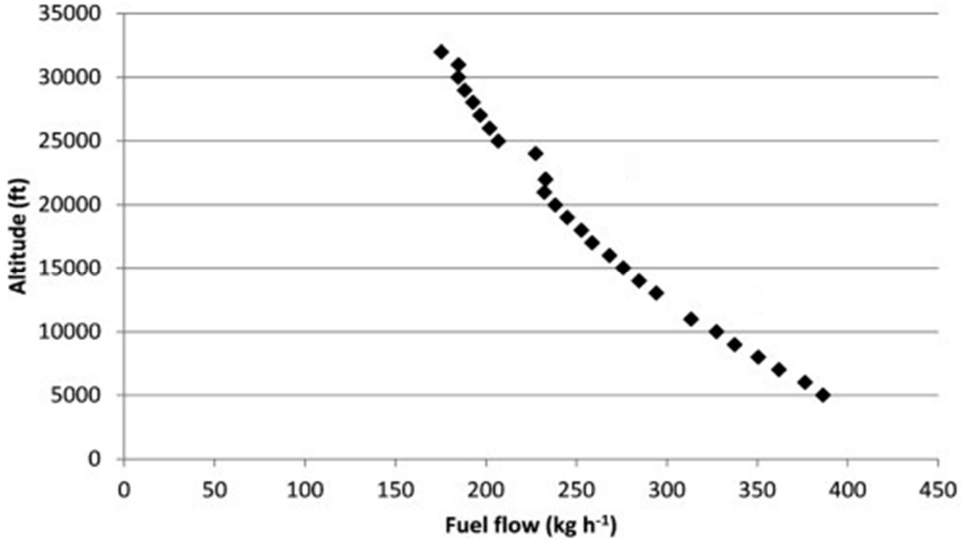


Figure 4 shows the change in fuel flow with respect to altitude.

H. Delayed Flaps approach procedure

The flaps extension can be delayed during approach. Flaps do help in increasing lift at slower speeds but increase drag at the same time. Given below is the data from a B737-800 aircraft where standard and delayed procedure was used for two different flap settings. As we can see from the table the delayed procedure significantly reduces the fuel burned.

Aircraft Type	Landing weight	Flap setting	Procedure used	Fuel Burned (Kg)
737-800	54,431	30	Standard	104
			Delayed	97
		40	Standard	121
			Delayed	104

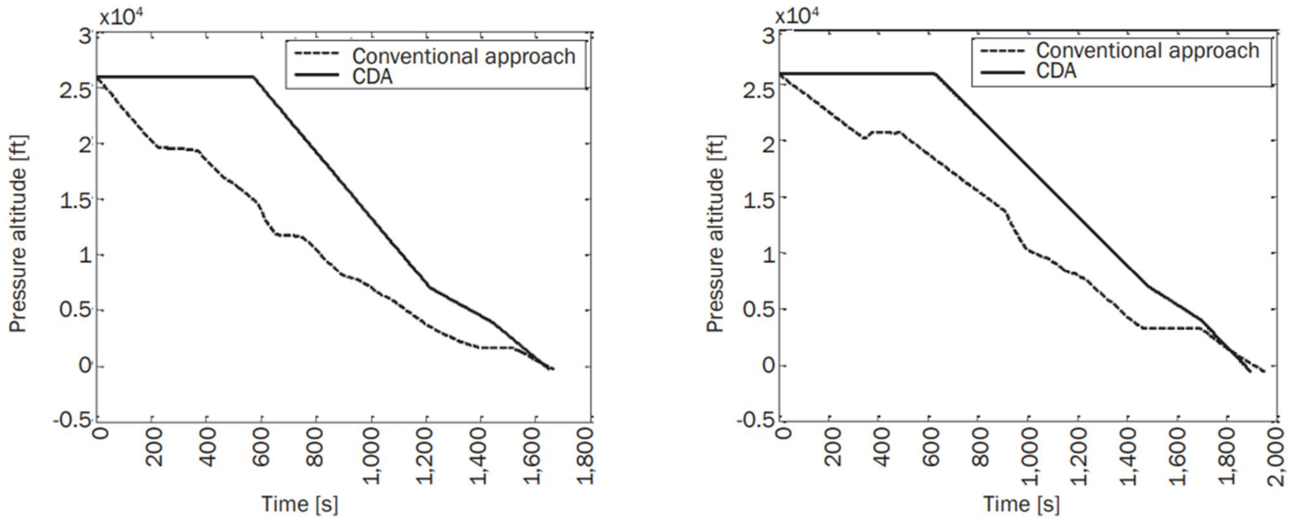
Table 4 shows comparison of fuel consumed for different procedure used.

I. Using Idle Reverse During Landing

This technique is used during landing where once the main wheels have touched down on the runway, the pilot will deploy the thrust reversers on the engines to help slow the aircraft down and instead of using full reverse thrust, the pilot will use idle reverse, which involves reducing the engine thrust to a minimum while still maintaining some level of reverse thrust. The engines will operate at a much lower thrust during this operation there by saving fuel. A combination of reverse thrust, and wheel brakes usage will be required to decelerate the aircraft during landing. This method can safely be used where long runways are used for landing.

J. Using Continuous Descend Approach (CDA)

Continuous descend approach refers to a type of aircraft approach where the plane descends at a steady rate from the top of the descent until touchdown, without leveling off or adding power. This approach is also known as a continuous descent arrival (CDA). In a traditional aircraft approach, the plane descends in a series of steps or levels, where the aircraft levels off at each step before continuing its descent. These level offs require additional engine power, which results in increased noise, fuel consumption, and emissions. Given below is the comparison of fuel consumed between CDA and conventional approach for two different flights.



a) Flight A *b) Flight B*

Figure 5 and 6 shows the flight path followed by Flight A and B

	Flight A	Flight B
Vertical speed [ft/min]	-3,222~227	-3,269~56
Pressure altitude [ft]	-329~25,943	-603~25,988
Longitudinal acceleration [g]	-0.06~0.156	-0.053~0.11
Airspeed [kt]	142~369	142~378
Initial gross weight [lb]	128,600	136,838
Flight path angle [deg)]	-4.21~0.69	-5.32~0.40
Along-track wind speed [kt]	-8.4~53.6	-9.9~65.9
Average wind speed [kt]	19.6	22.6
Total temperature [°C]	-12.8~9.0	-14.2~8.5

Table 5 shows the approach conditions of two flights.

	Flight A	Flight B
Fuel burn of conventional approach (lb)	1387	1806
Fuel burn of CDA (lb)	657	786
Fuel saved (lb)	730	1020

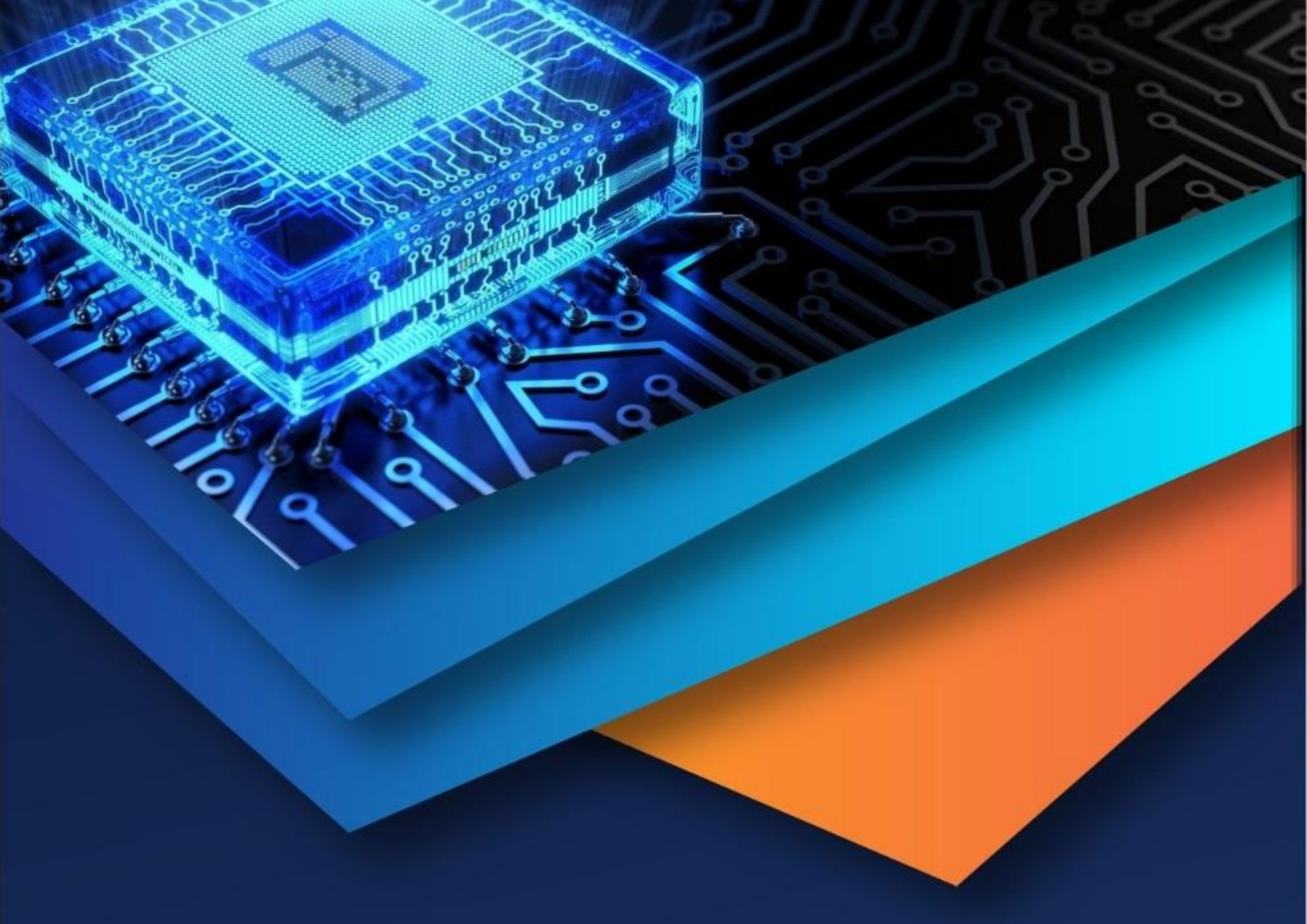
Table 6 shows the difference in fuel burn for Flight A and Flight B using two different approaches.

III. CONCLUSION

The above methods are few ways of saving fuel during a flight. By using these strategies, airlines can reduce their fuel consumption, lower their carbon footprint, and contribute to a more sustainable future for the aviation industry. More methods are being found and implemented to save fuel in the aviation industry. Using these methods will definitely lead to saving of more fuel during flights which will help the airlines in reducing their operating costs. Overall, reducing fuel consumption in aviation requires a multi-pronged approach that involves improving aircraft design, optimizing flight paths, and exploring alternative fuels. While progress has been made, continued innovation and investment will be necessary to achieve significant reductions in fuel burn.

REFERENCES

[1] https://fl360aero.com/detail/aircraft-derated-take-off-a-general-understanding/238
[2] https://www.sesarju.eu/sites/default/files/documents/webinars/Guiseppe.pdf
[3] https://www.skybrary.aero/articles/reduced-thrust-takeoff
[4] https://www.boeing.com/commercial/aeromagazine/articles/qtr_4_08/article_05_1.html
[5] https://www.sciencedirect.com/science/article/pii/S0306261915015081
[6] https://www.highskyflying.com/why-are-jet-engines-more-efficient-at-higher-altitudes/
[7] https://www.boeing.com/commercial/aeromagazine/articles/qtr_02_10/pdfs/AERO_Q2-10_article05.pdf
[8] Ye L-S, Cao L, Wang X-H. Evaluating Fuel Consumption for Continuous Descent Approach Based on QAR Data



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