

# Advanced development and future of jet engines

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**Abstract.** An aerodynamic reaction engine, a jet engine, is an internal combustion engine that produces thrust through jet thrust. A jet engine is an important power unit used in aviation and spaceflight, which generates thrust by pushing air in reverse. In recent decades, various developments and improvements have significantly enhanced the efficiency and performance of jet engines. These engines are divided into turbojets, turbojets, turboprops, turboshafts, and ramjets. This article will begin with an introduction to the different types of jet engines and then detail the design, benefits, and issues of the CFM International CFM56/LEAP engine. Finally, there is some description of the future of jet engines, including materials, greater efficiency, and applications in space exploration. The development of the jet engine dates back to the 1930s. British inventor Frank Whittle and German inventor Hans von Ohain developed the first jet engines independently. Jet engines were widely used during World War II and have been continuously improved and developed. The modern jet engine has become the main power unit of commercial and military aviation, and its structure and performance have also been greatly improved.

**Keywords:** jet engine, aerothermodynamics, CFM LEAP engine, sustainability.

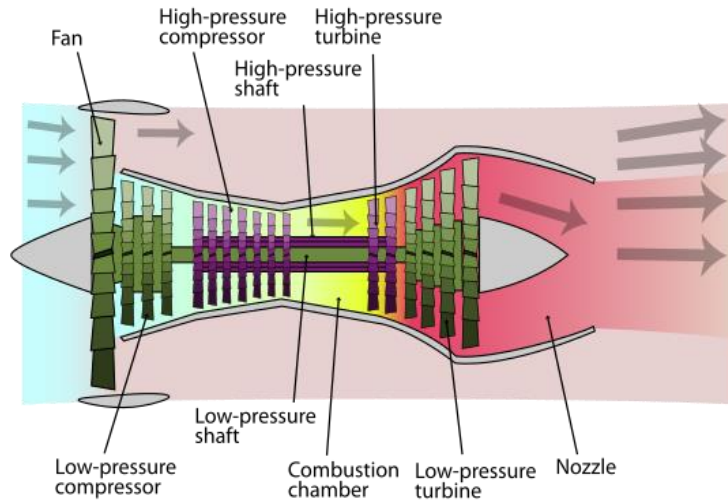
## 1. Introduction

Modern aviation is not complete without jet engines, which come in a variety of forms, each with its own set of benefits and drawbacks [1]. Simple and light, turbojet engines deliver strong thrust at great speeds. At slow speeds, though, they are not very effective. Turboprop engines are slower than turbojet engines but use less fuel and are quieter. Turbofan engines operate well at low speeds and balance speed and fuel efficiency, although they are more complicated and heavier than others. While scramjet engines can function at even higher speeds but are still in the experimental stage, ramjet engines are incredibly quick but inefficient at low speeds [2]. Jet engines generate thrust by jetting high-speed air. Different types of jet engines work on different principles, but the basic principles are similar. The turbojet engine compresses the air through the compressor, injects the fuel and ignites it to form a jet stream. Turbojet engines have narrower nozzles to achieve higher jet velocities. The turbofan, a modernized turbojet, features a large front fan propelled through a low-pressure turbine to generate extra force. Both turbojet and turbofan are typical illustrations of internal combustion jet engines.

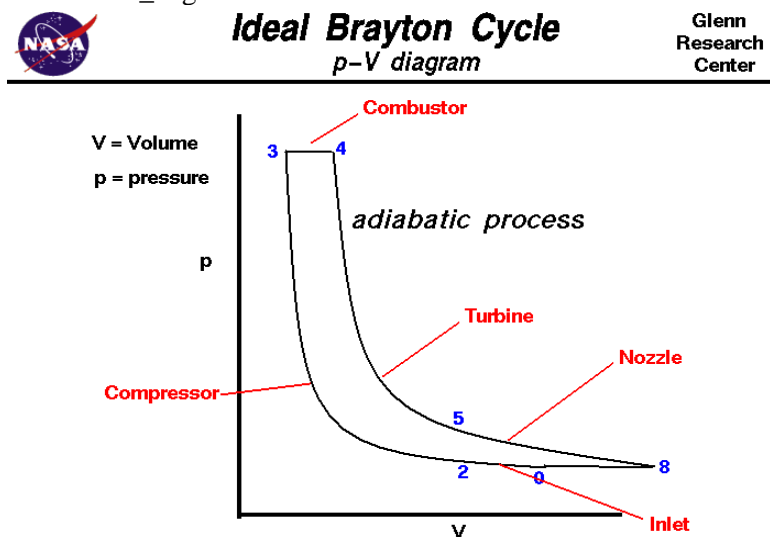
Advantages of jet engines include i) Efficiency: Compared to other types of engines, jet engines have higher thermal efficiency and thrust so that they can propel the aircraft forward more efficiently. ii) High speed: Jet engines allow aircraft to travel at higher speeds, allowing longer range and shorter flight times.

iii) High-altitude performance: Jet engines can operate at high altitudes, while other engines lose thrust due to thin air. iv) Reliability: Jet engines have a longer service life and fewer failure rates, thus improving flight safety. Disadvantages of jet engines include: i) High cost: Jet engines are expensive to manufacture and require much money to maintain and repair. ii) Loud: Jet engines make more noise than other types of engines. iii) Environmental pollution: The exhaust gas emitted by jet engines has caused some pollution to the environment.

The commercial use of jet engines is widespread, and almost all commercial aircraft are equipped with jet engines. The advantages of jet engines include high efficiency, high thrust, high speed and reliability. In addition, jet engines are also widely used in the military field, such as fighter jets and bombers. To improve the performance and efficiency of a jet engine, intake design, overall size, compressor stage, fuel type, exhaust stage, etc., are all important considerations.



**Figure 1.** The internal structure of the jet engine, reproduced from the website:  
[https://code7700.com/turbine\\_engine.htm](https://code7700.com/turbine_engine.htm).



**Figure 2.** The thermodynamic principles of the jet engine, reproduced from the website:  
<https://www.grc.nasa.gov/www/k-12/airplane/brayton.html#:~:text=Turbine%20Engine%20Thermodynamic%20Cycle%202D%20Brayton%20Cycle>

## 2. Mechanism and unique traits of jet engine

The mechanism of a jet engine is based on the principle of Newton's third law of motion, which states that every action has an equal and opposite force. Using a number of fans or compressors, the engine draws air from the atmosphere and compresses it. The fuel and compressed air are combined and ignited in a combustion chamber. As a result of the quickly expanding high-temperature, high-pressure gas, the aircraft is propelled forward by a high-velocity jet of exhaust gases. The cylindrical shape and a row of fan blades at the front give jet engines their distinctive appearance. These blades compress the incoming air before being directed into the combustion chamber. To release exhaust gases, the engine also features several exhaust nozzles at the back [3].

A jet engine has a complicated structure with several parts. The engine's inlet, or front, has a number of fans or compressors that condense the incoming air. The combustion chamber combines the fuel with the compressed air and ignites. The turbine that powers the compressor at the front of the engine is powered by the hot gases created during combustion. Finally, a series of exhaust nozzles near the back of the engine release the exhaust gases [4].

In contrast to a turbocharger, which increases an internal combustion engine's power output, a jet engine is designed to provide thrust for propulsion. Both devices use a compressor to compress the air, but a turbocharger doesn't have a combustion chamber and doesn't emit any exhaust gases.

The capacity of jet engines to operate at very high altitudes and speeds is one of its distinguishing characteristics. Jet engines maintain their power output at high altitudes by compressing incoming air before combustion, in contrast to conventional piston engines that lose power at higher altitudes due to decreasing air pressure. As a result, jet aircraft are able to fly higher and more quickly than other forms of aircraft. The effectiveness of jet engines is another distinctive quality. Compared to other types of engines, jet engines are able to convert a higher proportion of the energy in the fuel into thrust. This is because they can function at high pressures and temperatures, which enables more thorough fuel combustion.

## 3. Seeing present jet engines from “CFM International CFM56 and CFM LEAP engine”

One of the most widely used and typical examples of jet engines is the CFM International CFM56 series engine. The CFM International CFM56 series engine, a high bypass ratio turbofan with a large jet thrust, is a CFM International creation (Bilien). Its composite fan blades and fan casings are designed for lightweight operation. The majority of the air that the fan accelerates skips the engine's core and is expelled from the fan housing [5]. LEAP engine incorporates new materials and designs for improved efficiency and decreased fuel consumption. The LEAP engine uses advanced technologies such as dual-ring combustors and ceramic matrix composite materials. The engine also features a debris removal system for increased reliability and durability. The fuel efficiency of the LEAP engine is 15 percent higher, the majority of which is derived from the high-pressure compressor and the rest from the fan [6].

The LEAP engine has improved in three main aspects. First of all, LEAP has a method for rejecting debris. Variable bleed valves are opened during takeoff, a high-thrust operation by nature, especially at hot and high airports. This solves the problem of vulnerable engines in areas with poor air quality. Debris should be directed away from the engine rather than around it. The doors are shut during a lower-thrust flight routine. This encourages greater fuel efficiency. And the engine is stronger. LEAP has single-piece composite fan blades and a fan casing based on "fourth-generation aerodynamic design. The fan's utilization of the pioneering Carbon Fiber Reinforced Plastic (CFRP) composite material aids in diminishing the engine's overall weight. A three-dimensional loom is used to weave the carbon fiber, the resin is injected, and the assembly is baked in an autoclave as part of the novel process. The application of a titanium leading edge is the finishing touch. The new TAPS II twin-annular swirler from LEAP is put to use. Contemplate it as a nozzle with a dual intent: to cut down maintenance expenses and greenhouse gas emissions at the same time. Fuel and air are prepped before they enter the combustion chamber for ignition. The disparity between the average and peak temperatures is reduced by lean burn combustion. In addition, a high-pressure hot section compressor with a remarkable 22:1 compression ratio is used (Zhao). The CFM56 family's critical ratio is half as high as this one. Two

components of the engine account for LEAP's claimed 15 percent reduction in fuel consumption: The high-pressure compressor provides half, and the fan provides the other half.

#### 4. Future of jet engine

The future of jet engines is focused on improving efficiency, safety and performance, using more advanced materials while reducing environmental impact. More environmentally friendly engines that use less fuel and emit fewer emissions are in demand. New technologies, including hybrid-electric and all-electric propulsion systems, have emerged. Electric motors are used in these systems to power the propellers or fans, decreasing the need for fossil fuels and increasing efficiency.

The future of jet engines will also prioritize noise reduction. Due to their infamously loud operation, jet engines must adhere to tight restrictions that set a maximum noise level. Engine manufacturers are creating new models that integrate noise-canceling innovations, including acoustic liners, serrated edges on fan blades, and modified exhaust nozzles to address this problem [7]. Demand for more potent and effective engines is rising in addition to sustainability and noise reduction. New materials lighter and stronger than conventional metals, like composites and ceramics, have been created. These materials can withstand Higher temperatures and pressures, resulting in more effective combustion and greater thrust. Artificial intelligence (AI) and machine learning (ML) will be used in jet engines in the future to enhance performance and safety. These technologies provide real-time engine performance monitoring, early failure detection, and condition-based engine performance optimization.

About the materials: Nb Silicide Composites have reasonable fracture toughness, good fatigue resistance, high-temperature strength, and impact resistance and can be cast quite well. They also exhibit strong oxidation resistance and resistance to pests (intermediate-temperature pulverization). For these composites, good coatings have also been created. Composites made of ceramic-matrix. Even when measured on a density-normalized basis, their power is modest. This system is a desirable choice for well-designed systems due to its superior impact resistance and stability at high operating temperatures; Surge is a type of failure brought on by the compressor's low flow coefficient when operating [8-10].

#### 5. Conclusion

In summary, jet engines have seen remarkable progress in the last few decades and are indispensable for aerospace. Modern jet engines, like the CFM International CFM56/LEAP series engines, excel in performance and include cutting-edge architecture. Jet engines work by compressing air and injecting it with fuel, igniting the mixture to produce hot, high-pressure gases. These gases are expelled through the nozzle, creating a reaction force that pushes the plane forward. Common jet engines include turbojets and jet propulsion engines. A turbojet uses a turbine to compress air and drive jet thrust, while a jet propulsion engine ejects gas directly from burning fuel to generate thrust. It can be reasonably anticipated that more material and technological advancements will boost the effectiveness and dependability of jet engines and broaden their application areas, including space travel. Overall, the future of jet engines is optimistic, with a host of fascinating developments just around the corner. The aircraft sector continuously pushes the envelope of what is possible, from sustainability and noise reduction to more potent and efficient designs. There will be even more significant developments in the years to come with ongoing investment in research and development.

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