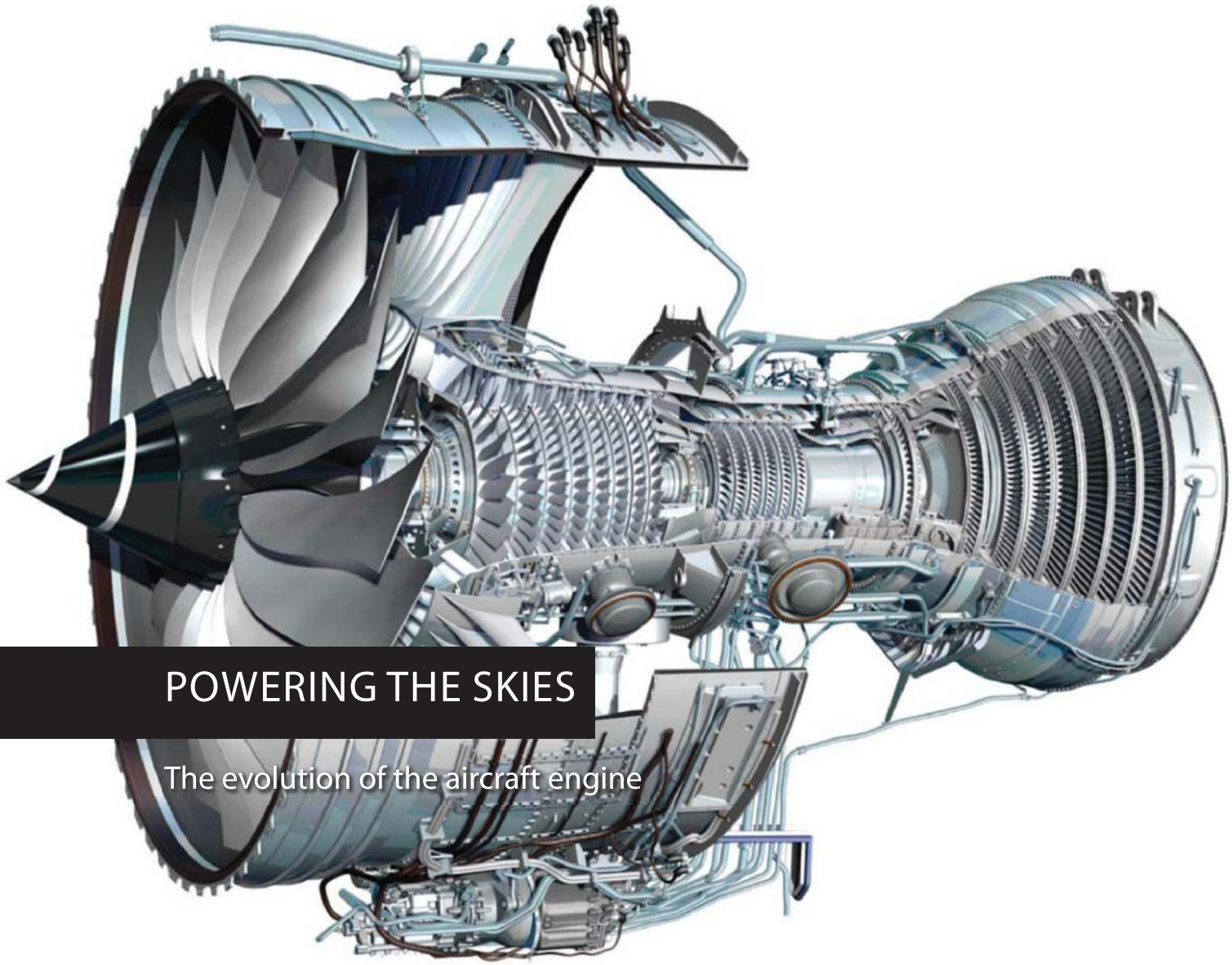

POWERING THE SKIES

The evolution of the aircraft engine

The propulsive unit is one of the most expensive components of any new aircraft, and one of the most complicated. Modern propulsion systems are extremely efficient, using advanced technology to produce huge amounts of thrust or power, while still meeting strict noise and emission regulations. But how did these engines develop to where they are now?

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INTRODUCTION

The first manned powered flight with a fixed wing aircraft in 1903 took a chain of visionaries, engineers and inventors, each of them solving one piece of the puzzle. Essential to solving this puzzle was Sir George Cayley who strongly believed that flight with fixed wing aircraft instead of flapping ones was the better approach. His unmanned glider experiments in 1809were important steps in that direction. The unpowered manned gliders from Otto von Lilienthal were an important sequel to those of Cayley, showing the capability of lifting a human being with a fixed lifting surface. What was not there was a lightweight propulsion system to overcome drag and go beyond gliding, the understanding of the importance of roll control next to pitch and directional control, wing warping for roll, proper understanding of stability, and light and strong airframes to carry man, engine and fuel. The Wright brothers' solution to the puzzle was a lightweight wooden structure, stiffened and strengthened with bracing wires, piston engines with enough specific power, propellers, a fabric covered wing to generate lift, a proper weight distribution, three axis control, acceptable stability using a canard configuration, and a landing gear. Once a solution to the puzzle was demonstrated, an explosion of aircraft designs occurred in different parts of the world.

THE NEED FOR POWER

Sir George Cayley envisioned a fixed wing aircraft with separate elements for lift generation, propulsion, flight controls and pilot cabin, way back at the end of the 18th century, more than a century

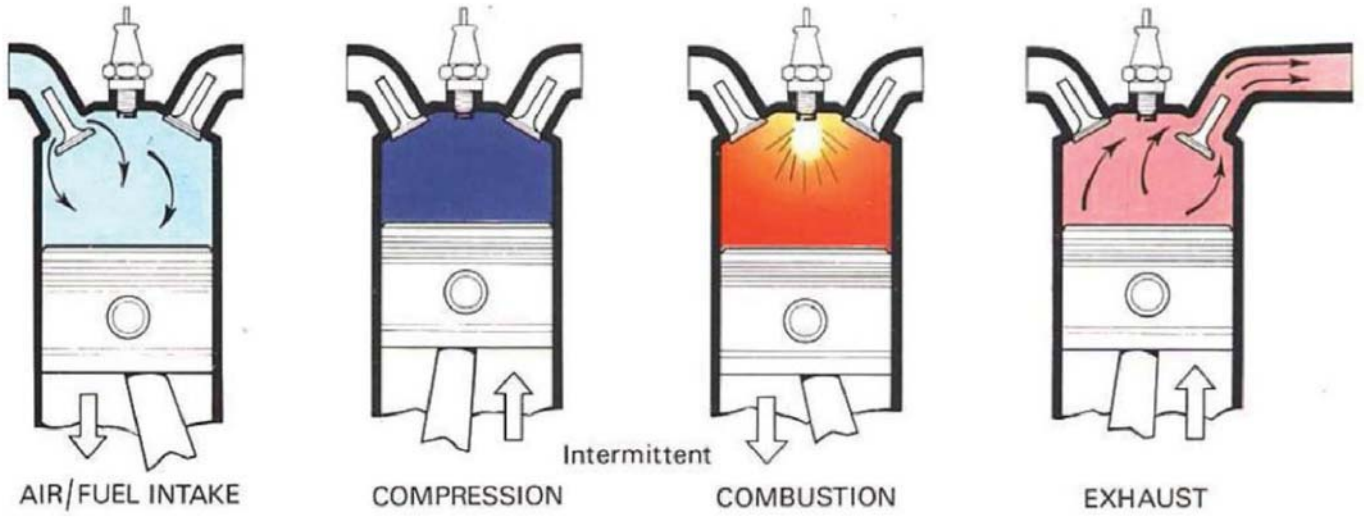

Figure 1. The working of a four stroke internal combustion engine

before the first successful flight test by the Wright brothers. He also predicted that the powered flight would be possible if an engine would be able to produce "more power in a given time, proportional to its weight, than the animal system of muscles".

Approximately half a century later steam engines were invented to be used in aviation. Even though the steam engines, in accordance with their time, were the state of the art engines, they were too bulky and were just not powerful enough to be used in heavier than air aircraft. A few years later in 1859 Belgian engineer Jean Lenoir invented the first internal combustion (IC) engine, a single cylinder 2-stroke reciprocating engine that used coal gas as fuel. Although there were several problems with this engine, it paved the way for a radically different kind of engine that was more efficient and compact than the steam engines. The internal combustion engine was further developed by the Germans, namely by Nikolaus Otto, the inventor of the 4-stroke engine, and Karl Benz, who designed and built 4-stroke engines to be used for the first time in automobiles. By the end of the century, reciprocating IC engines proved their ability and hence became the choice of propulsion for aircraft.

Unlike a steam engine where the fuel is burnt outside the engine to create steam pressure, an IC engine burns the fuel inside the cylinder, forcing the piston to move within the cylinder. The piston is connected to a crankshaft that converts the reciprocating motion of the piston to rotational motion. A large flywheel is attached to the crankshaft to store some of the energy in the form of inertia for the subsequent strokes of the piston which are used to push the exhaust air out of the engine, to suck in fresh air and fuel, and for compression of the air before ignition. The valves in the cylinder open and close appropriately to create boundary conditions for different operations within the stroke, see figure 1. A piston engine therefore has only one power stroke in 2 or 4 strokes (depending on whether it is a 2 or a 4-stroke engine).

THE FIRST FLIGHT

The power-to-weight ratio has always been the most essential criteria in selecting a powerplant for the aircraft. Therefore the Wright brothers used a reciprocating IC type engine to power their Wright Flyer in 1903. The Wright brothers built their own engine with the help of their mechanic Charlie Taylor. This 4-stroke engine weighed around 90kg and produced around 12hp of power. A simple sprocket chain drive with a gear system powered the twin propellers that rotated in opposite directions while a basic gear system allowed them to change the propeller speed in spite of the engine rotating at a fixed speed, figure 2. The first Wright Flyer engine was by no means a state of the art engine (cooling problems meant it became less efficient the longer it ran) but it did make a mark of its own in history. In contrast to their engine, the propellers used by the Wright brothers were very good. In absence of any theory on propellers, they designed their own propeller and were among the first to understand that the propeller works in a similar way to a wing.

The need for more power, a higher power-to-weight ratio and reliability were the key drivers in the design and development of aircraft engines. It did not take long for the military to see the potential of aircraft being used as a potent weapon in warfare. World War I saw many new developments in aircraft and aircraft engines. Many of the WWI fighters were powered by rotary engine. These engines rotate with the propeller and had the advantage of being air cooled meaning they could dispense with the heavy and complicated liquid cooling systems required in other types of engines. However after the war, the rotary engines were becoming obsolete due to the more powerful and advanced non-rotary engines (inline, V type and radial) that revolved at high rpms and did not have the smoke inhalation problems for the pilot that rotary engines had.

After WWI, civil aviation emerged with the birth of KLM Royal Dutch Airlines, the oldest airline today which started in May 1920. This fledgling industry was aided by the historic first non-stop flight across the Atlantic in 1927, after which pioneer Charles Lindburgh used his reputation to promote the development of civil aviation. This ushered in a new era in aviation and radial engines which continued to be at the forefront of the propulsion systems.

World War II again saw remarkable developments in aircraft and related systems, and pushed the developments in these areas to their limits. In order for early engines to achieve higher speeds or higher thrust levels, it required the propeller to run at a higher speed. Therefore they soon became limited by the formation of shock waves at the propeller blades that reduced the efficiency drastically. In addition, flying higher was not possible with reciprocating engines because as the density of air reduced at higher altitudes, the engine power reduced dramatically. The adjustable pitch system in propeller and superchargers helped in enlarging the flight envelope, however by the end of the war, designers started to realize the fundamental limitations of the IC engine-propeller type of propulsion system.