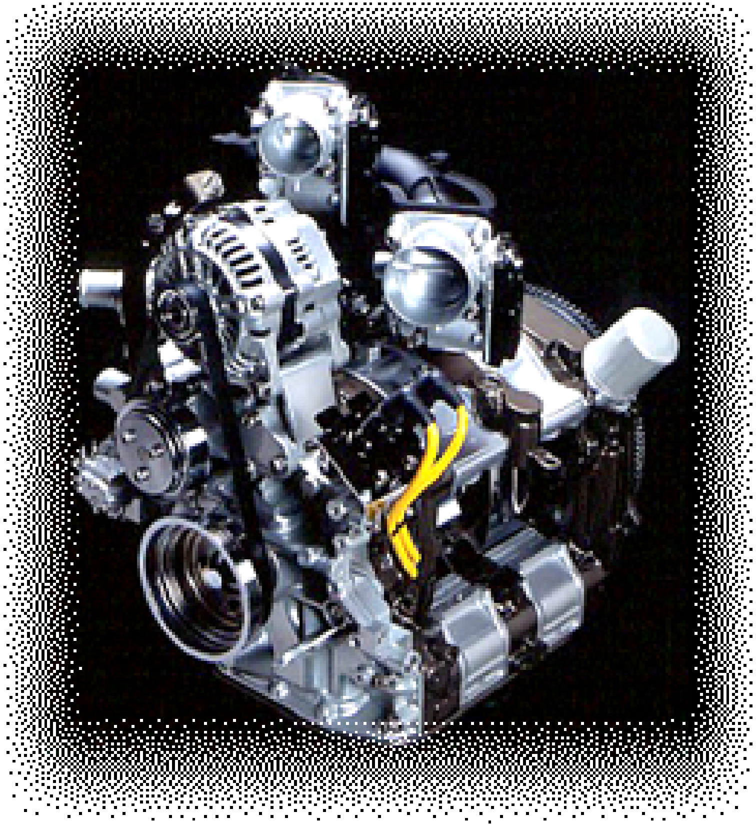
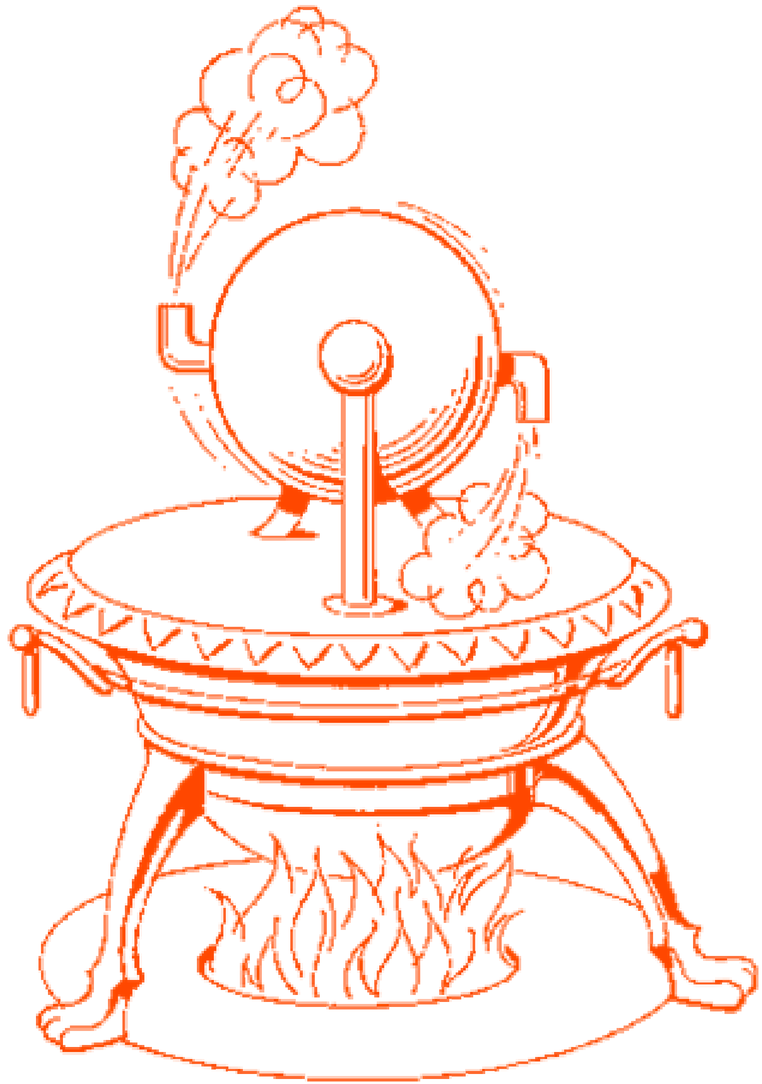
Gas Turbines

Mazda Rotary

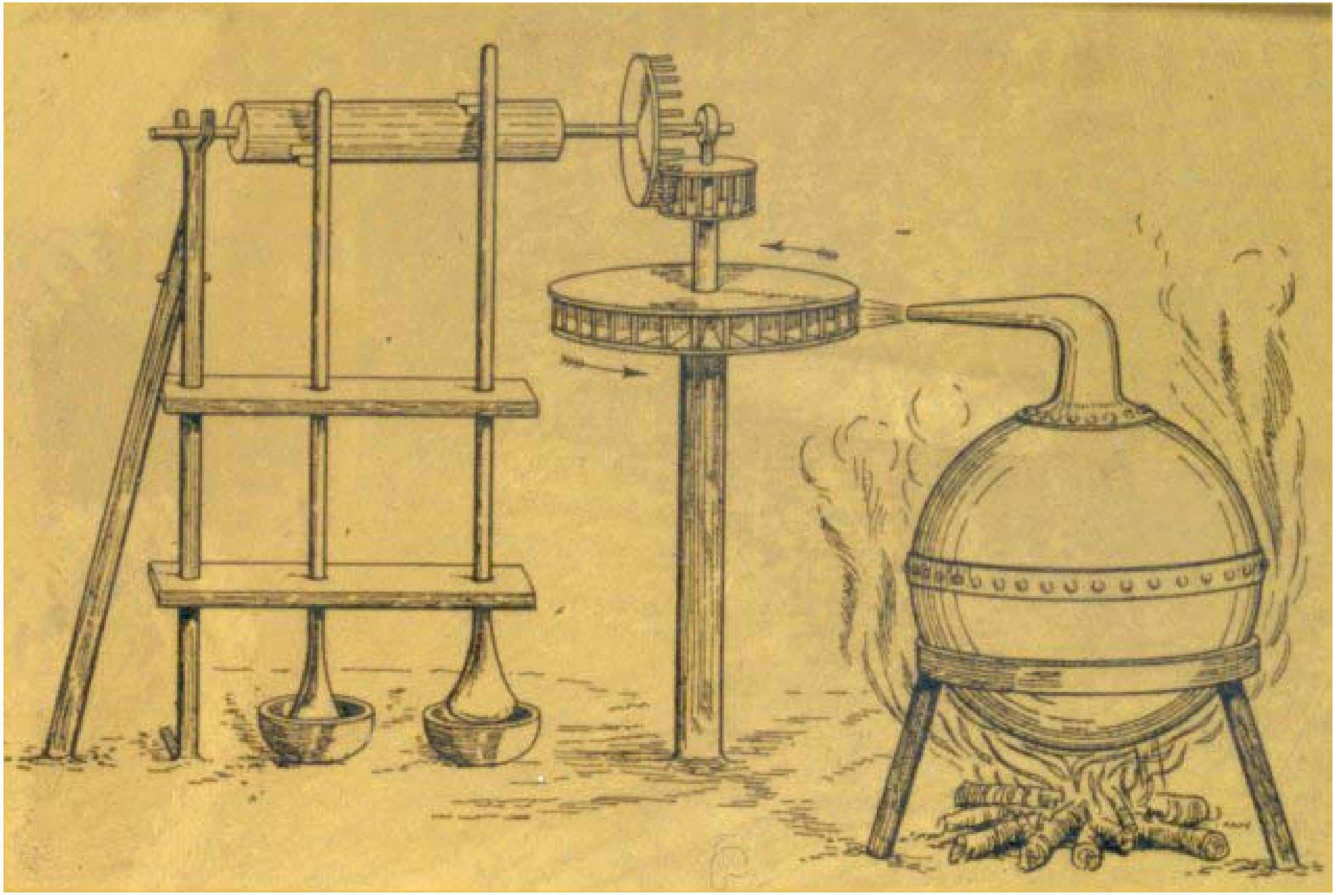


Hero's Turbine 120BC

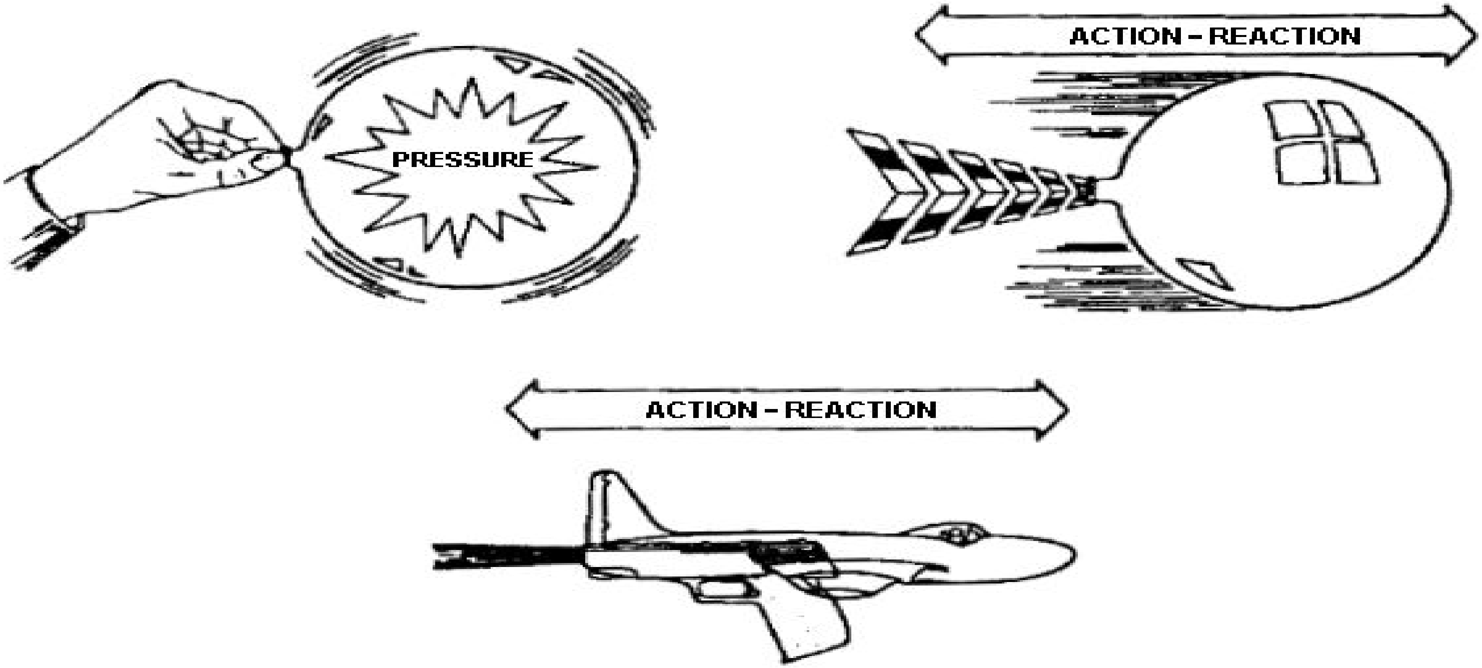


It is thought that Hero may have used this invention to open temple doors

Giovanni Branca's Idea 1629

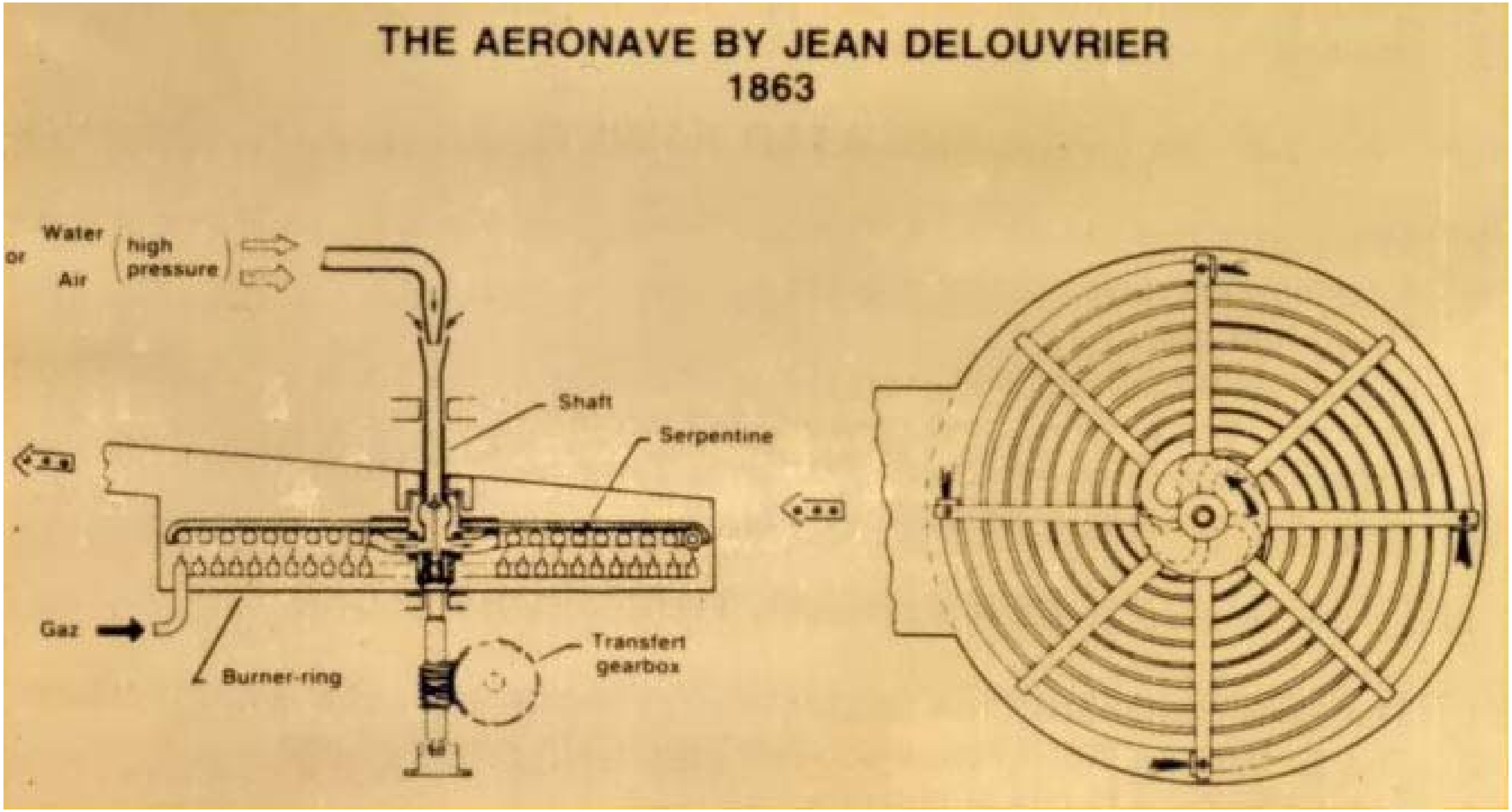


1690 Isaac Newton explained the principles behind the phenomenon. He came up with his third law of motion. This stated; 'Every action produces a reaction of the same magnitude in the opposite direction.'

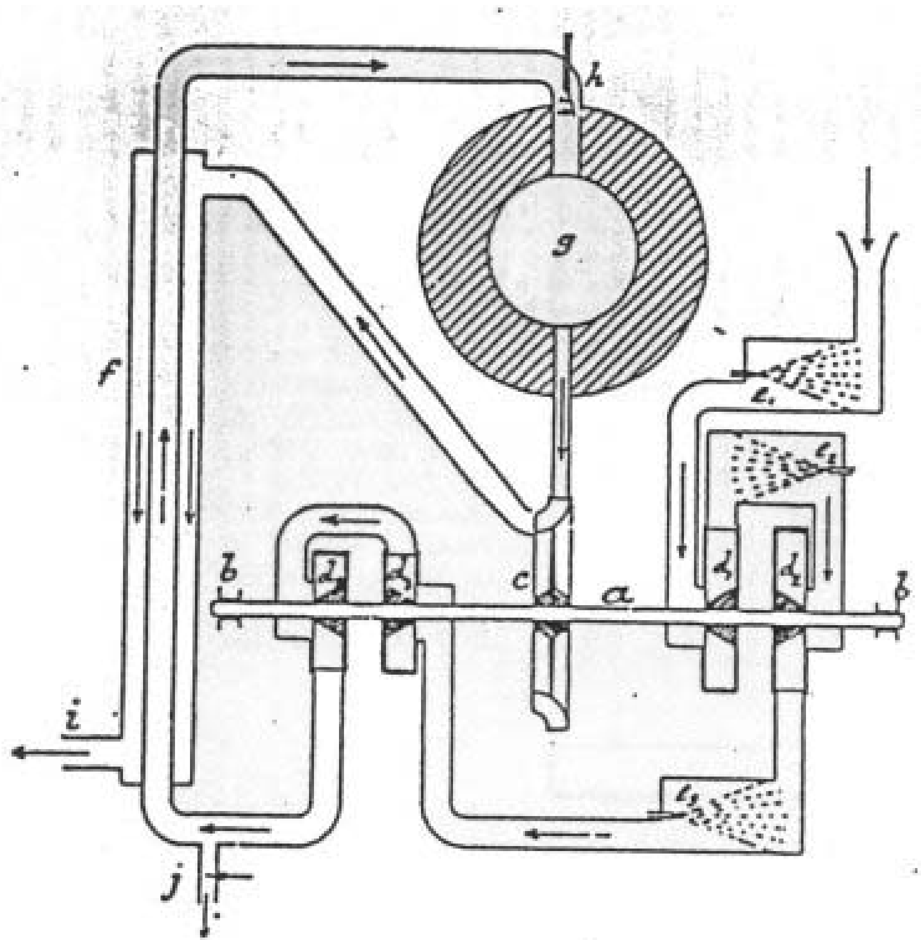


The Jet Propulsion Principle (Newton's Third Law of Motion)

Aeronave 1863

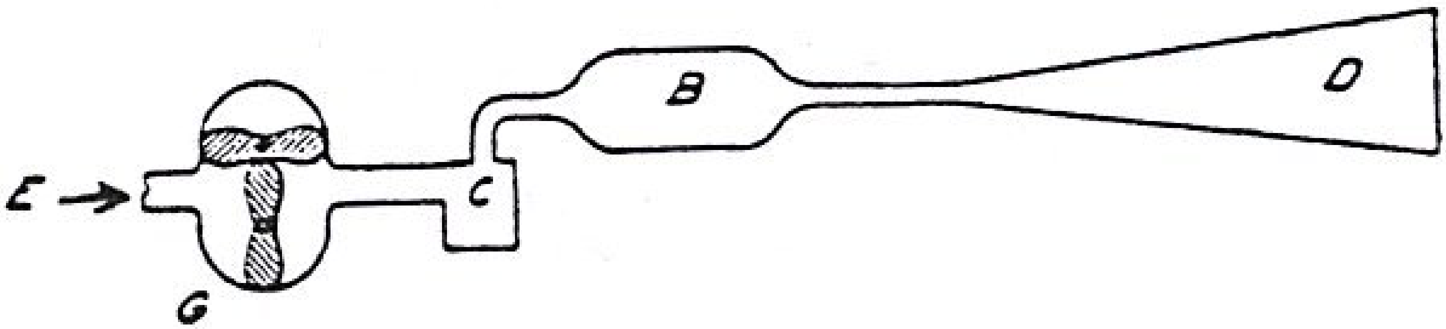


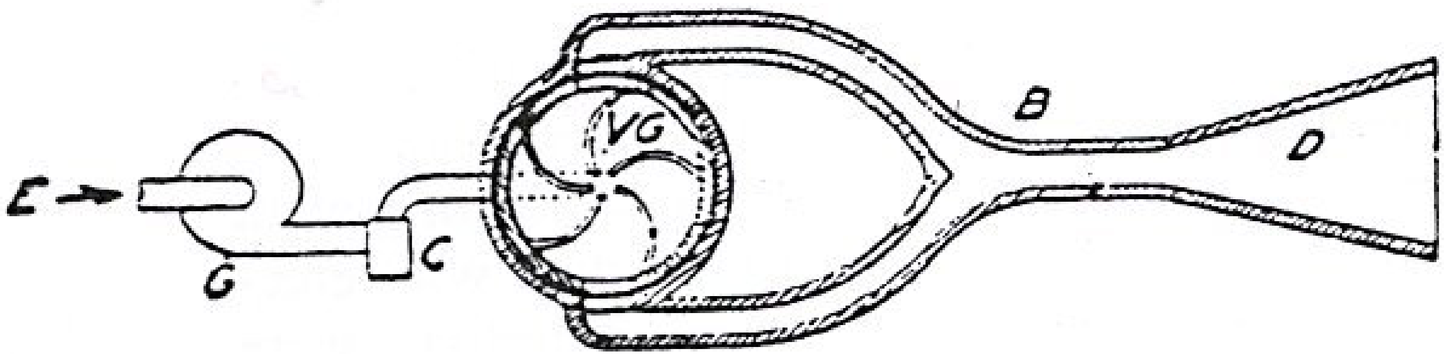
Elling’s Patent 1904



Elling's new concept, 1904

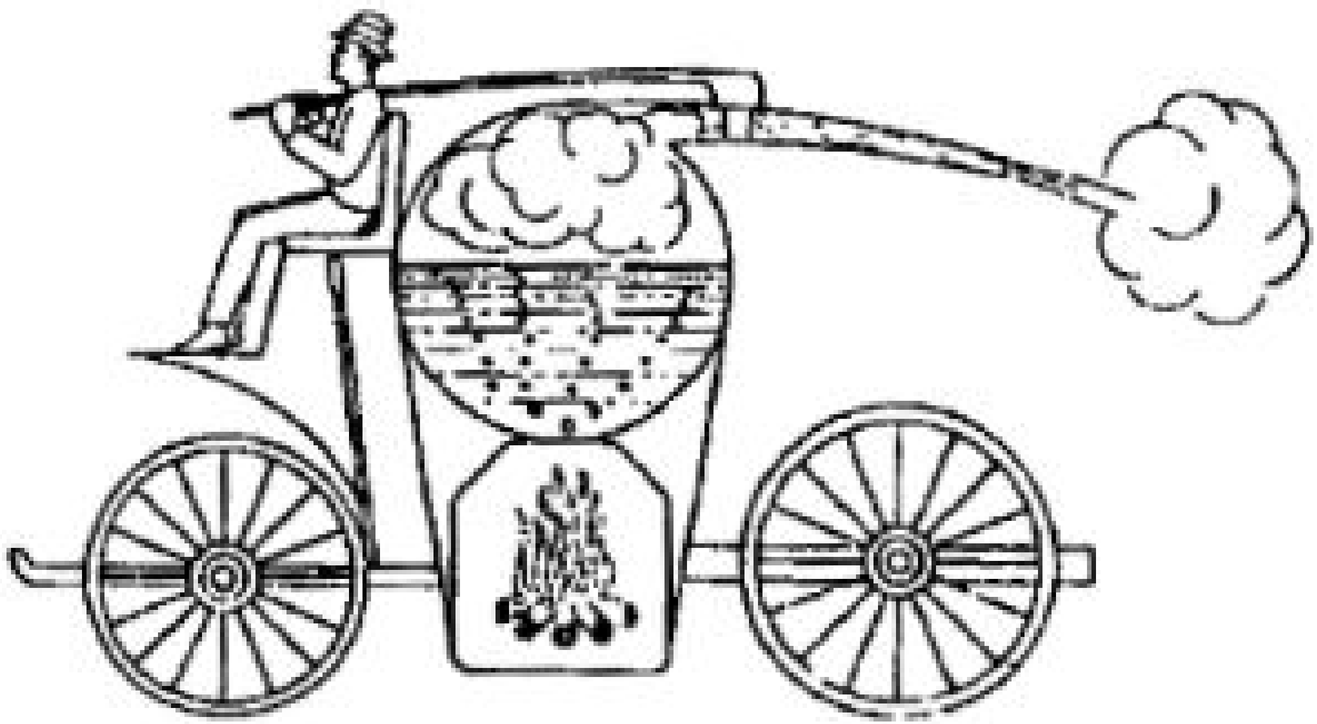
Marconnet's Patent 1909





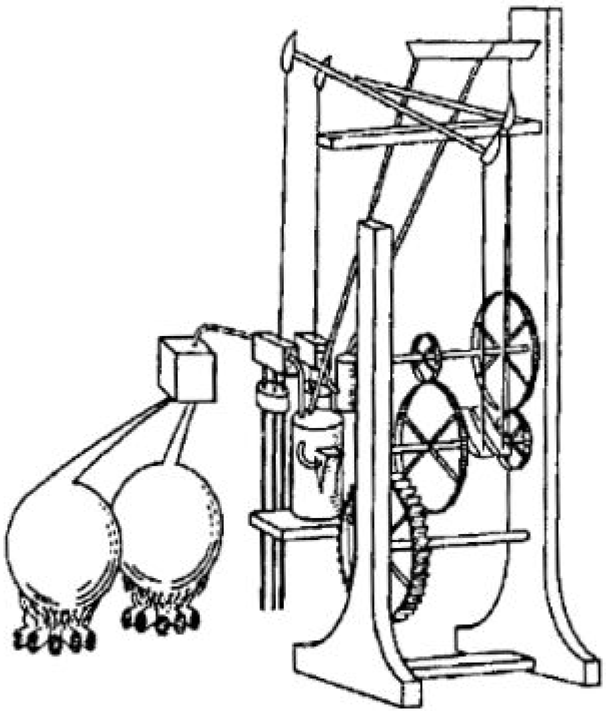
Newton Steam jet vehicle

The wagon had a boiler on it and there was a nozzle from the boiler directed rearwards. The nozzle ejected the steam and Newton hoped this would power the wagon forwards. However, due to lack of power from the steam, the wagon never moved.



Newton's Steam Wagon

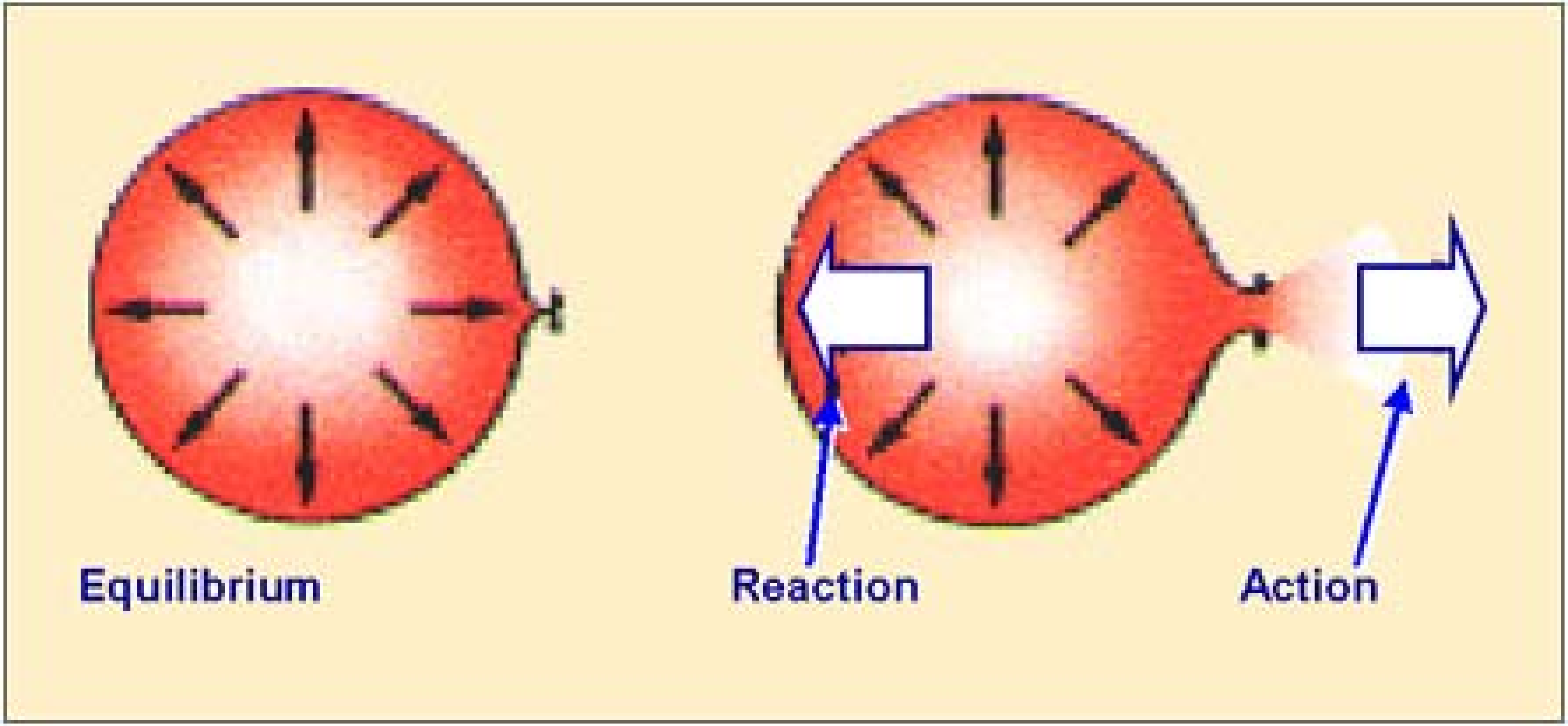
The first turbine jet ?



Barber's British Patent - 1791

In 1791, an Englishman by the name of John Barber patented the first design that incorporated the thermodynamic system used in modern gas turbine designs. The design contained the main elements of a modern engine, namely; compressor, combustion chamber and turbine. However, the turbine was fitted with a chain-driven reciprocating compressor. His intention was to use his design for jet propulsion:

How it works
Newtons 3rd Law



Equilibrium, Reaction and Action

Thrust = Mass x Velocity

Sir Frank Whittle and his 1st engine on test

Frank Whittle (Centre) and Stanley Hooker (Right)

Frank Whittle
A short history of the development of the jet engine

- Whilst at Cambridge, Frank Whittle formed a company called Power Jets, with the aim of taking his idea for the development of jet engines further, with the cooperation of two ex RAF officers, R.D. Williams and J.C.B. Tinling.
- The RAF agreed to let Frank remain at Cambridge for a further post graduate year, to continue working on his idea.

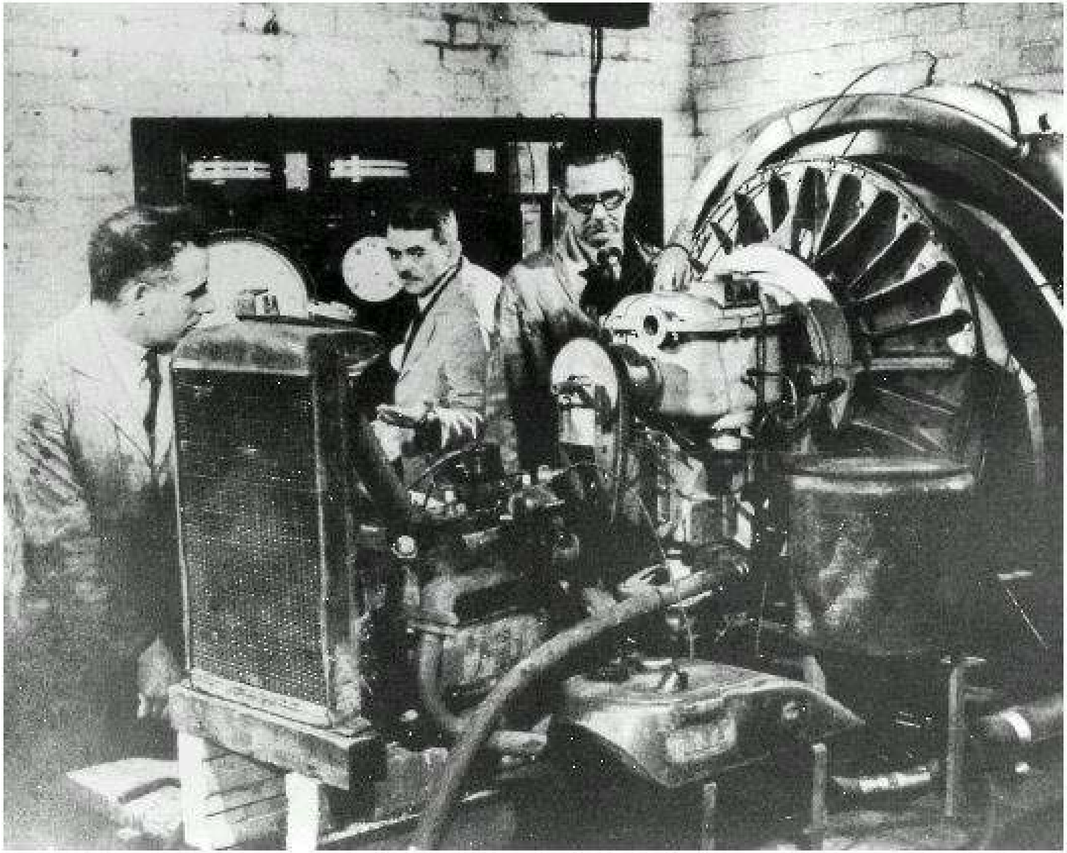
Frank Whittle

- There were many difficulties, including turbine blade failure, which was overcome by the development of a high nickel alloy by Mond Nickel, called Nimonic 60. Testing of the prototype engines (1937-41) was dominated by problems with combustion. Sir William Hawthorne, who was later to become the Head of the Engineering Department at Cambridge, helped to solve these.
- The first of Whittle's test jet engines took to the skies on 15 May 1941, powering an aircraft that had been specifically designed for the purpose: the Gloster E28/39.

Frank Whittle

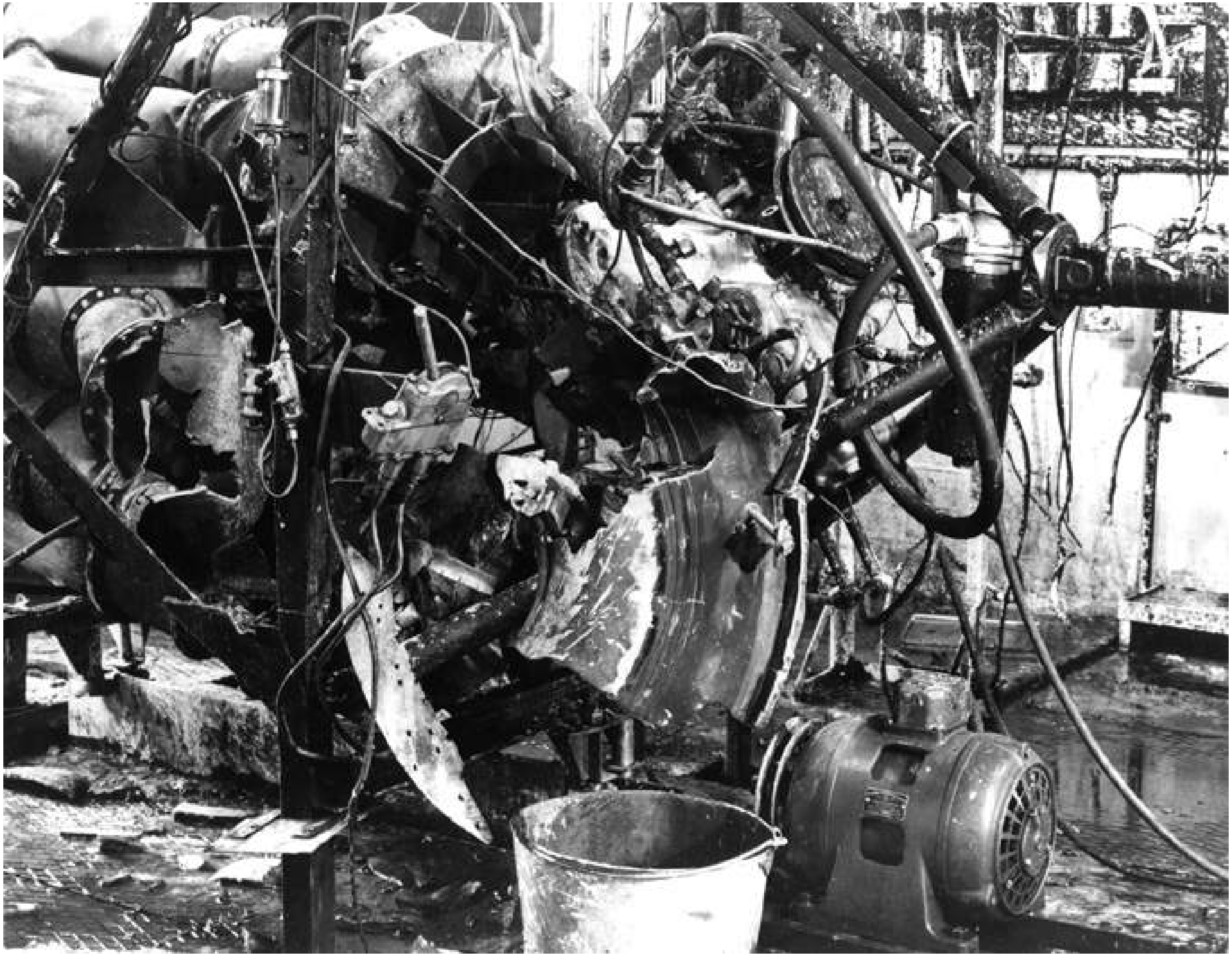
- This aircraft was conceived and built in only 15 months. Take-off for the test flight, with pilot Gerry Sayer at the controls, took place at RAF Cranwell at 7.45pm, and lasted 17 min, having achieved speeds of over 500mph. The plane used can now be seen at the Science Museum, where it has been on display since 1946.

Whittle W1 Engine



A reconstruction of work on the W1X engine at the disused foundry at Lutterworth. From the COI film "Wonder Jet".

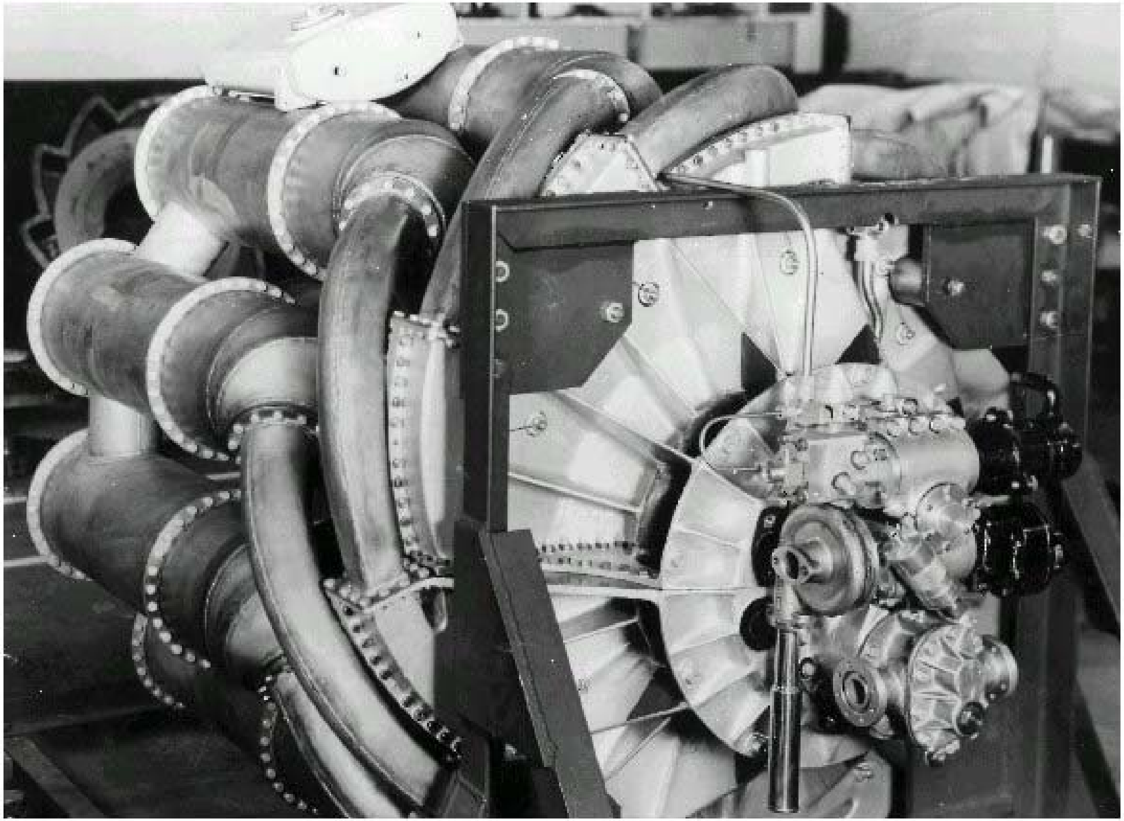
Whittle Engine Explosion



First Whittle jet in a plane Gloster E28/39

Whittle's Flight Engine

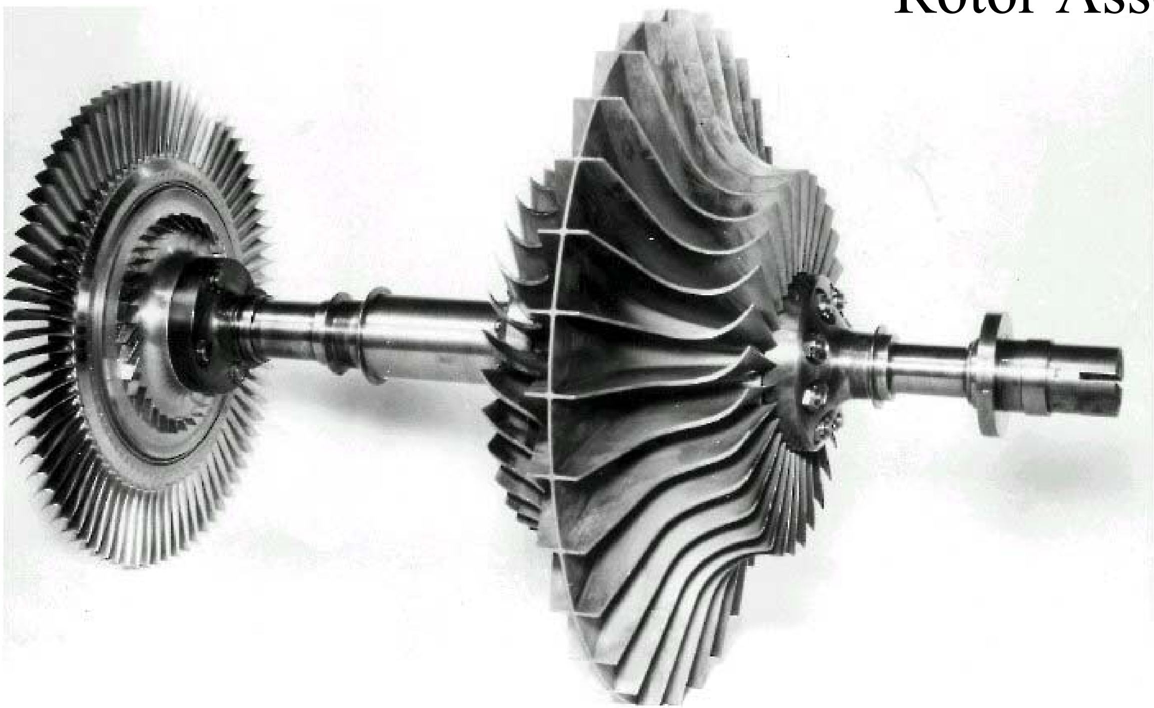
View from Gearcase End



View from Gearcase End of the W1, the First Flight Engine.

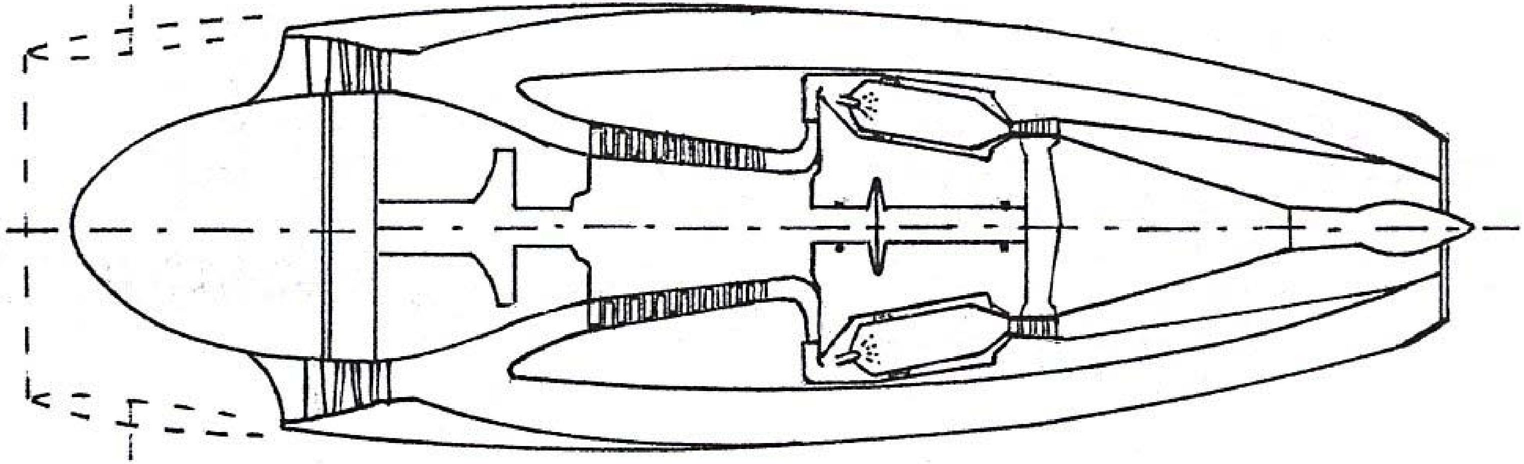
Whittle's Rotor: Centrifugal Compressor and Axial Turbine

Rotor Assembly



Rotor Assembly of the W1 Engine

Whittle's Bypass Engine



Gloster E28/39

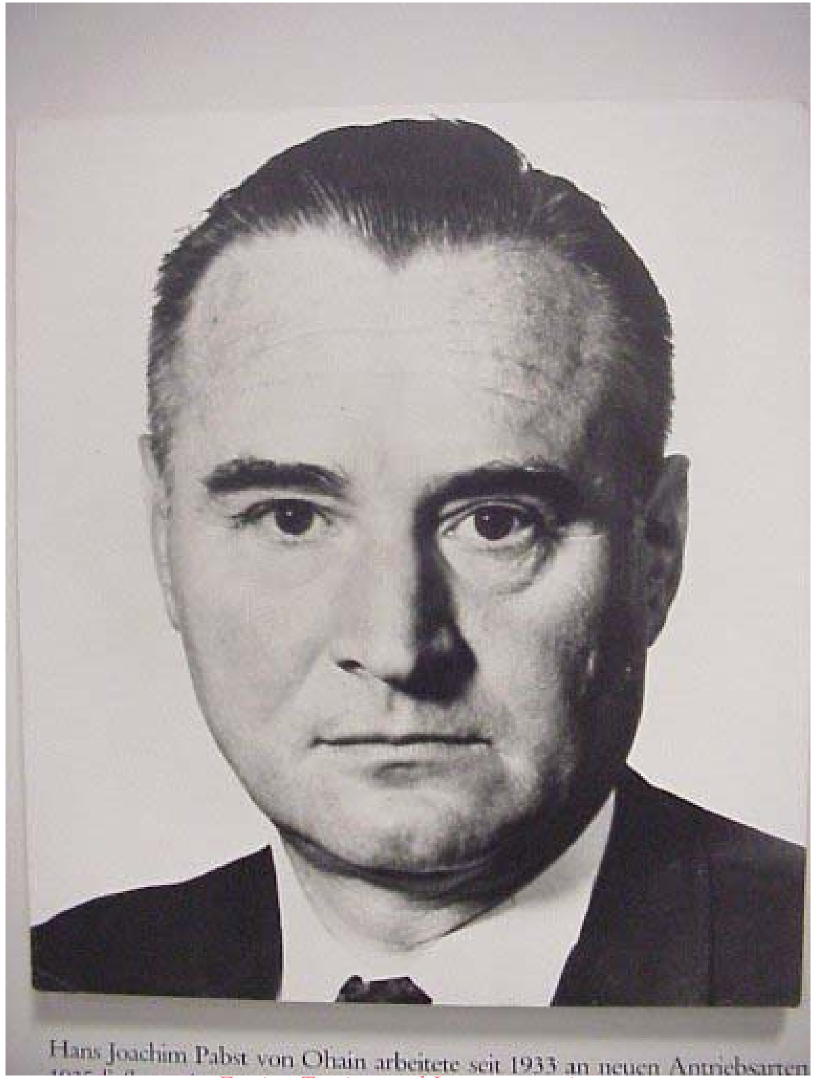
Gloster Experimental Aeroplane E28/39 at Takeoff.
(Royal Aerospace Establishment, Crown Copyright.)

Who invented the jet engine ?

- Key players:
  - Frank Whittle
  - Ernst Heinkel
  - Werner von Braun
  - Hans van O'Hain
  - Hugo Junkers

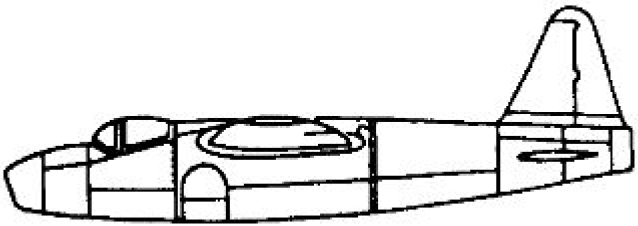
They all have claims

Hans von O'Hain



Hans von O'Hain

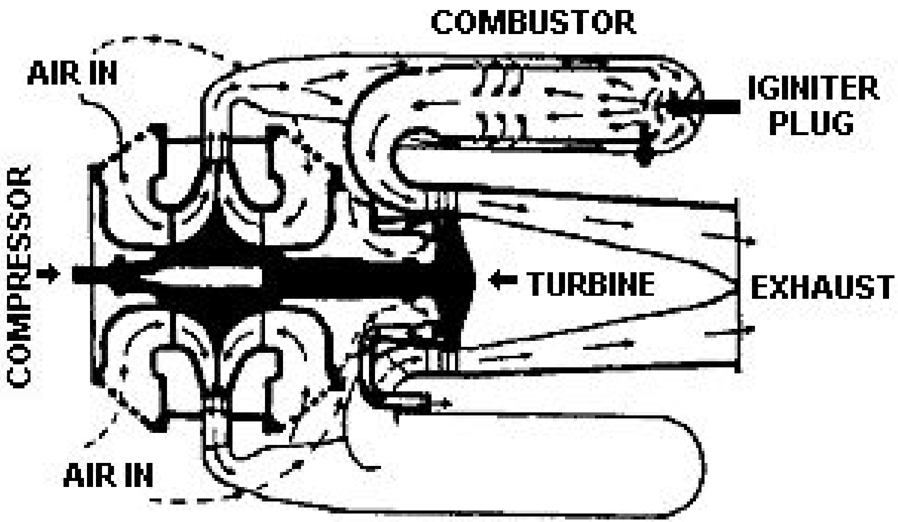
- German student by the name of Hans von O'Hain submitted his patent in 1935 for a petrol-fuelled jet engine. He was unaware of Whittle's developments across the Channel.
- The first bench test of a liquid-fuelled jet engine took place in England in 1937 but the jet engine had to wait till August 1939 to be tested on an aircraft. The test took place in Germany on a Heinkel He 178 fighter, ironically just weeks before the outbreak of World War 2.



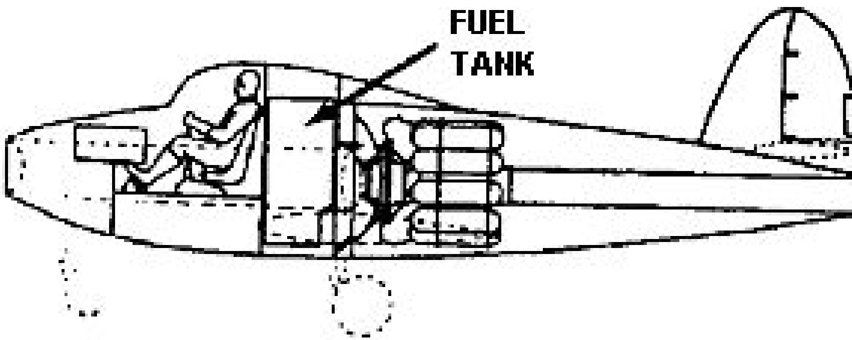
The German Heinkel HE-178

The theory

- Both Whittle and von O'Hain wanted to find a more economical way to use the potential energy in the air to power aircraft, than the traditional propeller. They both realised that Newton's third law of action and reaction could still be used. The law states: if a body *A* exerts a force on a second body *B*, body *B* will exert a force of the same magnitude on body *A* but in the opposite direction. Applied to the situation of a propeller, air going through the propeller will exert a backwards force on the propeller, causing it to move forward through the air. The problem is that the propeller can only accelerate a large mass of air over a short distance, which is uneconomical. The jet engine is capable of accelerating a small mass of air over a large distance. They realised that a combustion reaction of the air with a fuel source could convert chemical energy into massive amounts of kinetic energy.



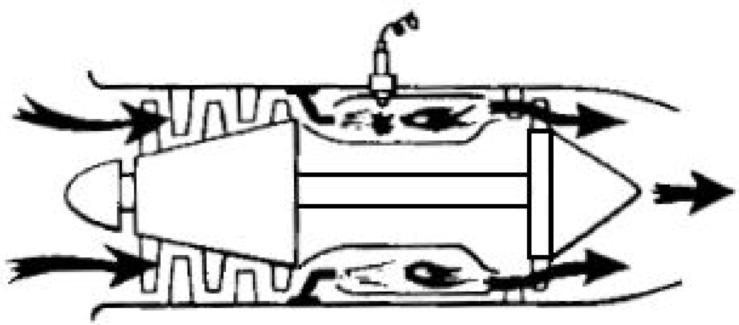
Whittle's Reverse-Flow Combustion Chamber



Fuselage Arrangement of the E28/39 Experimental

The Brayton cycle

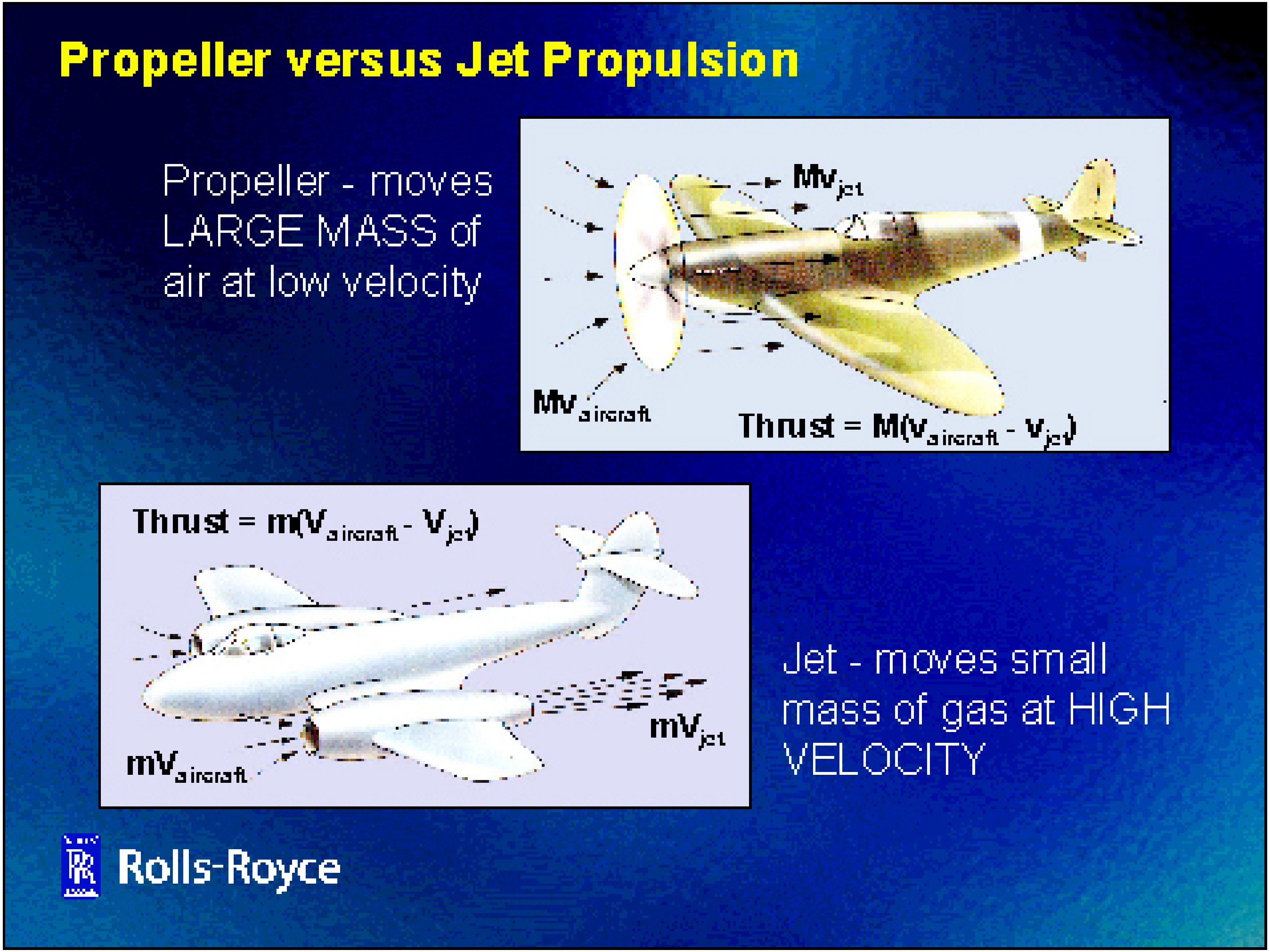
The Brayton Cycle is the thermodynamic system that shows how air can be placed under pressure within the engine as well, causing the reaction force to be greater, allowing the engine to move forward quicker for the same amount of harnessed potential energy.



The Brayton Cycle

How it works

- The modern jet engine contains three main components; the **compressor**, the **combustion chamber** and the **turbine**. The **compressor** consists of a series of blades attached to wheels that decrease in radius and get closer together. The front blade system draws air into the engine. As the air is pulled back through the engine and the wheels get smaller, the air is pushed into a smaller space and therefore its pressure increases, increasing the potential energy contained in the air. When it reaches the **combustion chamber**, it is under massive pressure. In the chamber, a nozzle squirts fuel into the air where it mixes and is then ignited by a spark. The explosion causes the exhaust gases to be expelled through the back of the engine (exhaust) through the **turbine**. The turbine is another system of blades attached to a wheel. It is connected to the compressor by way of an axel, providing the turning power for the compressor to operate.

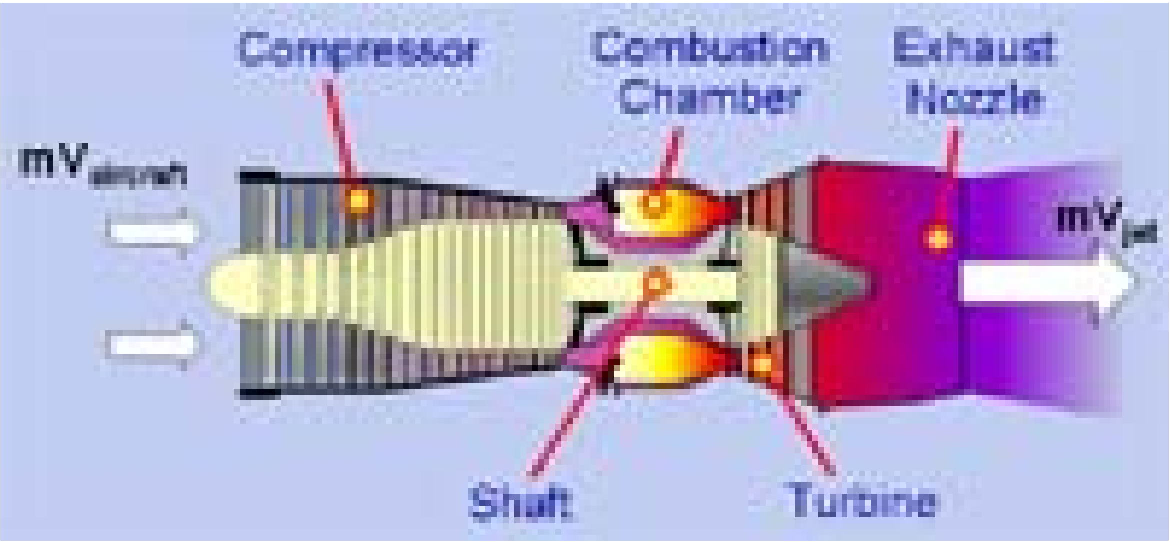

Propeller versus Jet Propulsion
Propeller - moves LARGE MASS of air at low velocity
Mv_jet
Mv_aircraft
Thrust = M(v_aircraft - v_jet)
Thrust = m(V_aircraft - V_jet)
mV_aircraft
mV_jet
Jet - moves small mass of gas at HIGH VELOCITY
Rolls-Royce

Propeller versus jet propulsion

- Aircraft propellers and jet engines do not store their own supply of air like the balloon. Instead, they have a steady supply of air entering the front. The thrust is achieved by accelerating this gas, so that it leaves the rear faster than it arrives at the front.
- The amount of thrust achieved is equal to the mass of air multiplied by the change in velocity. A propeller engine moves a large mass of air at low speed: thrust = $M(v_{aircraft} - v_{jet})$, whilst a gas turbine moves a smaller mass of air at a greater speed: thrust = $m(V_{aircraft} - V_{jet})$.

Jet engine~ thrust development

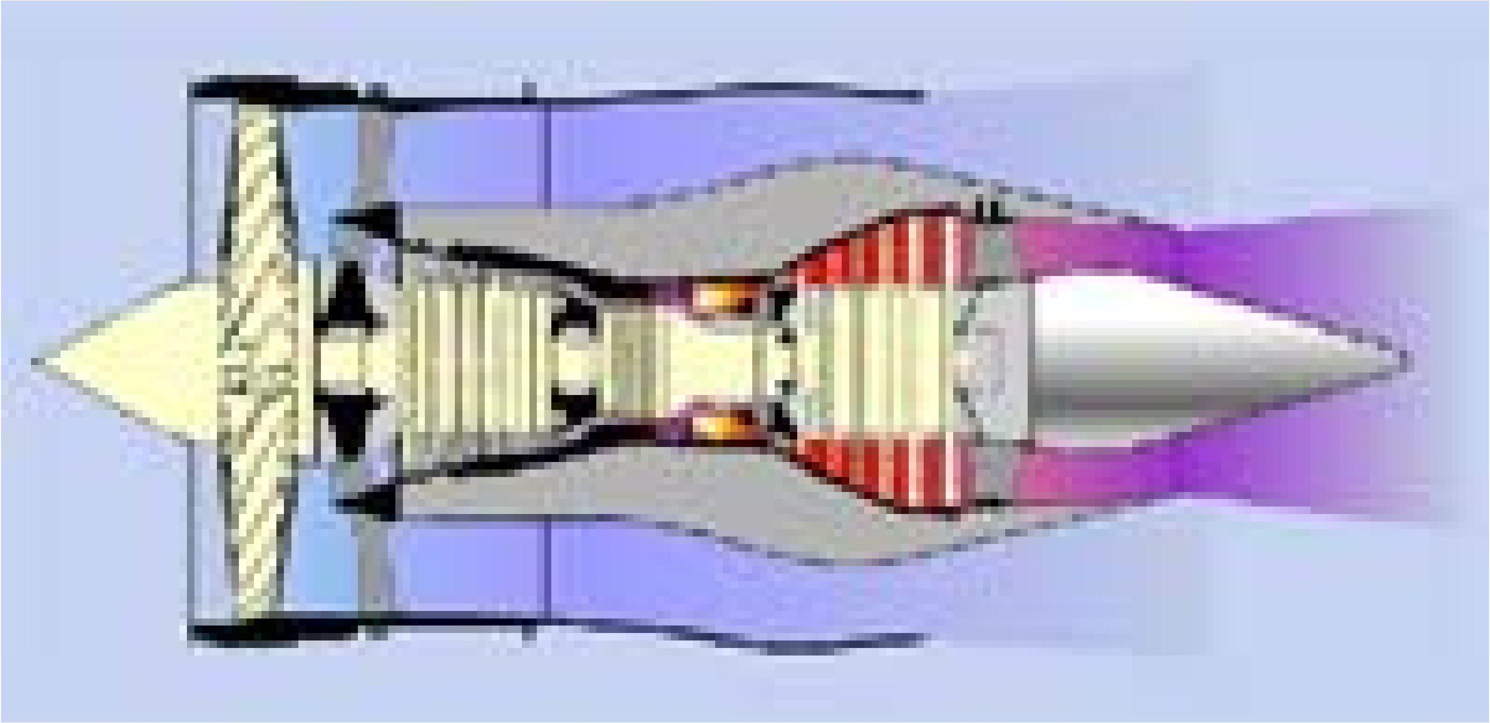
- So how is this achieved? A jet engine mechanically compresses the air it receives through a self driven compressor, prior to the combustion stage. The expanding exhaust gases drive a turbine which drives the compressor through the shaft. These are then accelerated through the exhaust nozzle to produce thrust.



Different jet engine types

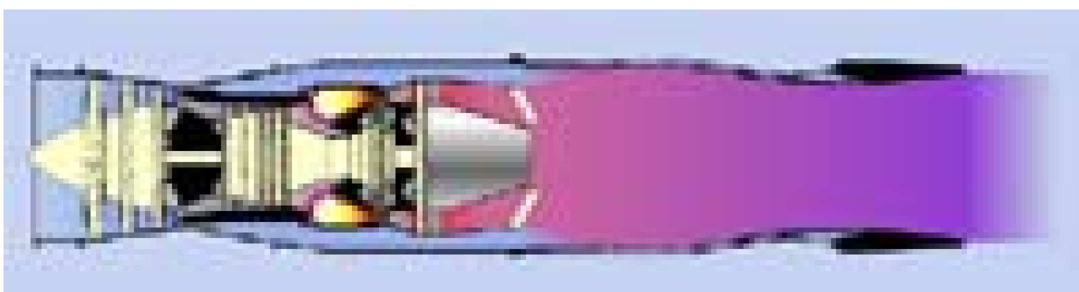
- The turbojet. In this engine, all the air passes through the compressor, combustor and turbines. This type of engine is very powerful, but it is also very noisy and inefficient. Modern civil and military aircraft therefore use a variation on the turbojet, called the turbofan, or bypass engine. A large fan at the front of the engine feeds some air into the compressor, where it is combusted, whilst the rest is ducted around the outside of the engine and re-mixed with the exhaust gases at exit.

Trent



Reheat

- On the EJ200 engine, the thrust can be increased from 13,000 lbf without reheat to around 20,000 lbf with reheat. However, the corresponding fuel consumption more than doubles, so this thrust boost is only used briefly during critical manoeuvres such as take-off and in combat.



Fighter Aircraft

- The first operational jet fighter was the American Bell Aircomet, which made its maiden flight in October 1942, followed by the UK's Gloster Meteor fighter aircraft in March 1943.
- The Meteors, with a top speed of 480 mph were used to great effect in the Second World War to knock the VI flying bombs out of the sky, using their wing tips! A total of 3875 Meteors were built between 1943 and 1954.

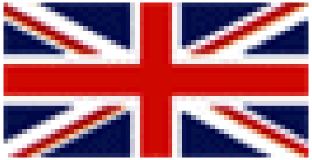
The first jet airliner, the Comet (shown below), was launched in Britain in 1949.

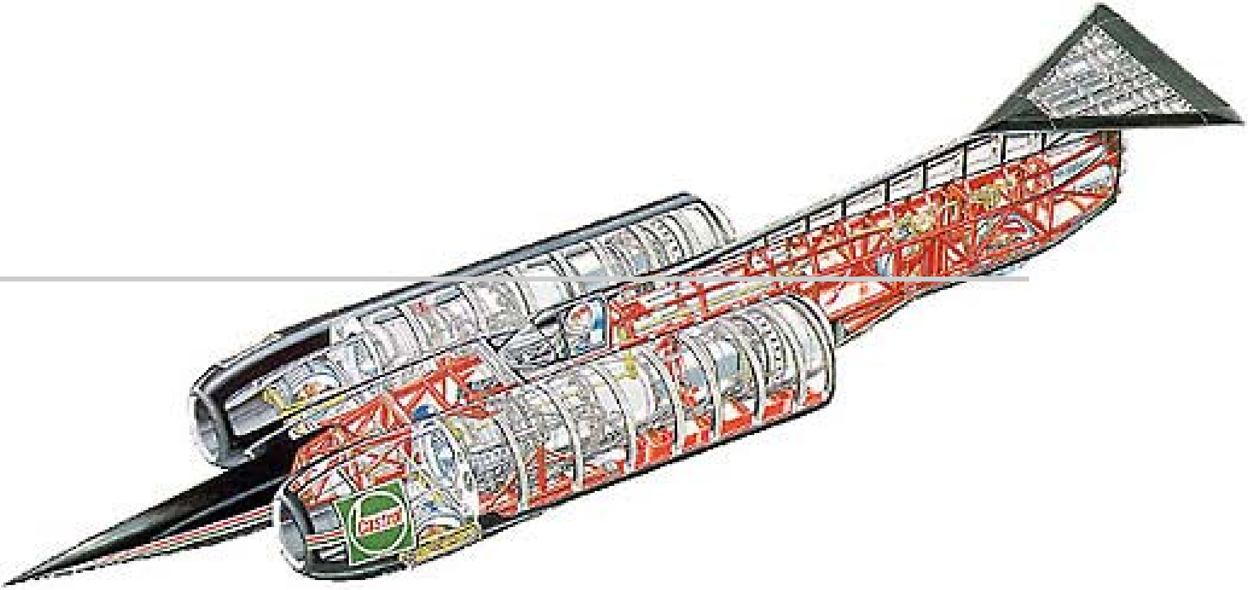
Improvements in design

- The first Whittle engines used centrifugal flow compressors for both military and civilian applications, but today, jet engines use axial compressors. These are more difficult to make, and rely on good aerodynamic design to work. The axial flow compressor is essentially a turbine in reverse, with air flowing between alternate rows of stationary (stator) and rotating (rotor) blades, each having an aerofoil shape.

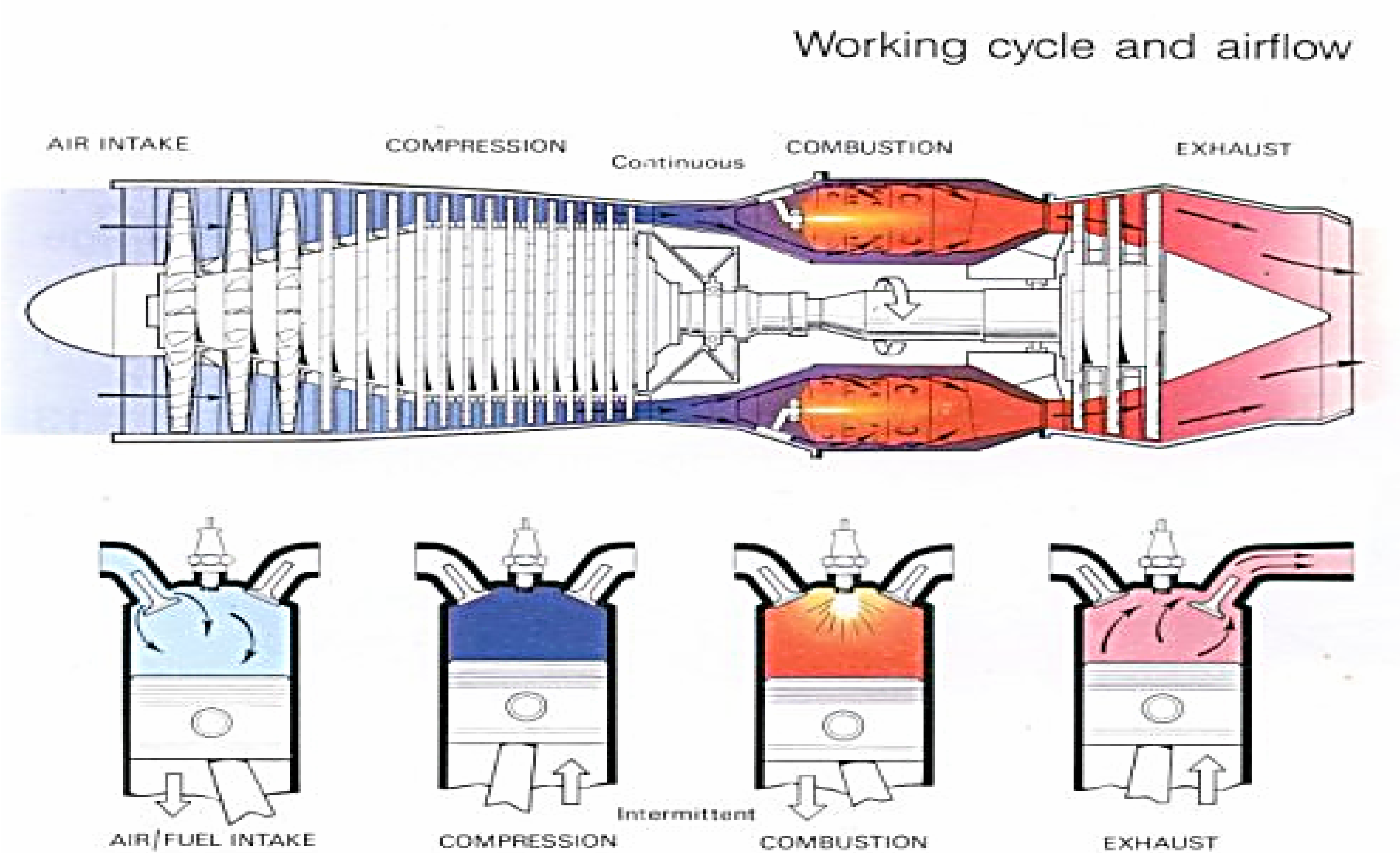
Other applications

Thrust cut away 100,000 BHP !



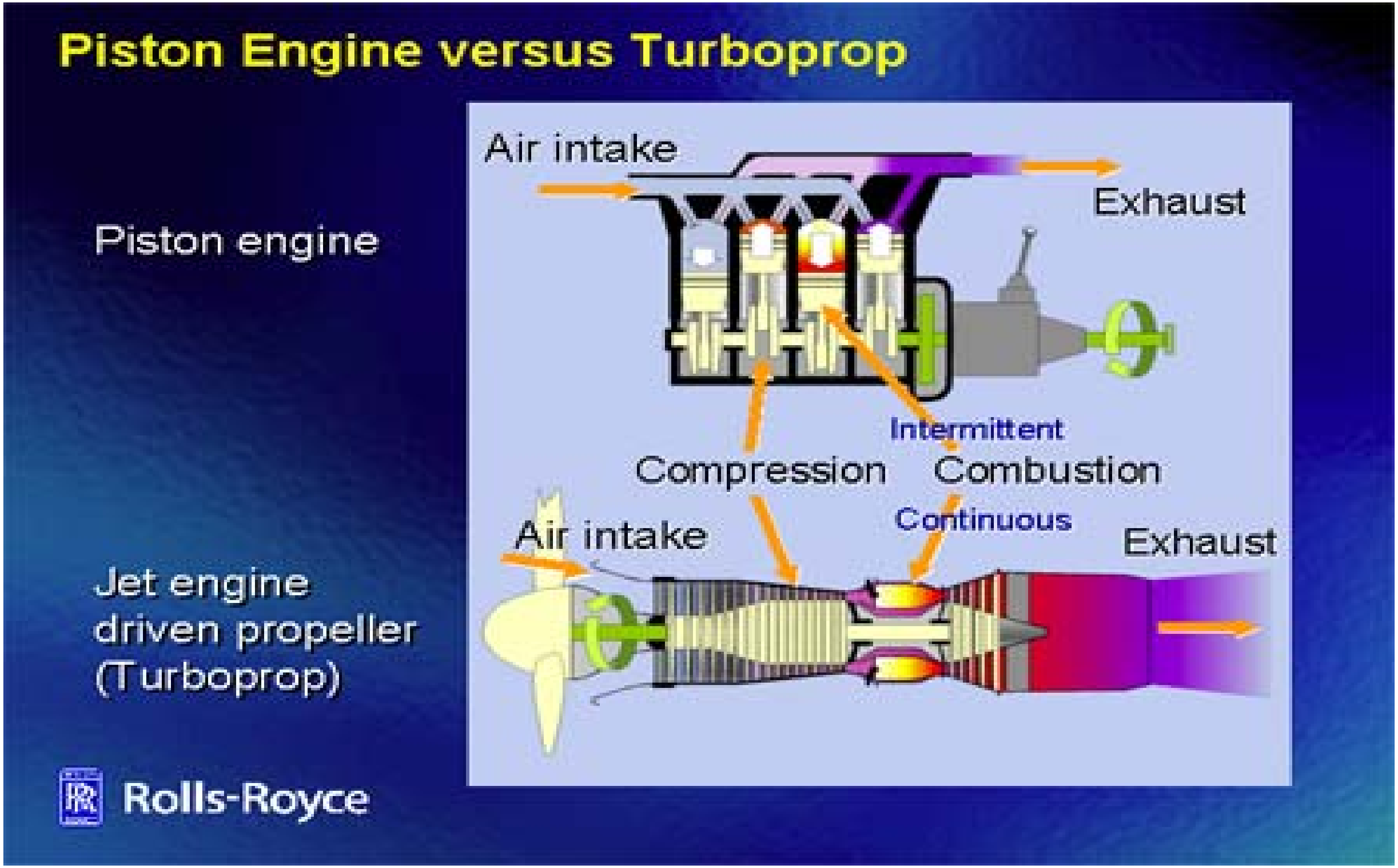


Gas Turbine and IC Engine Compared

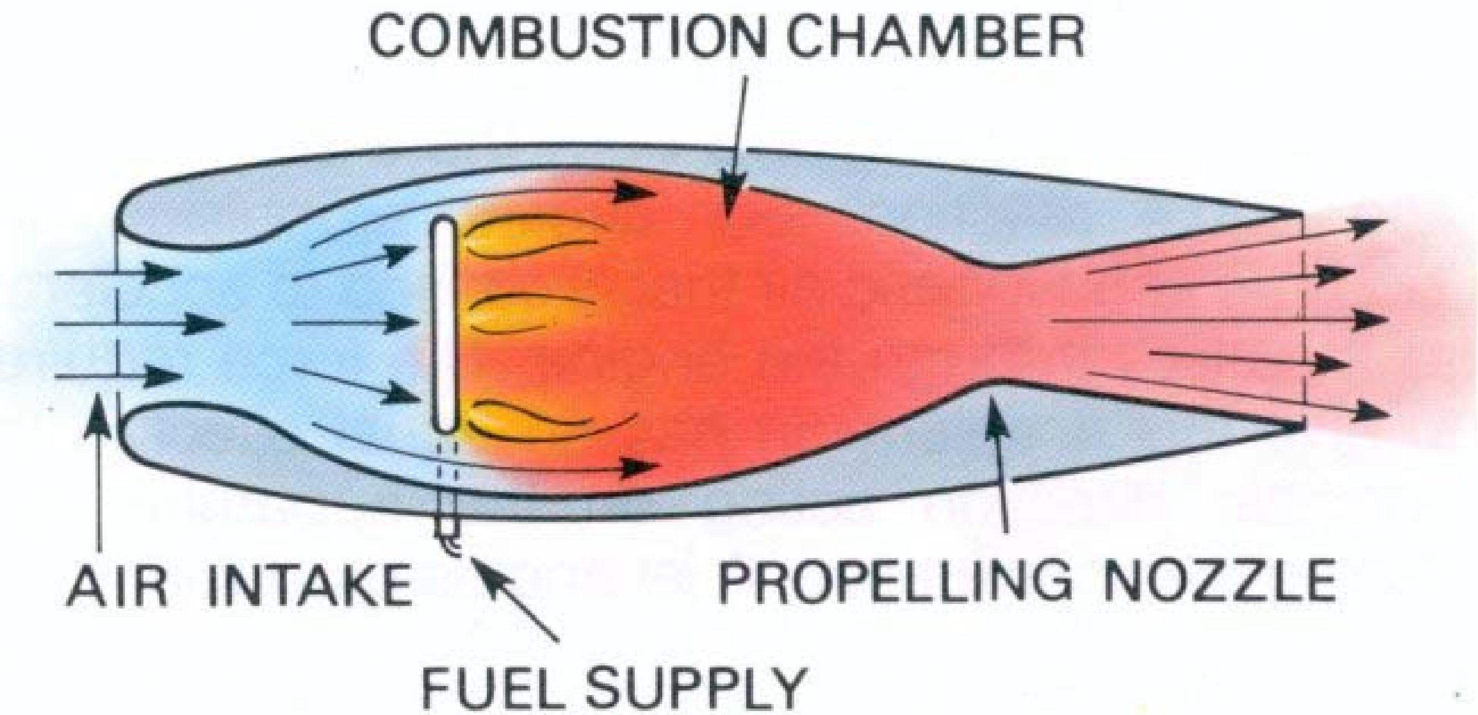


A comparison between the working cycle of a turbo-jet engine and a piston engine.

A neat comparison

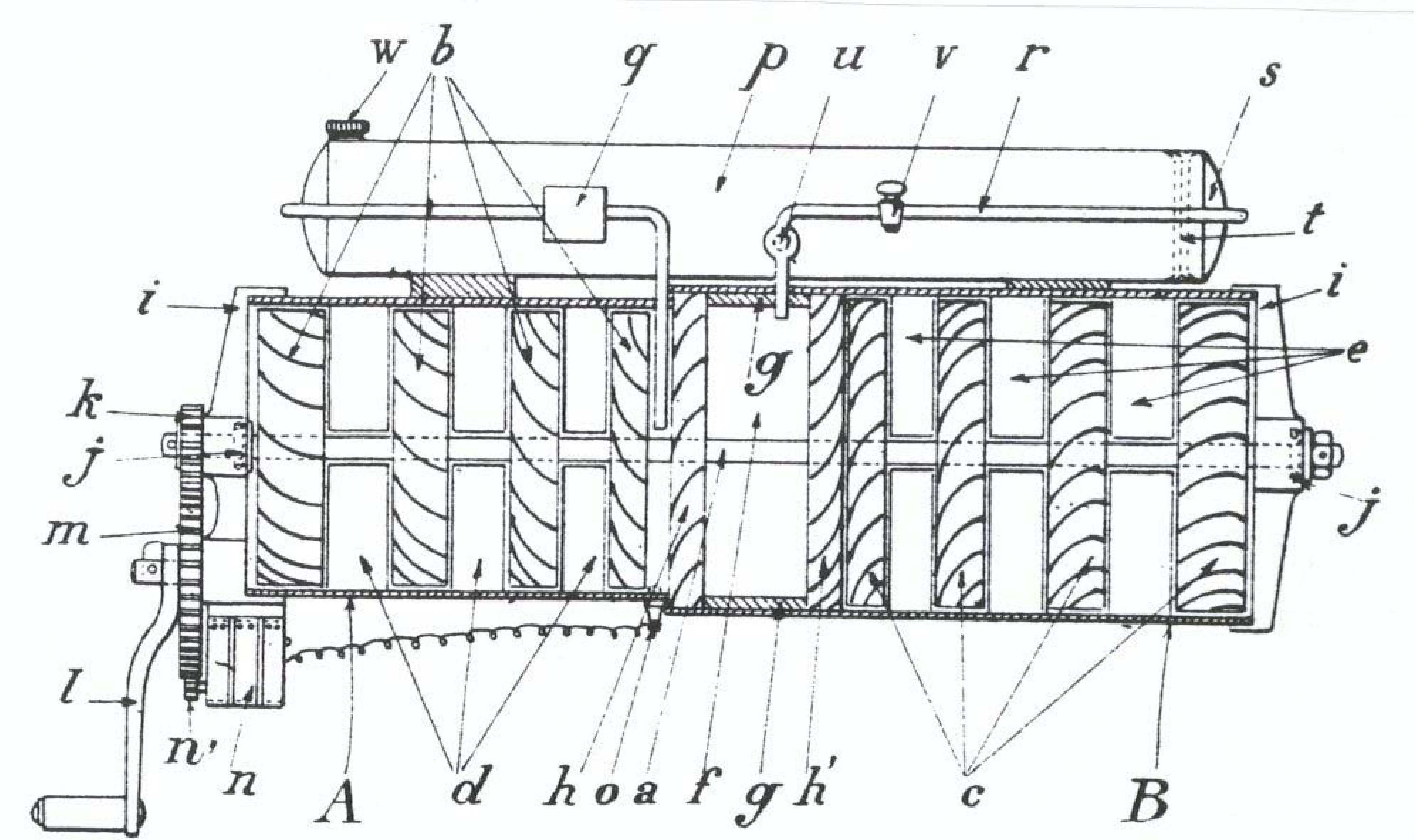


Rene Lorin's 1913 Ramjet Patent

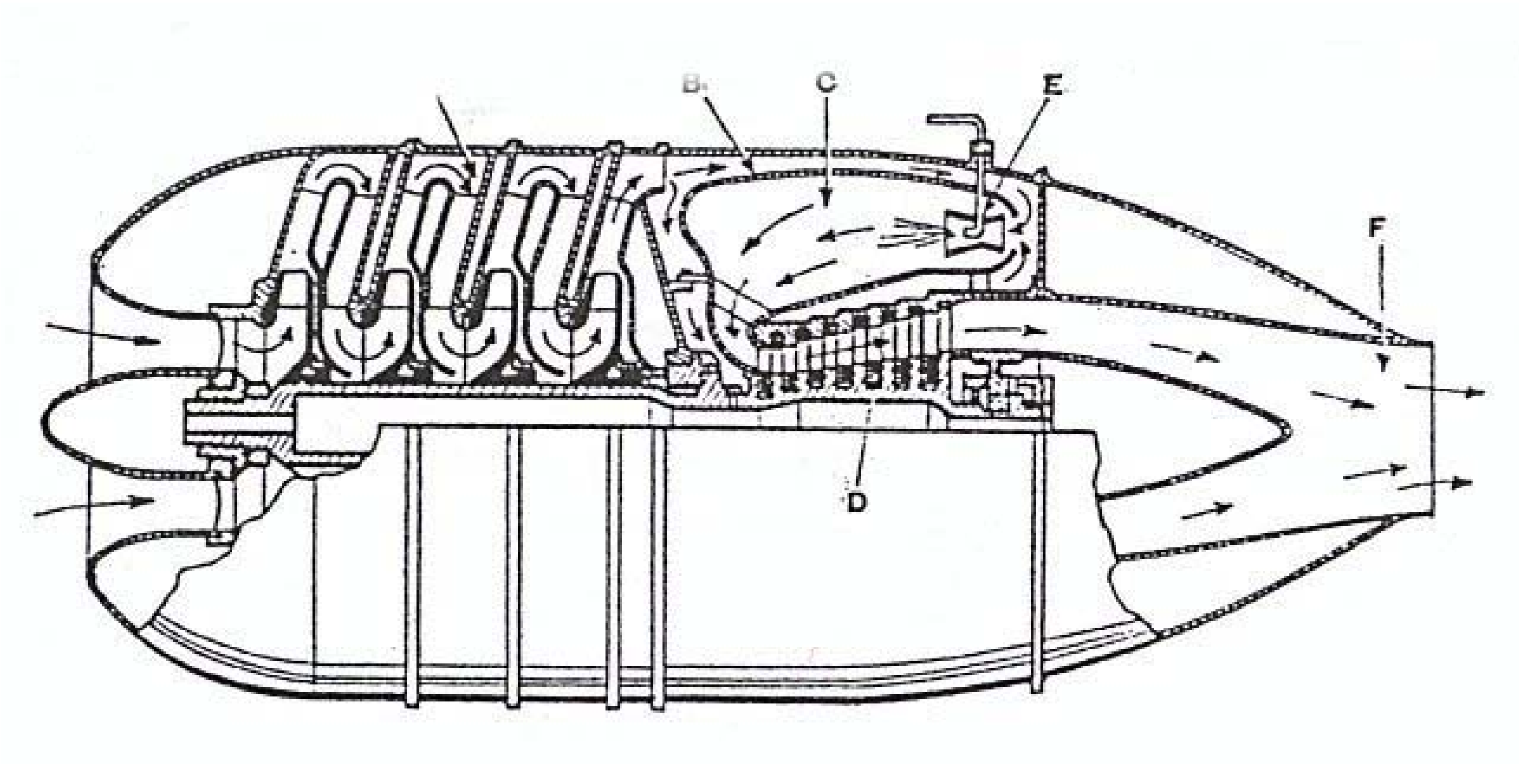


Lorin's jet engine.

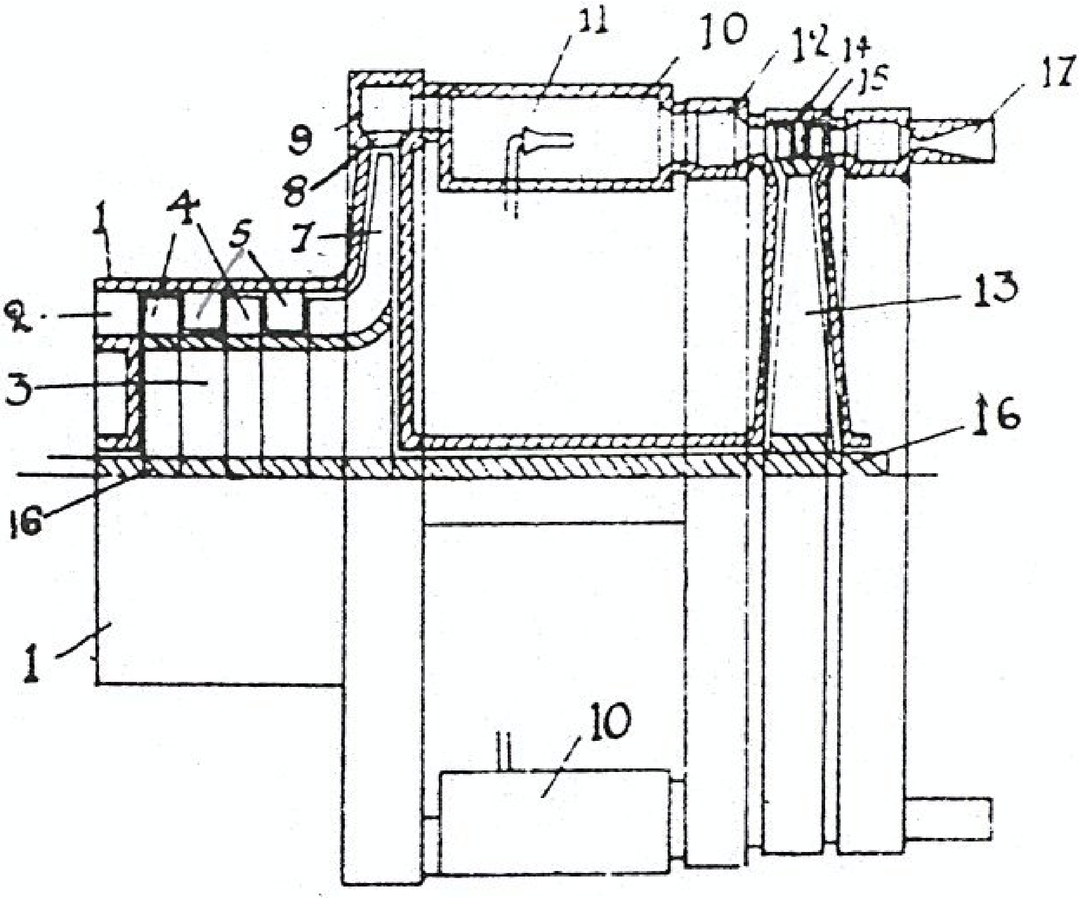
Maxime Guillaume Patent, Paris 1921



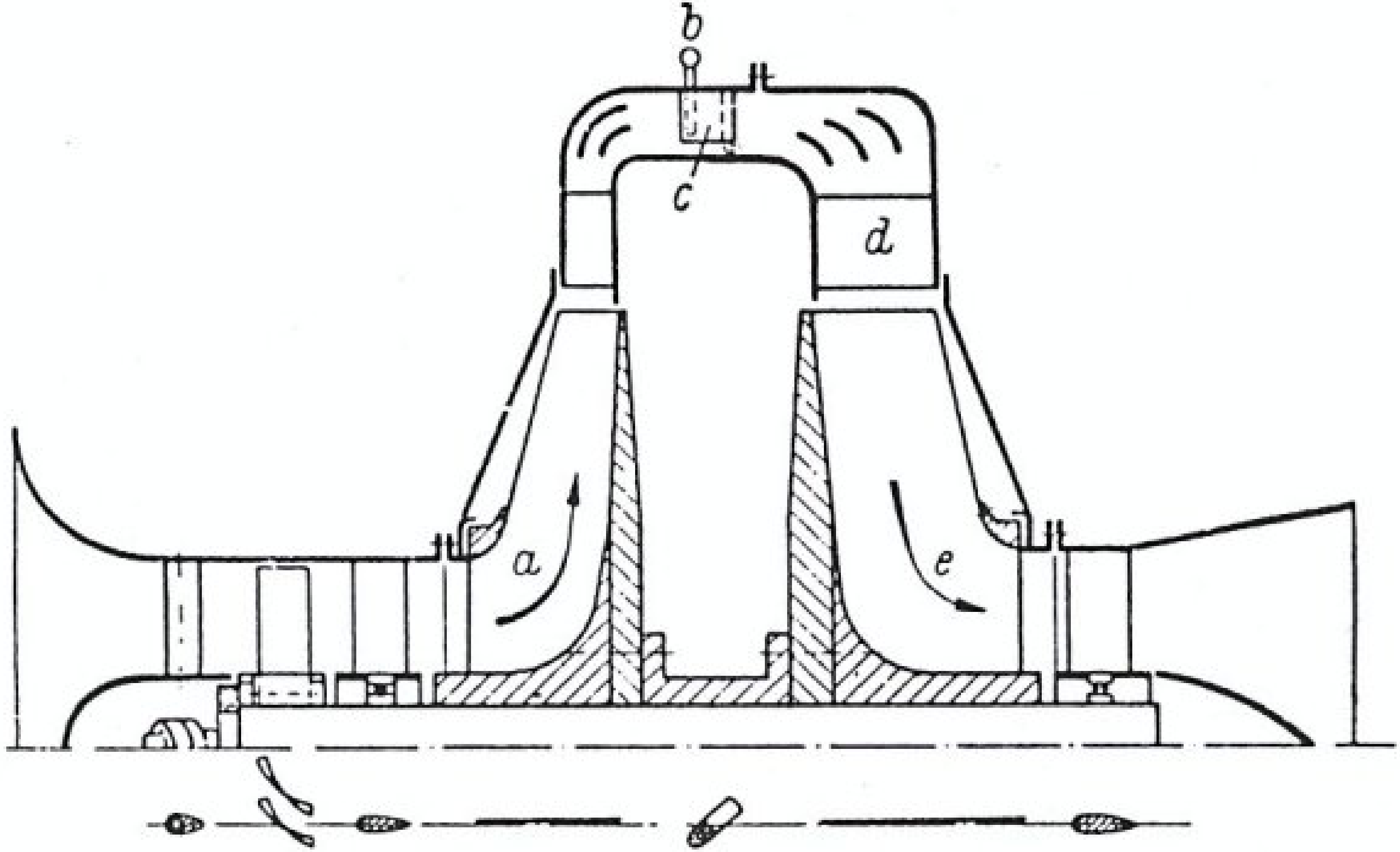
Milo’s Swedish Patent 1933



Whittle's 1930 Jet Engine Patent

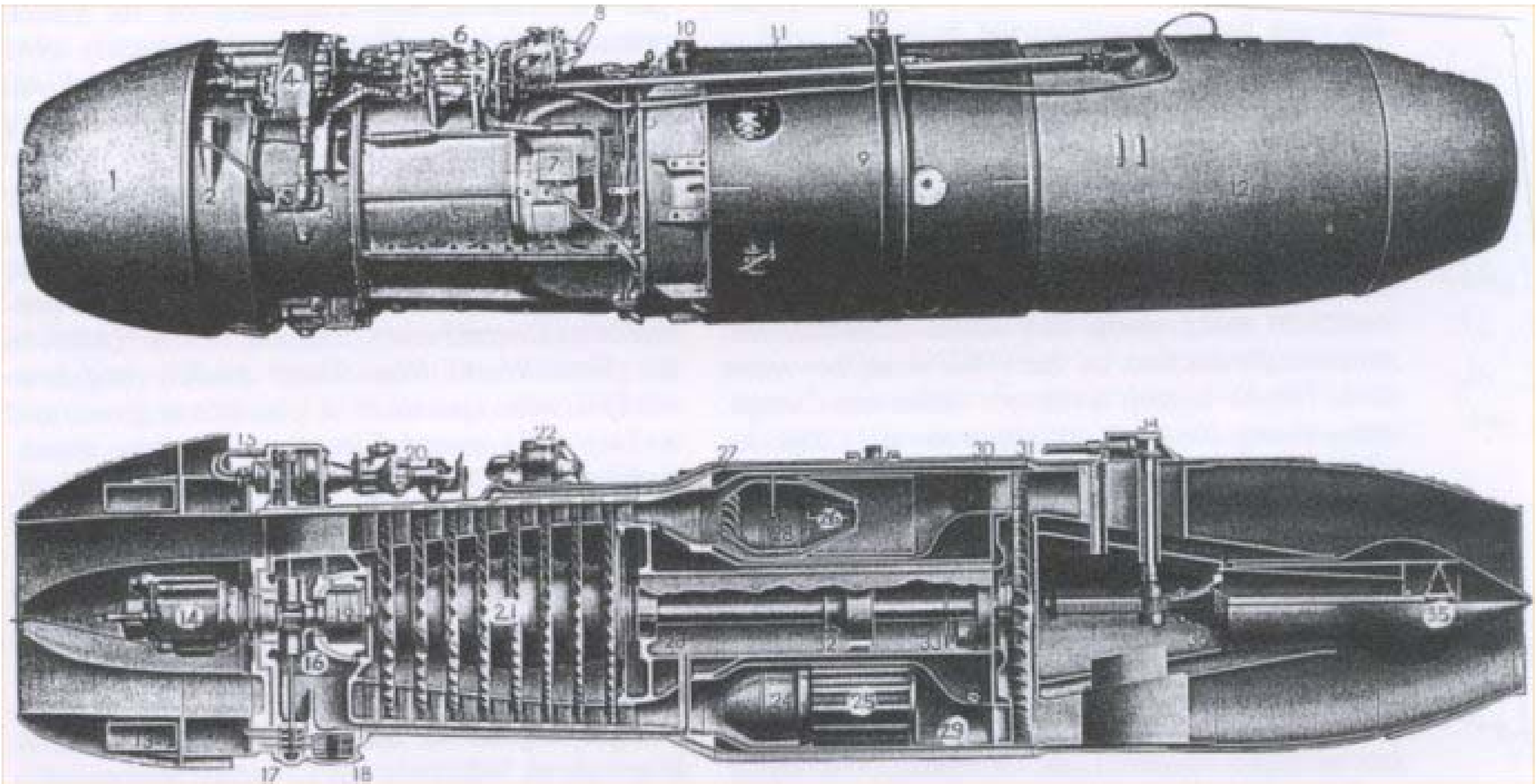


Von O'Hain's German Patent 1935



Von O'Hain's Engine

Jumo Engine From Me262



ME 262 Aircraft

Jumo Engine On ME 262

The First British Axial Flow Engine

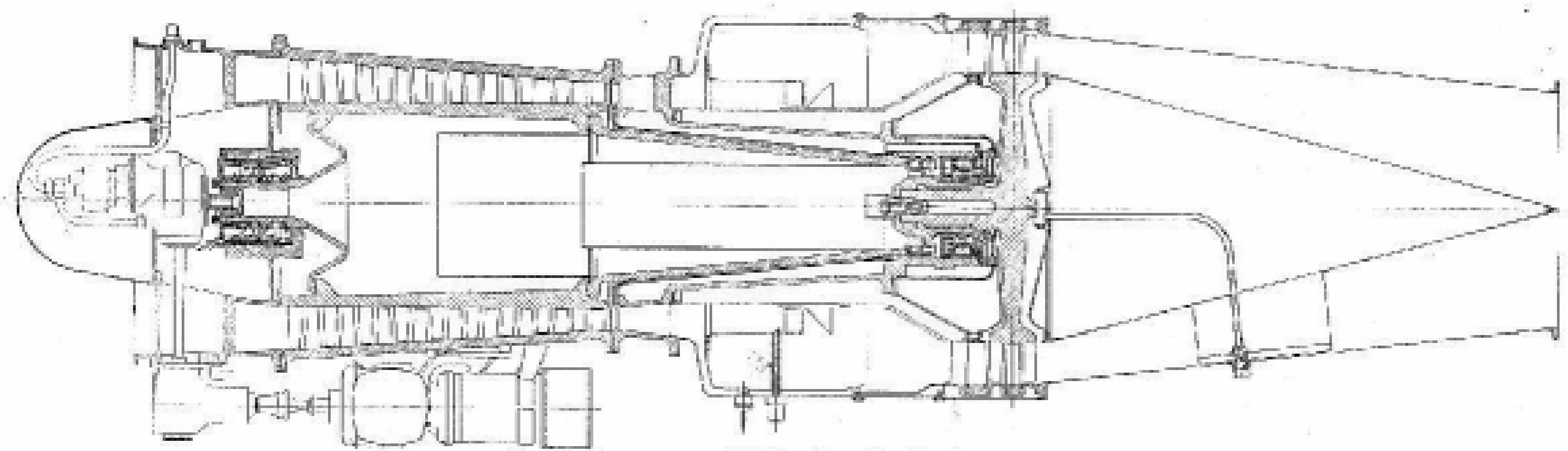
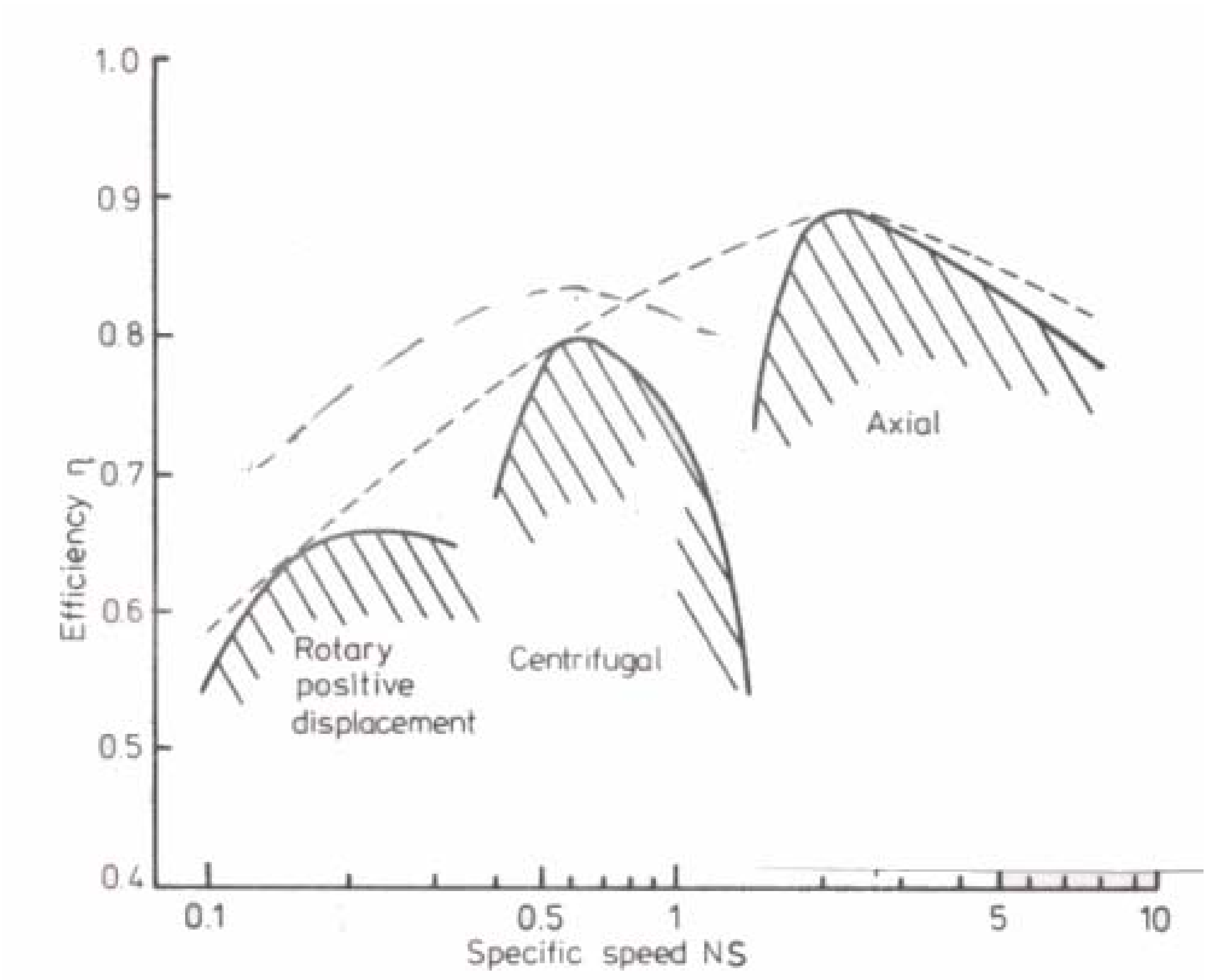


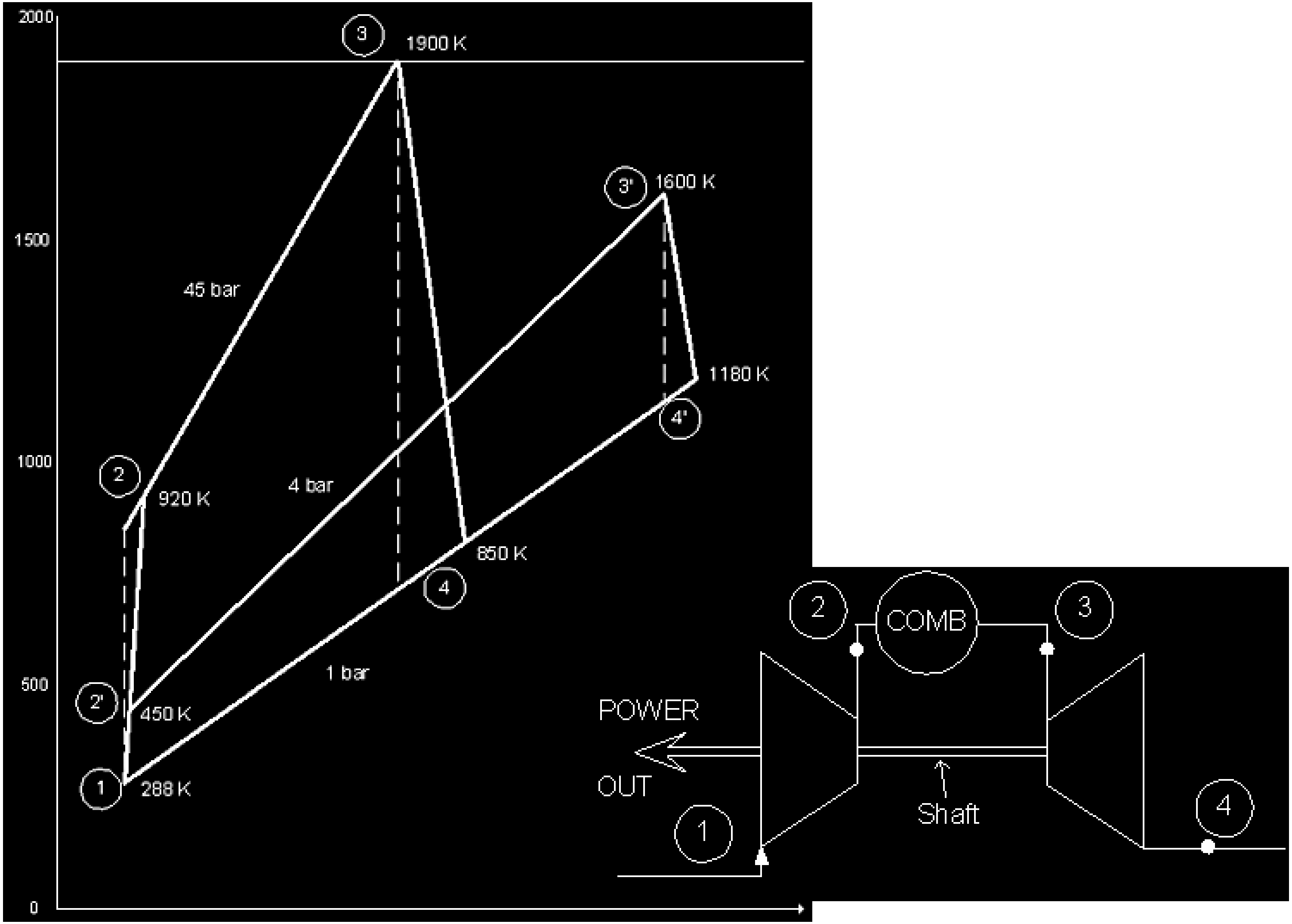
Fig. 22. Arrangement of F.2 Jet Propulsion Engine

Metropolitan-Vickers Axial-Flow Compressor Engine, 1940. (I. Mech. E.)

Efficiency Of Different Compressors



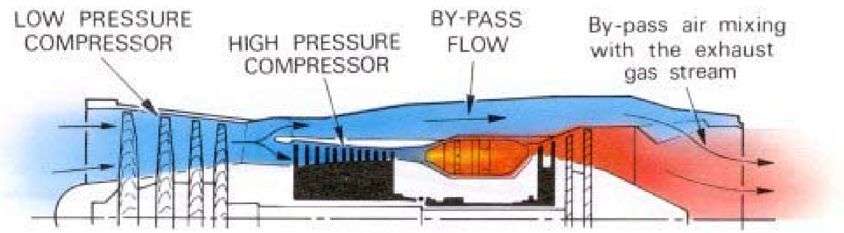
T-s Diagrams



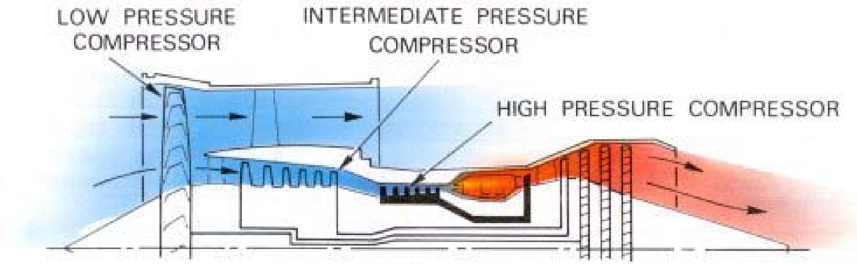
2000
1500
1000
500
0
3
1900 K
3'
1600 K
45 bar
1180 K
4'
2
920 K
4 bar
850 K
4
1 bar
2'
450 K
1
288 K
2
COMB
3
POWER
OUT
Shaft
1
4

Hotel Where Rolls-Royce Swapped A Tank Factory For Jet Engines

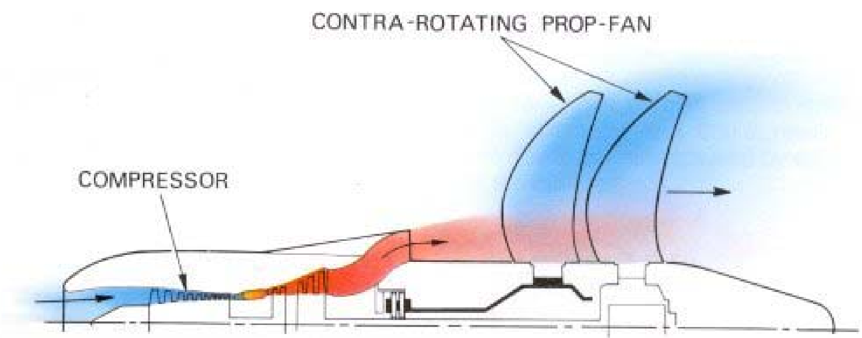
Bypass Engine Sections



TWIN-SPOOL AXIAL FLOW BY-PASS TURBO JET ENGINE (low by-pass ratio)



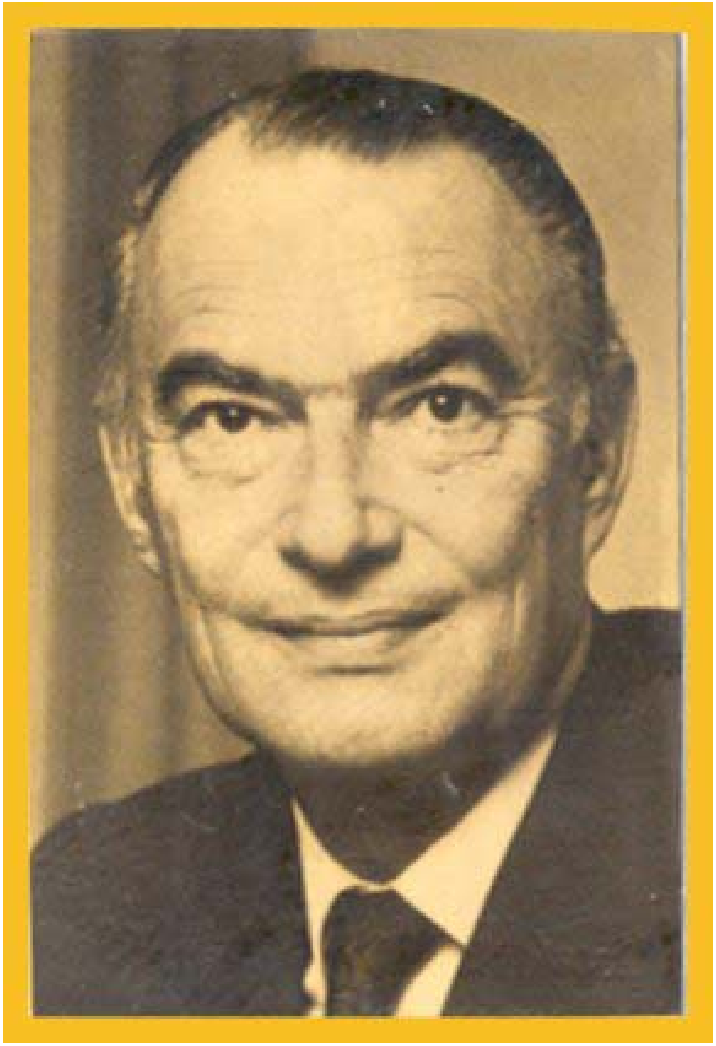
TRIPLE-SPOOL AXIAL FLOW FRONT FAN TURBO JET ENGINE (high by-pass ratio)



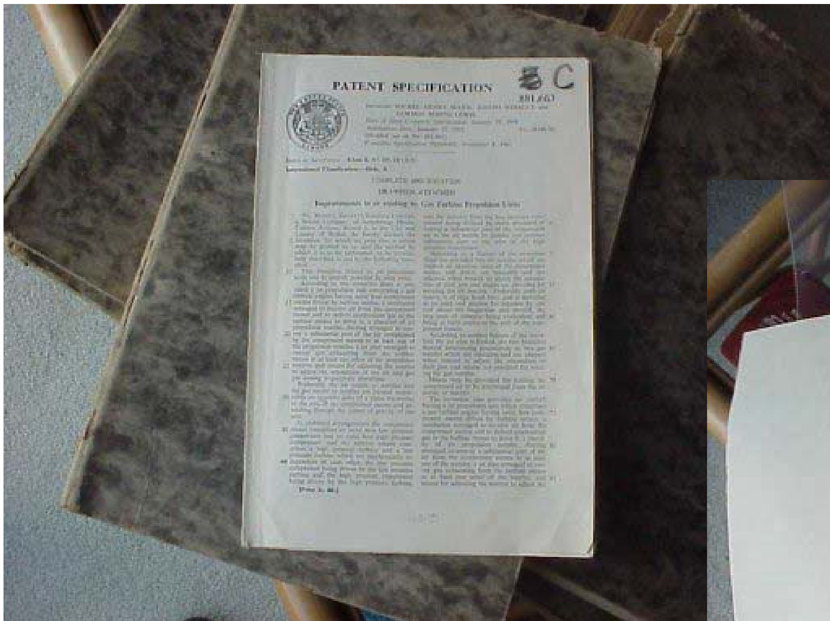
AXIAL FLOW CONTRA-ROTATING PROP-FAN (with free power turbine)

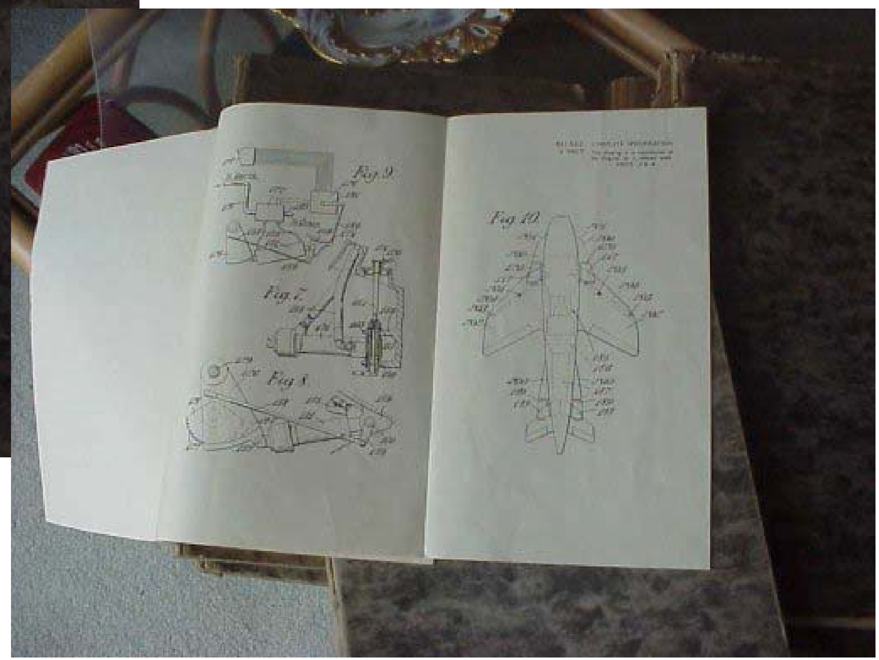
Gordon Lewis

Inventor of Olympus
Engine and Harrier Aircraft



Harrier Patent And 17 Folders Containing Original Olympus Hand Calculations

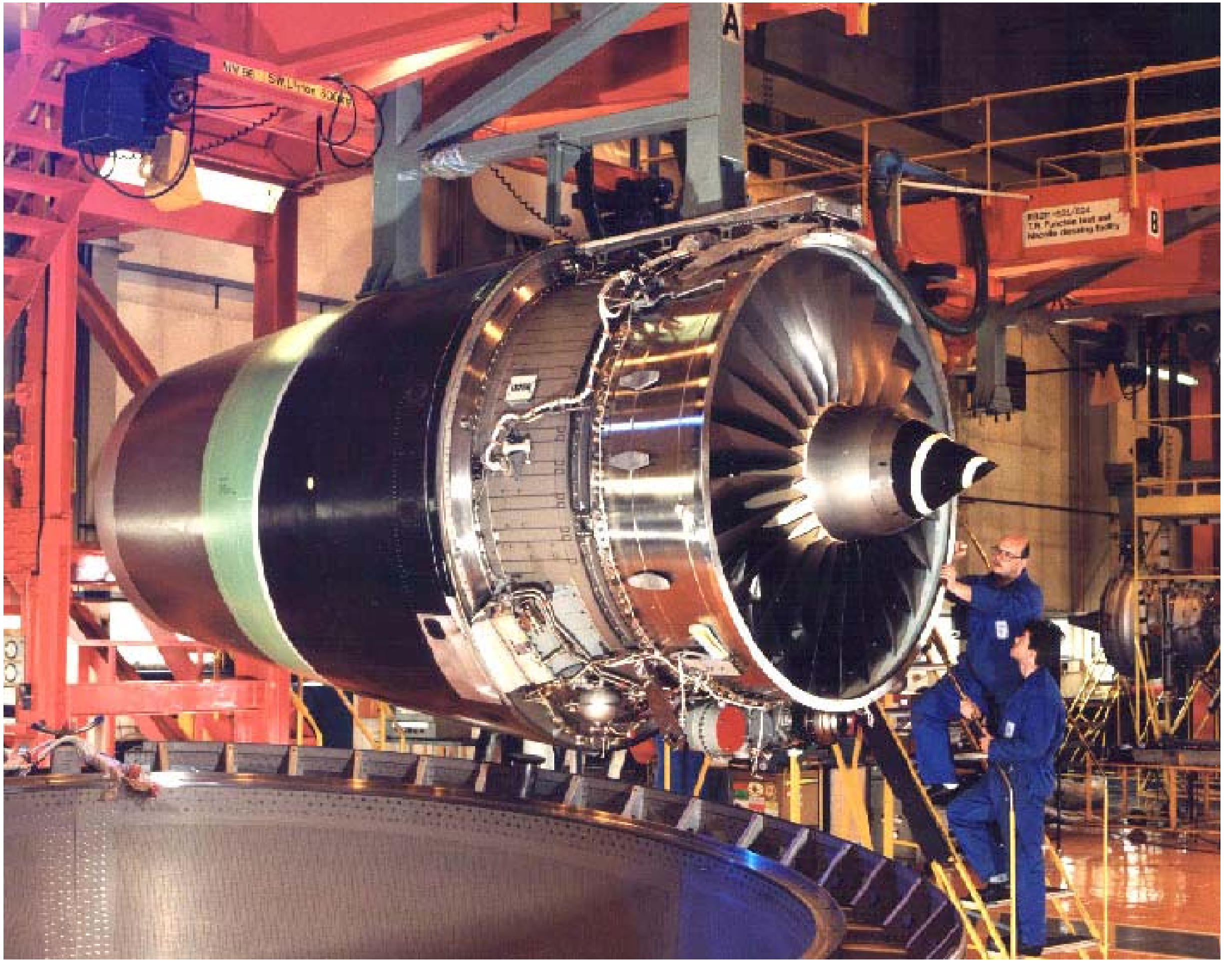




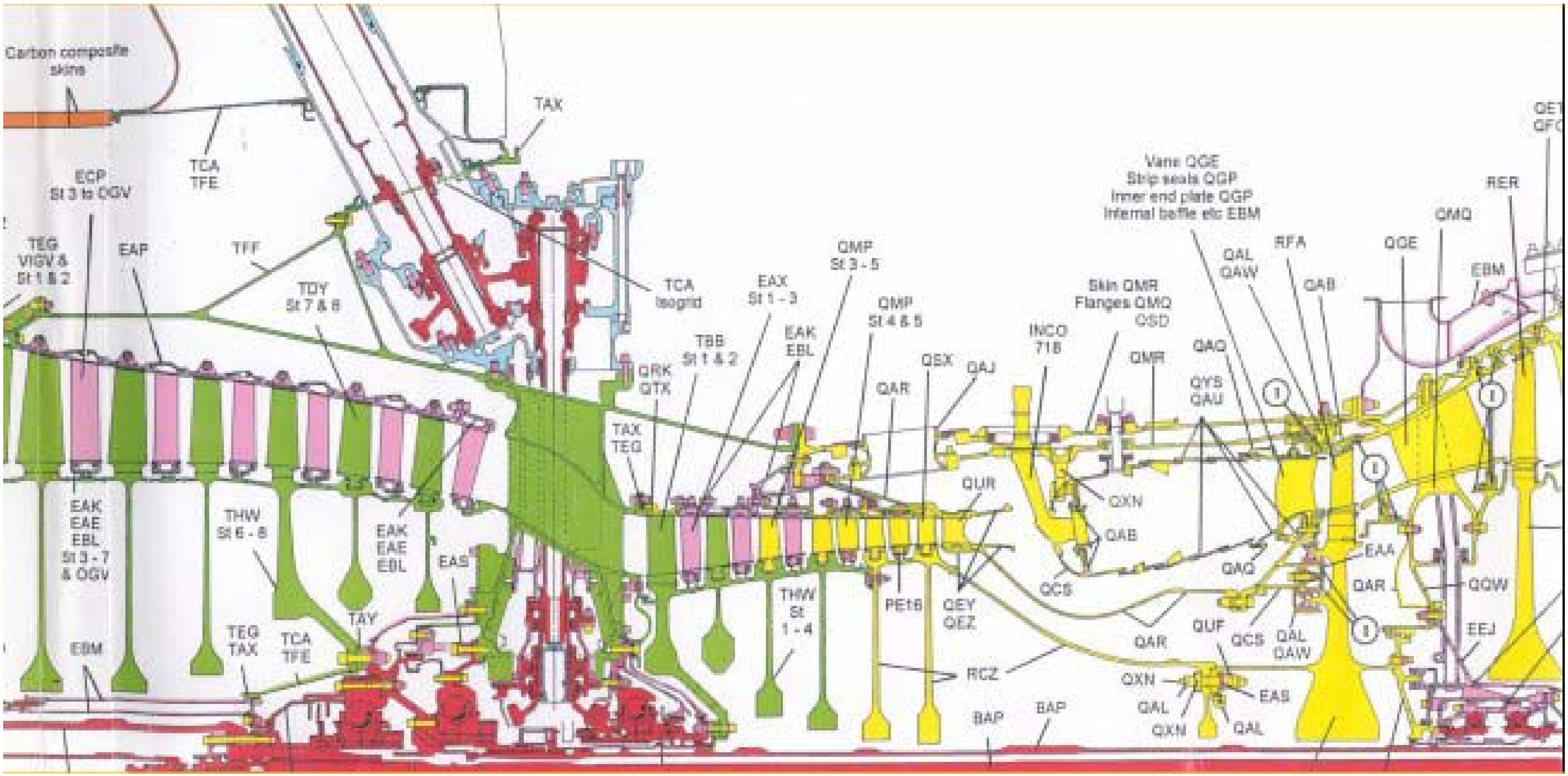
US Boeing version of the Harrier

Harrier in its natural environment

Rolls-Royce Trent 700



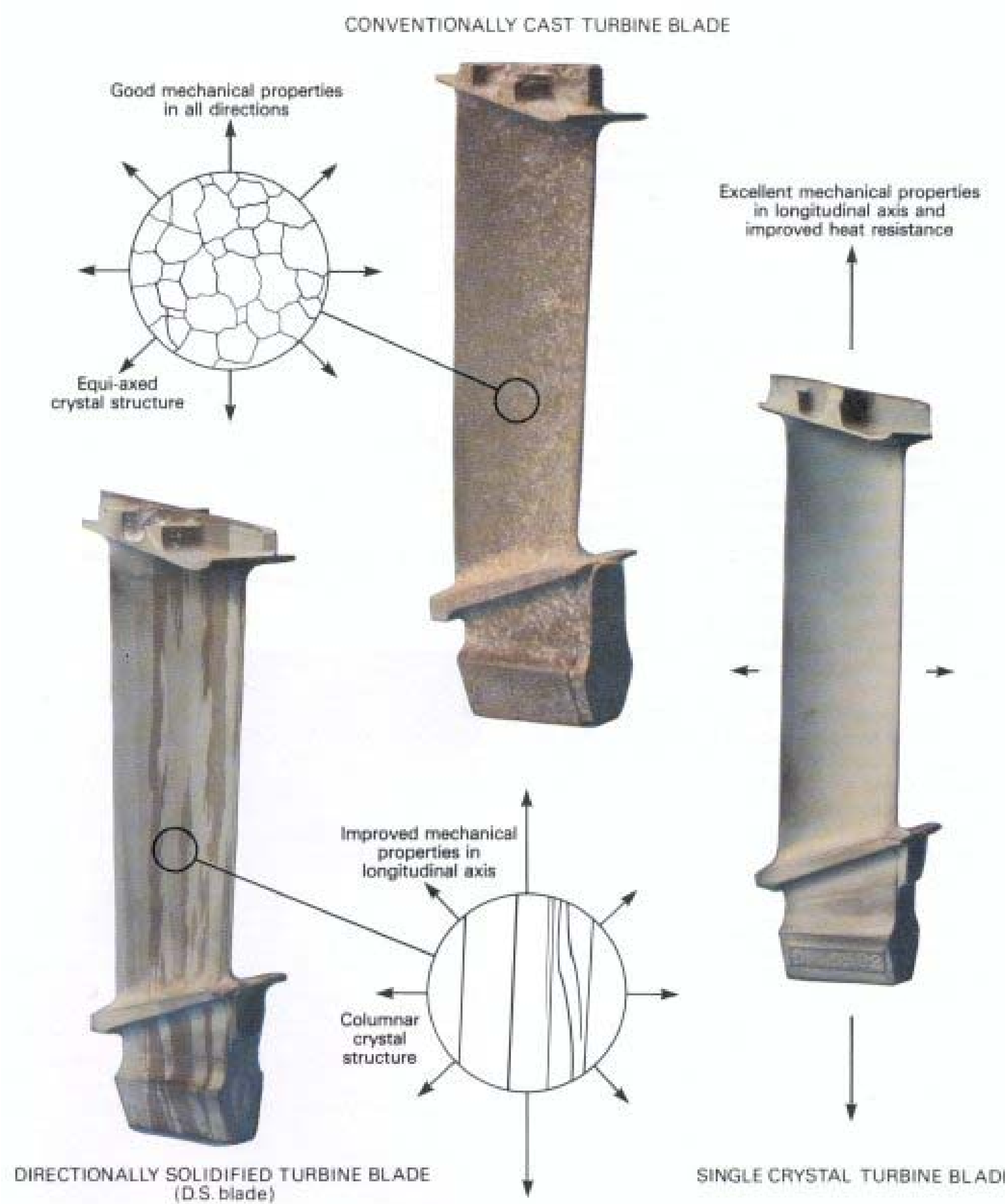
Turbofan Materials and the Titanium Problem



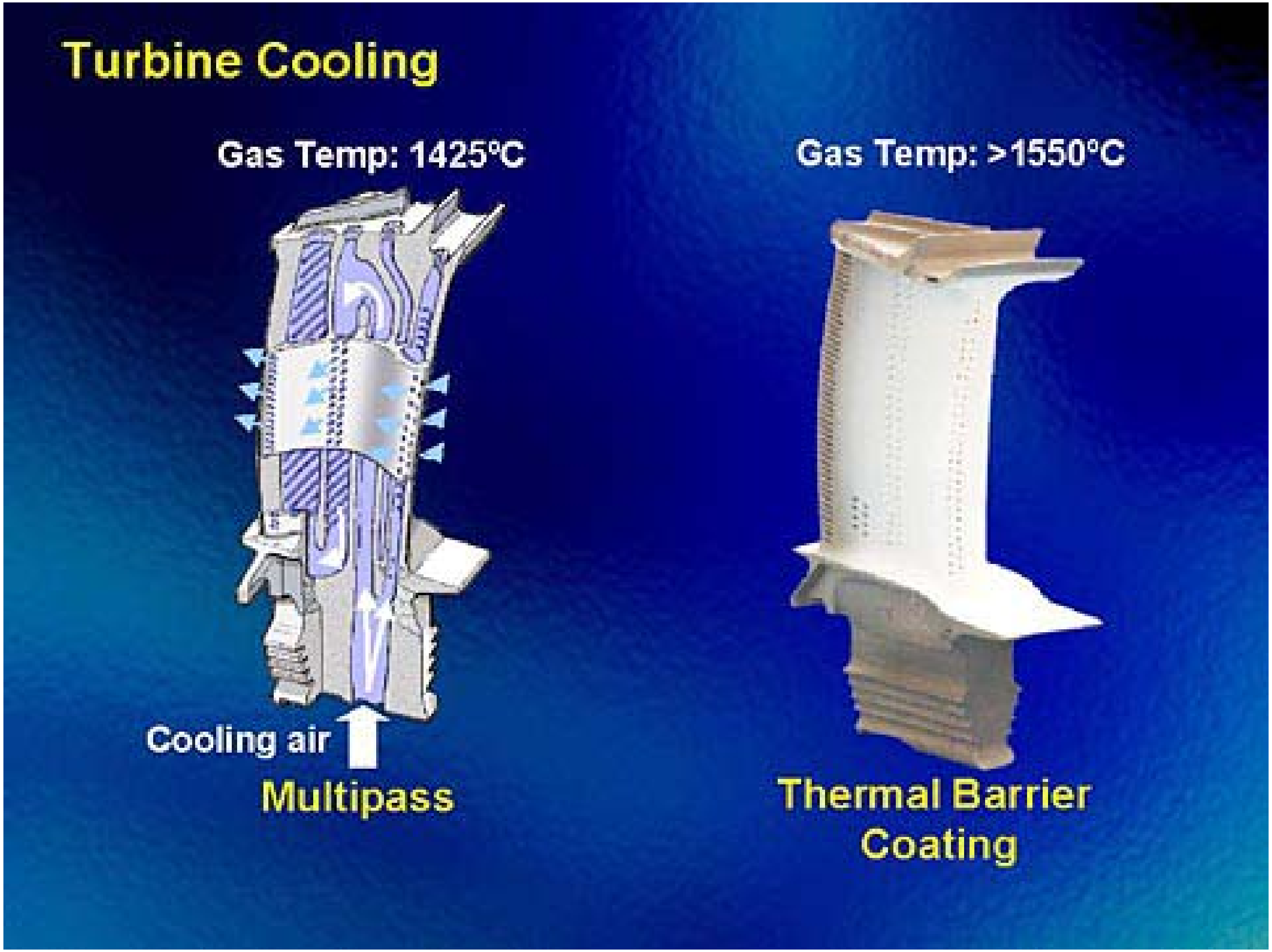
GE 90 Fan

GE 90 Carbon Fibre Fan Blades With Titanium Leading Edges

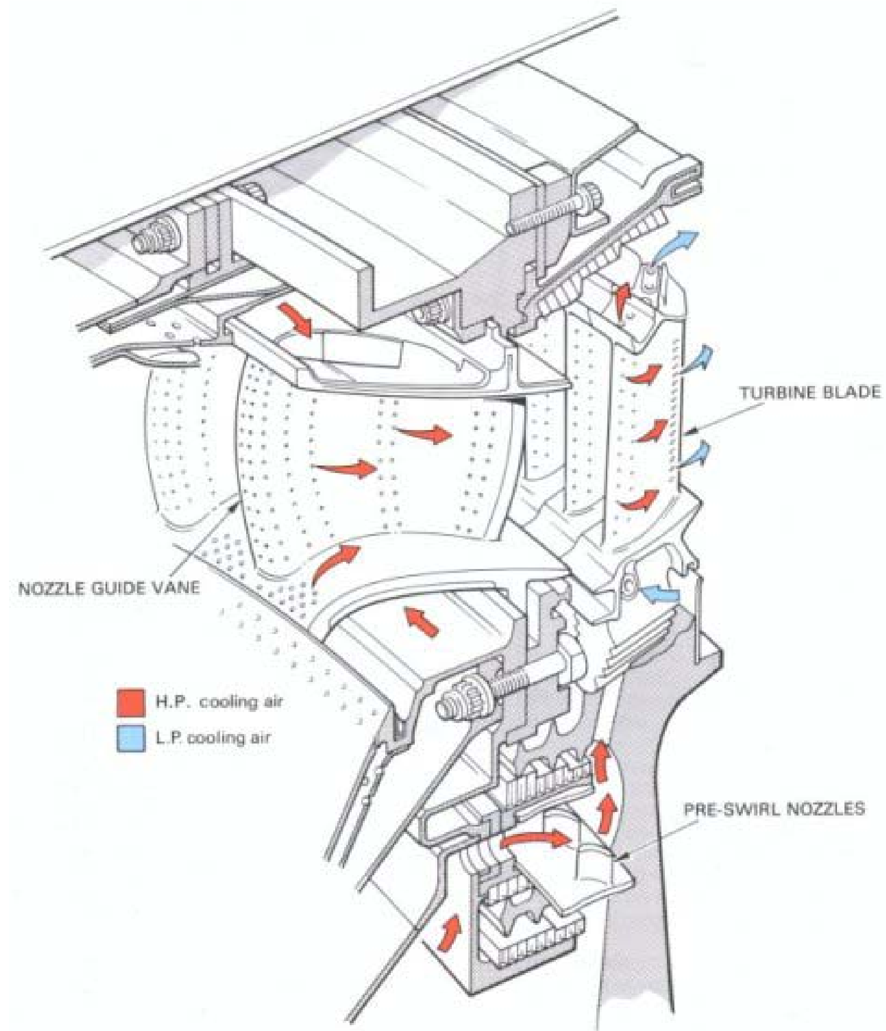
Cast Nickel Chrome Alloy Turbine Blades



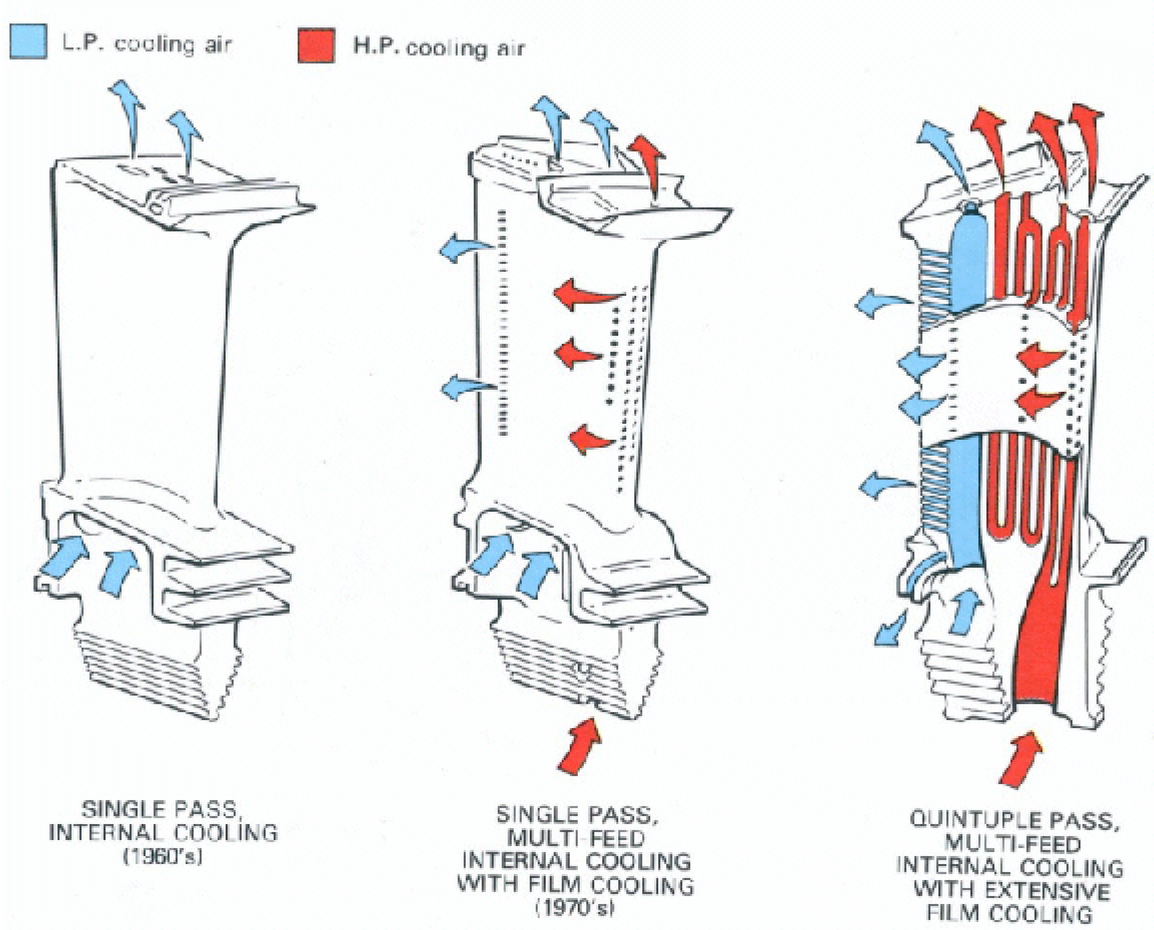
Control of blade temperature ~ A problem



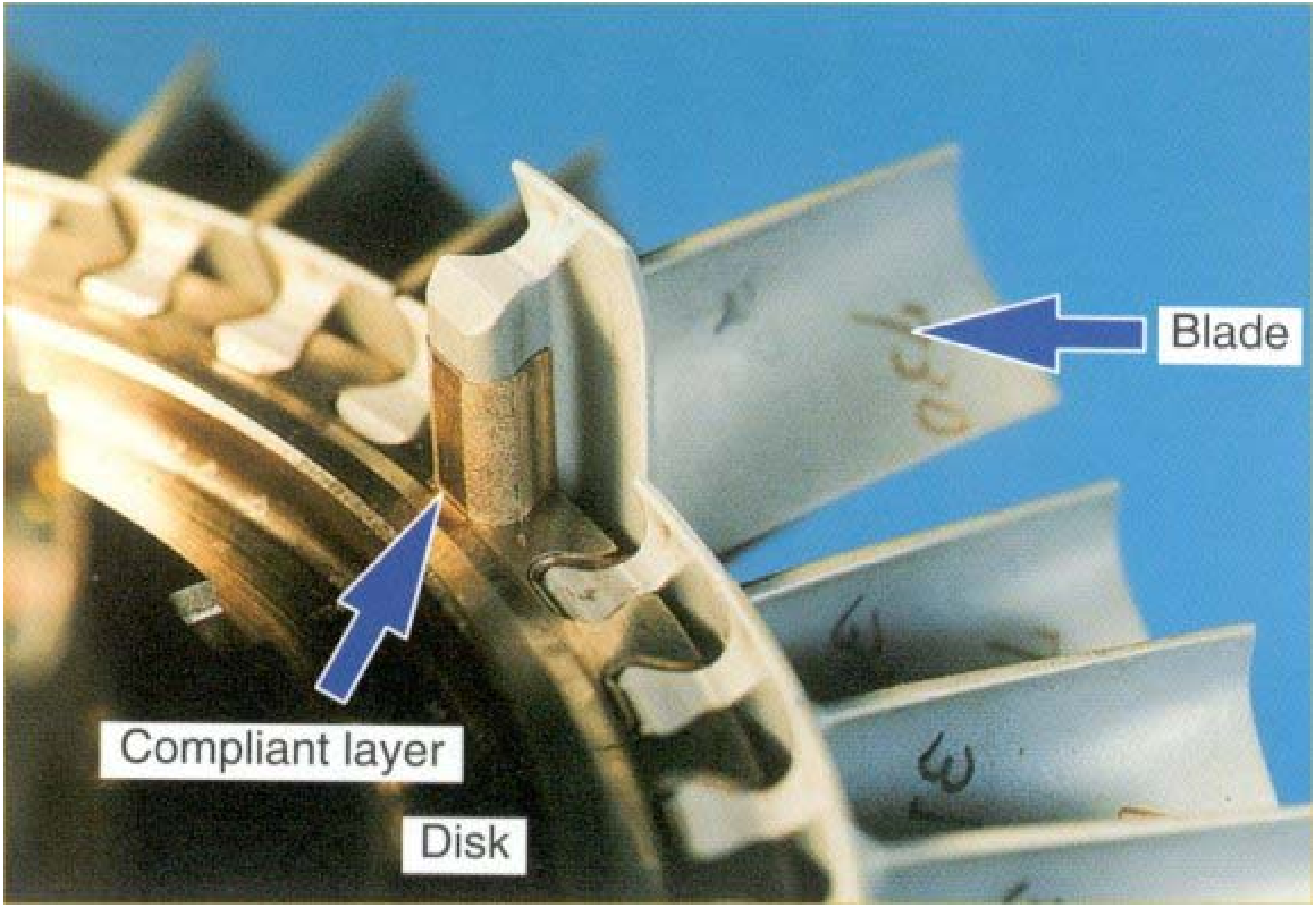
Turbine Blade Cooling



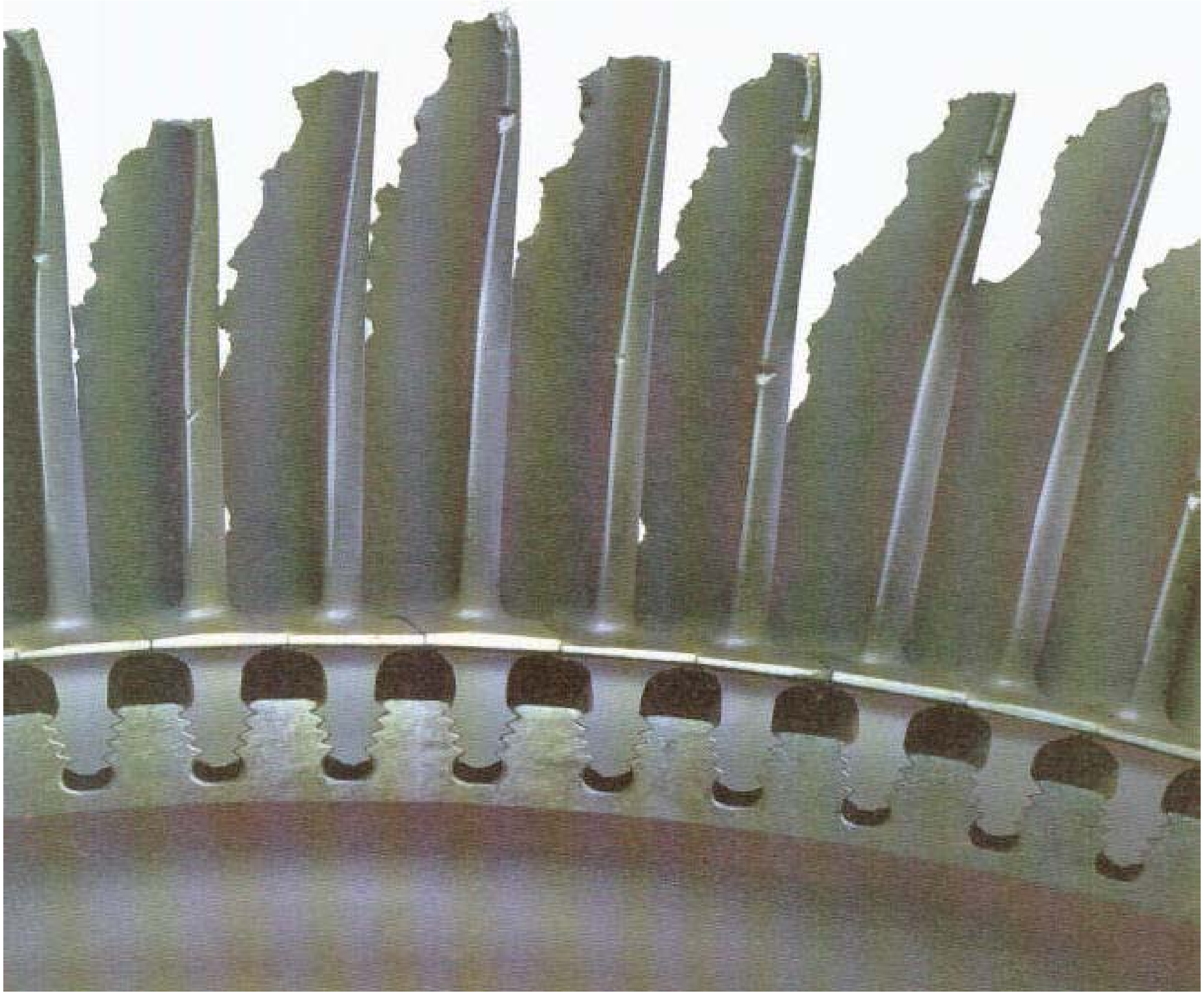
Turbine Blade Cooling System



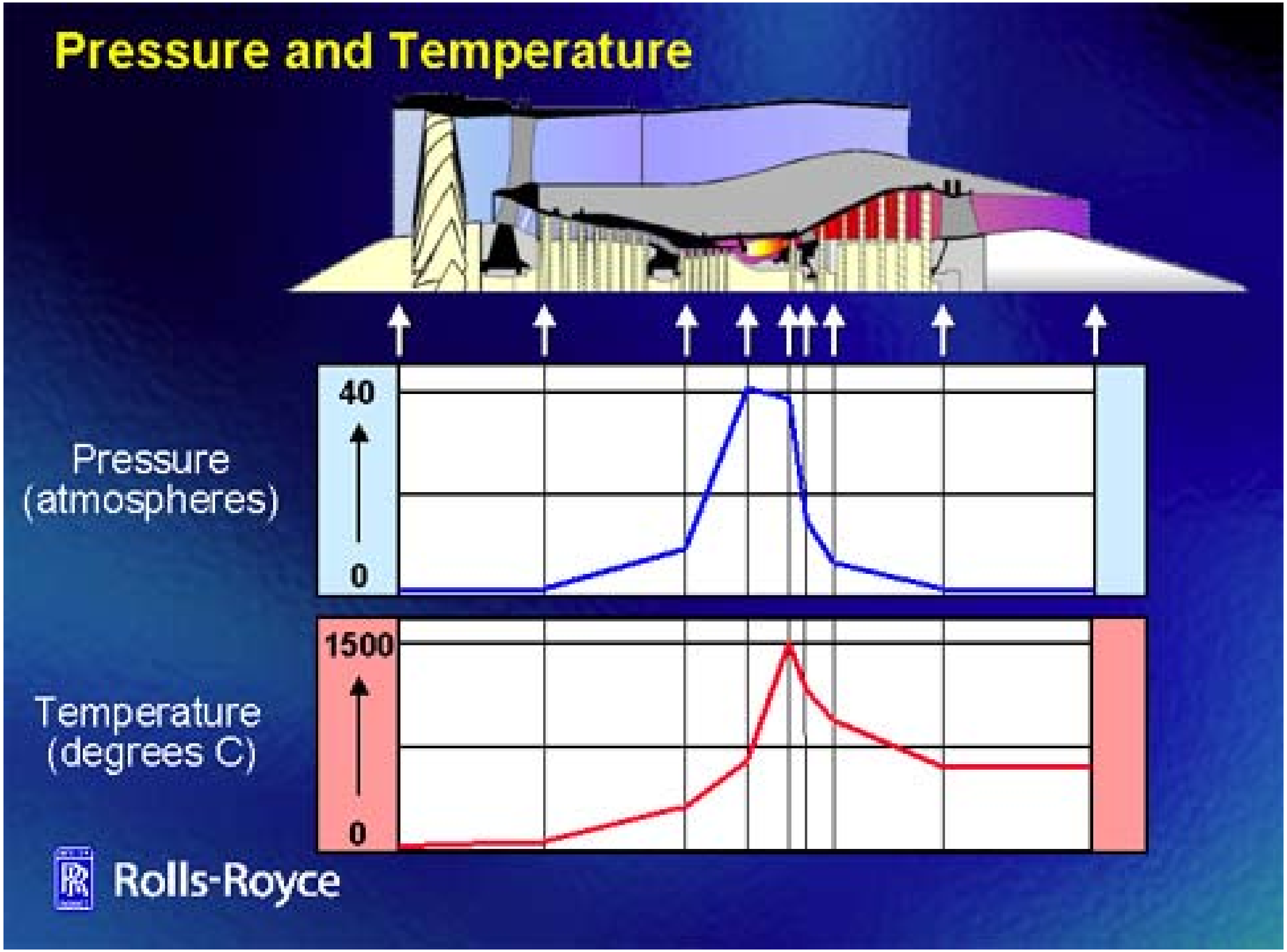
Ceramic Blades Metallic Disc



Damage due to overheated blades

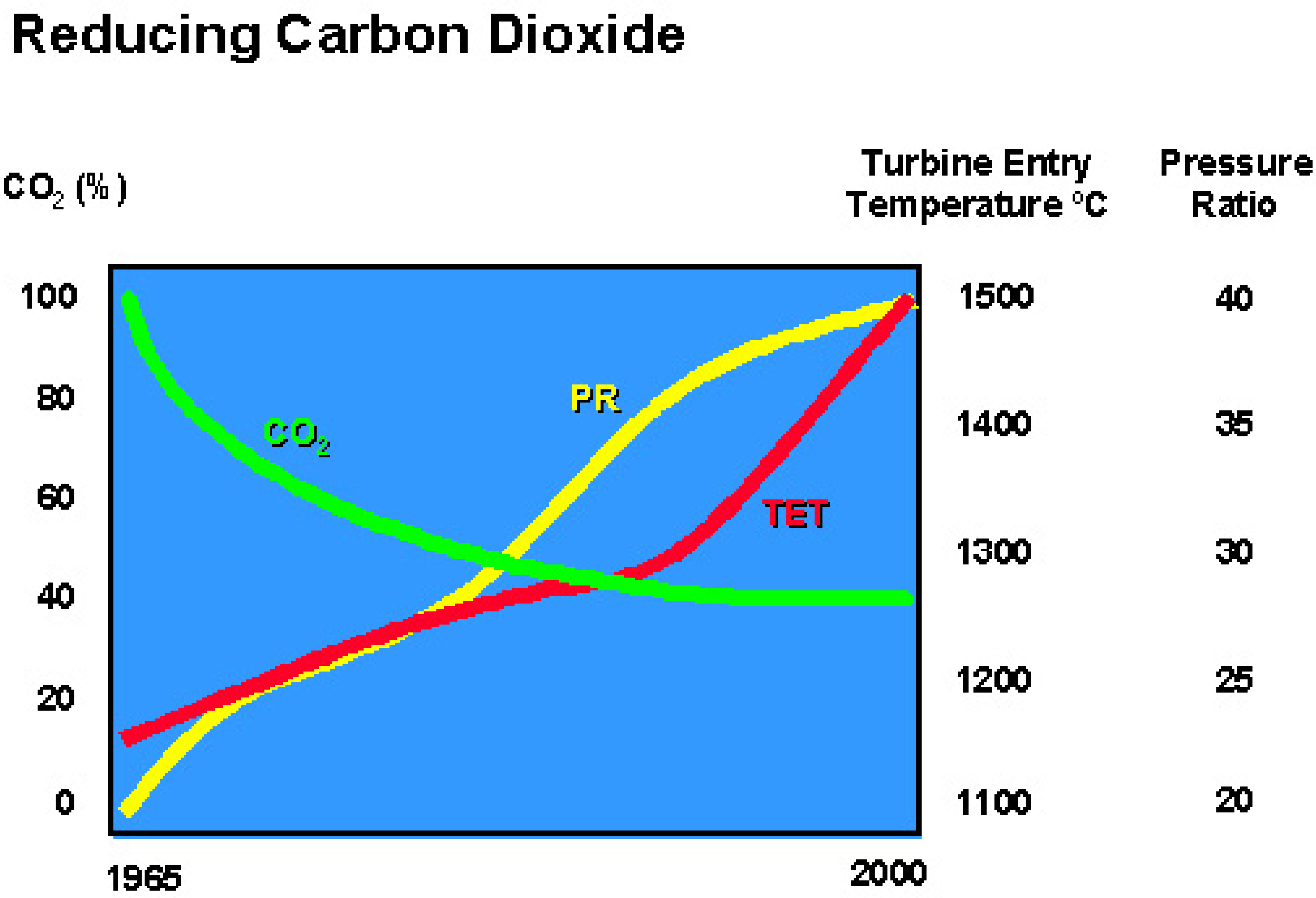


Pressures and temperatures across the unit



Emission reduction

Huge increases have been achieved in turbine entry temperature and pressure ratio, as shown in the chart. This has more than halved fuel consumption and hence carbon dioxide, which is the unavoidable product of burning any fossil fuel.



Carbon Dioxide (Green)

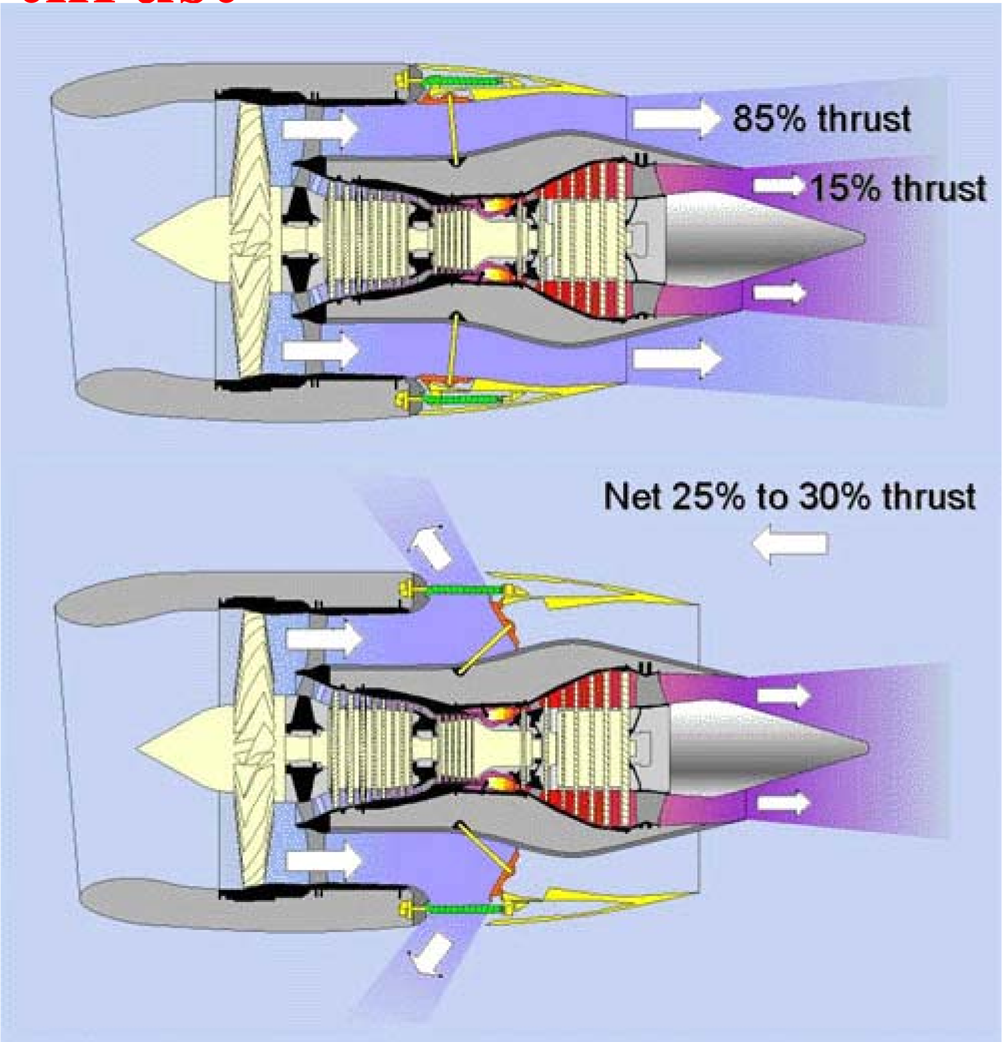
Turbine Entry Temperature (Red)

Pressure Ratio (Yellow)

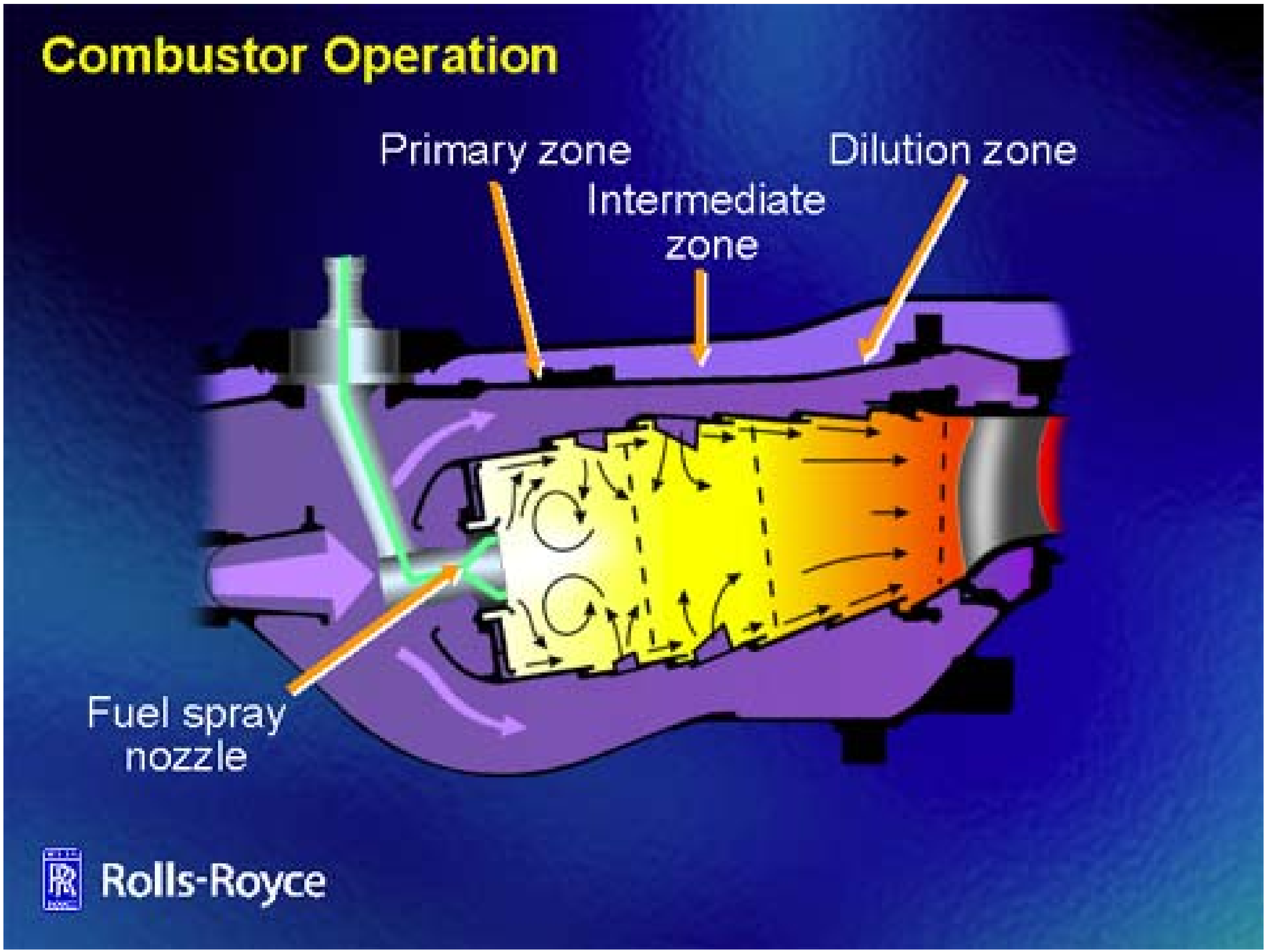
CO_2 ~ Fuel Consumption

- Huge increases have been achieved in turbine entry temperature and pressure ratio, as shown in the chart. This has more than halved fuel consumption and hence carbon dioxide, which is the unavoidable product of burning any fossil fuel.

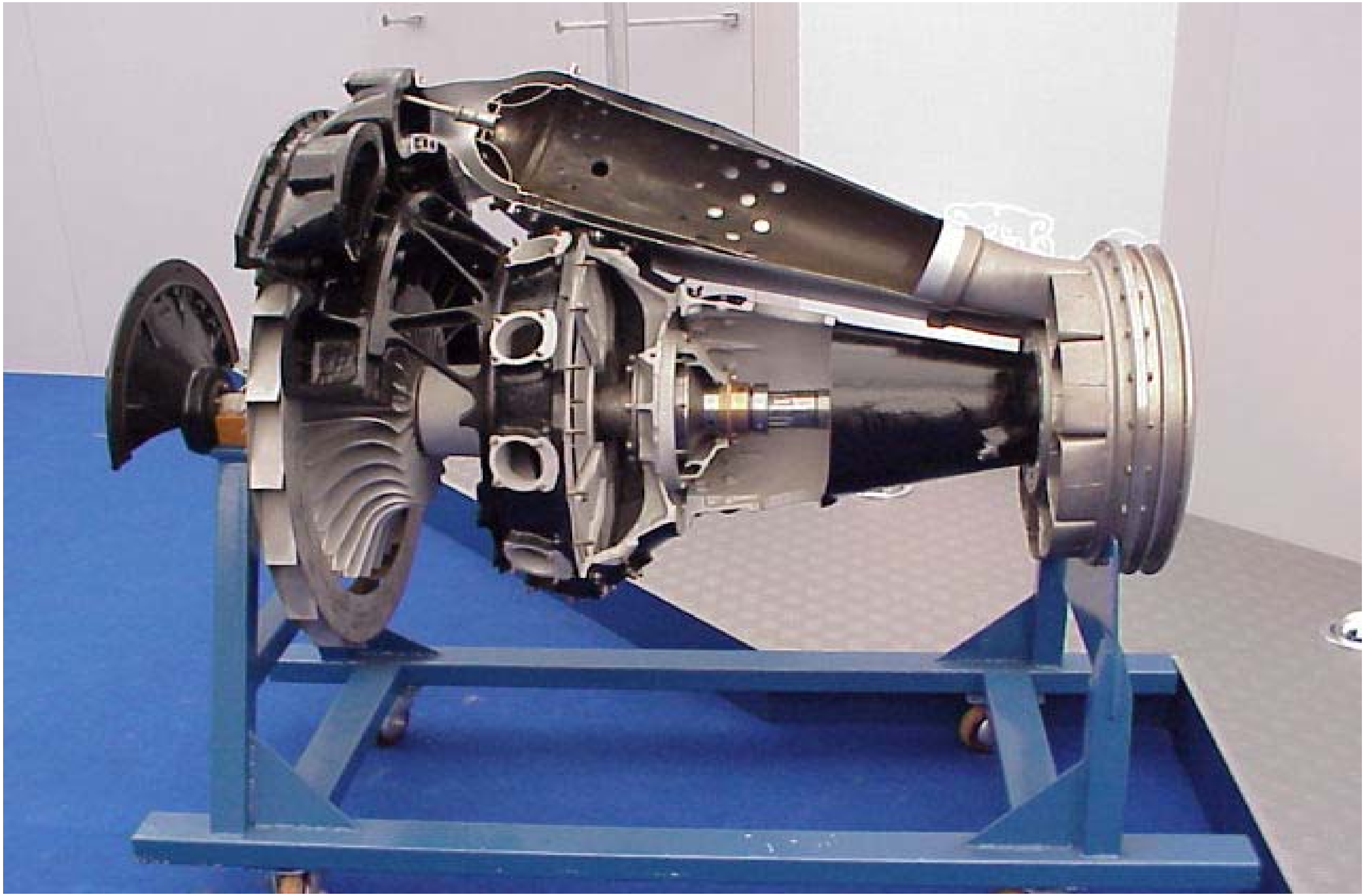
Reverse thrust



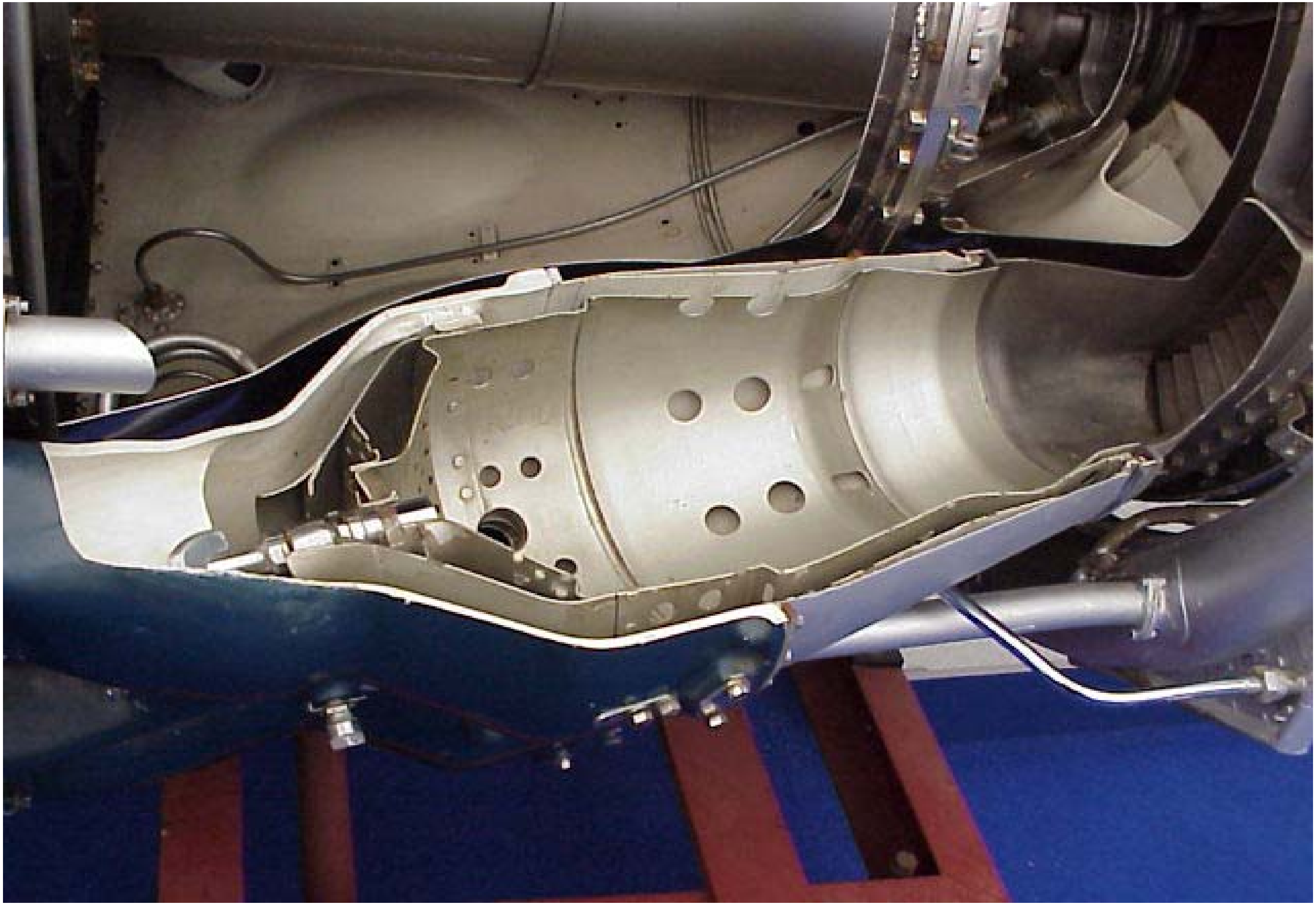
Fuel~air mix, combustion



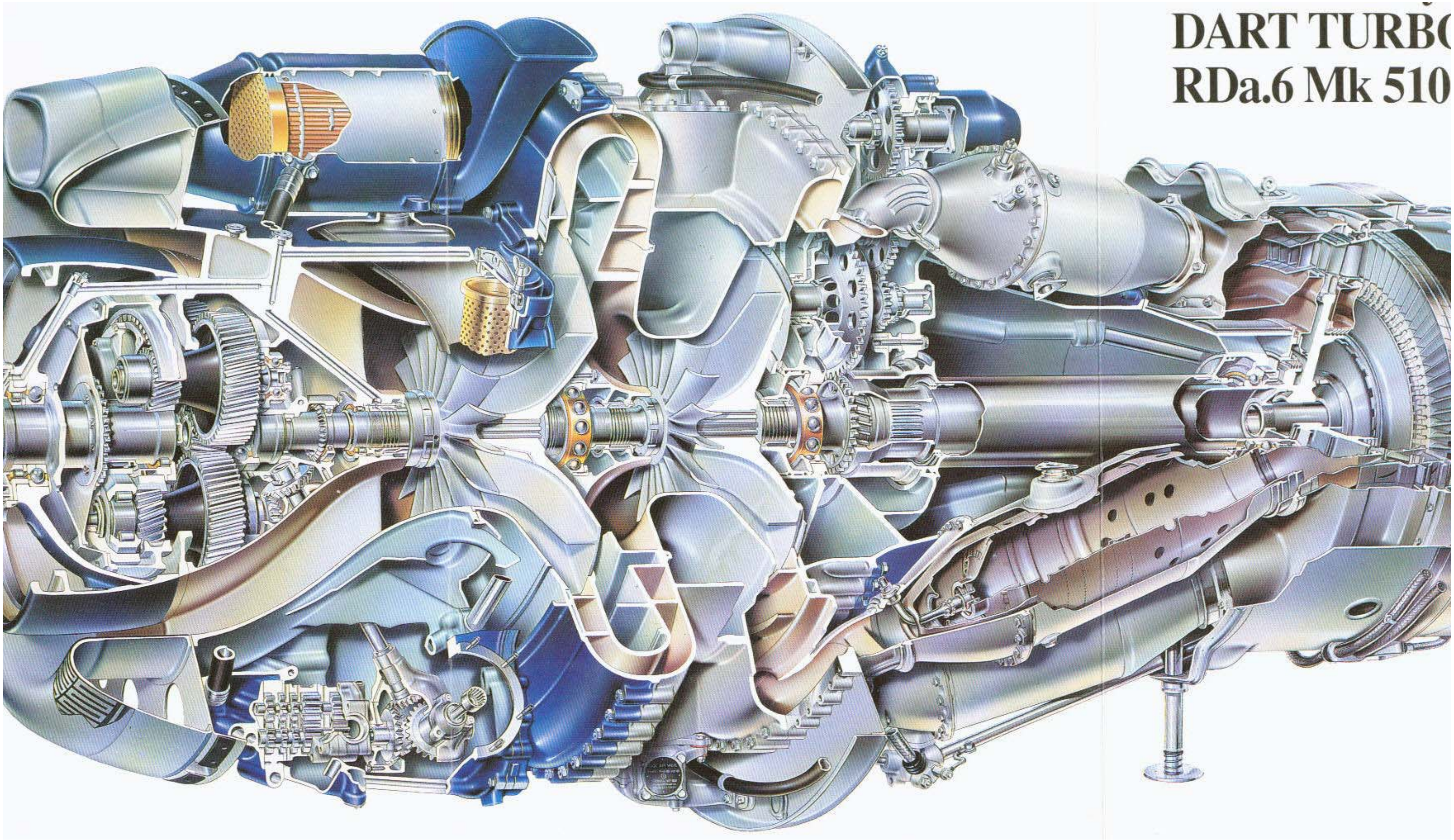
Note the combustion chamber



The combustion chamber

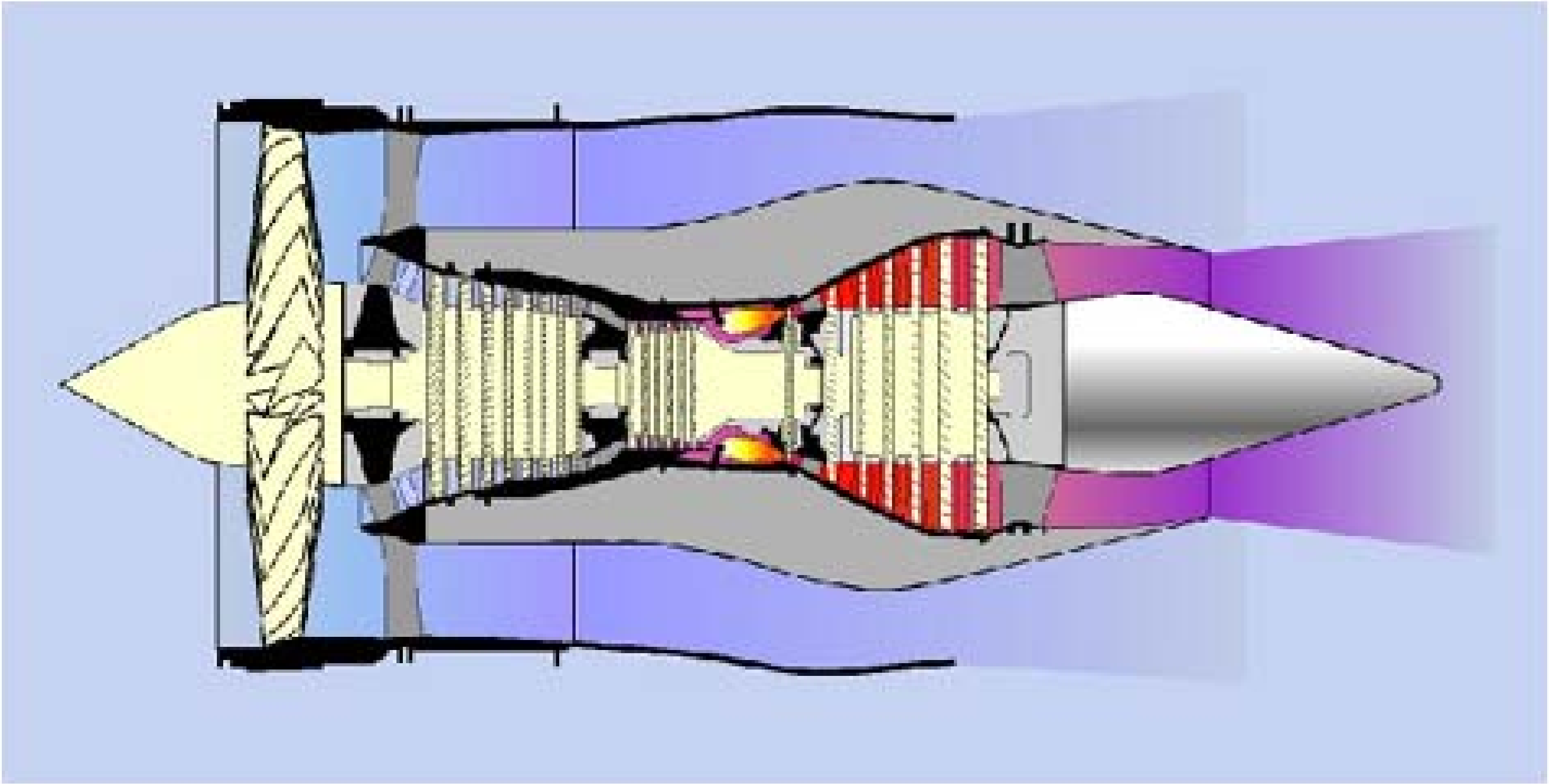


Complex ? The principles are basic

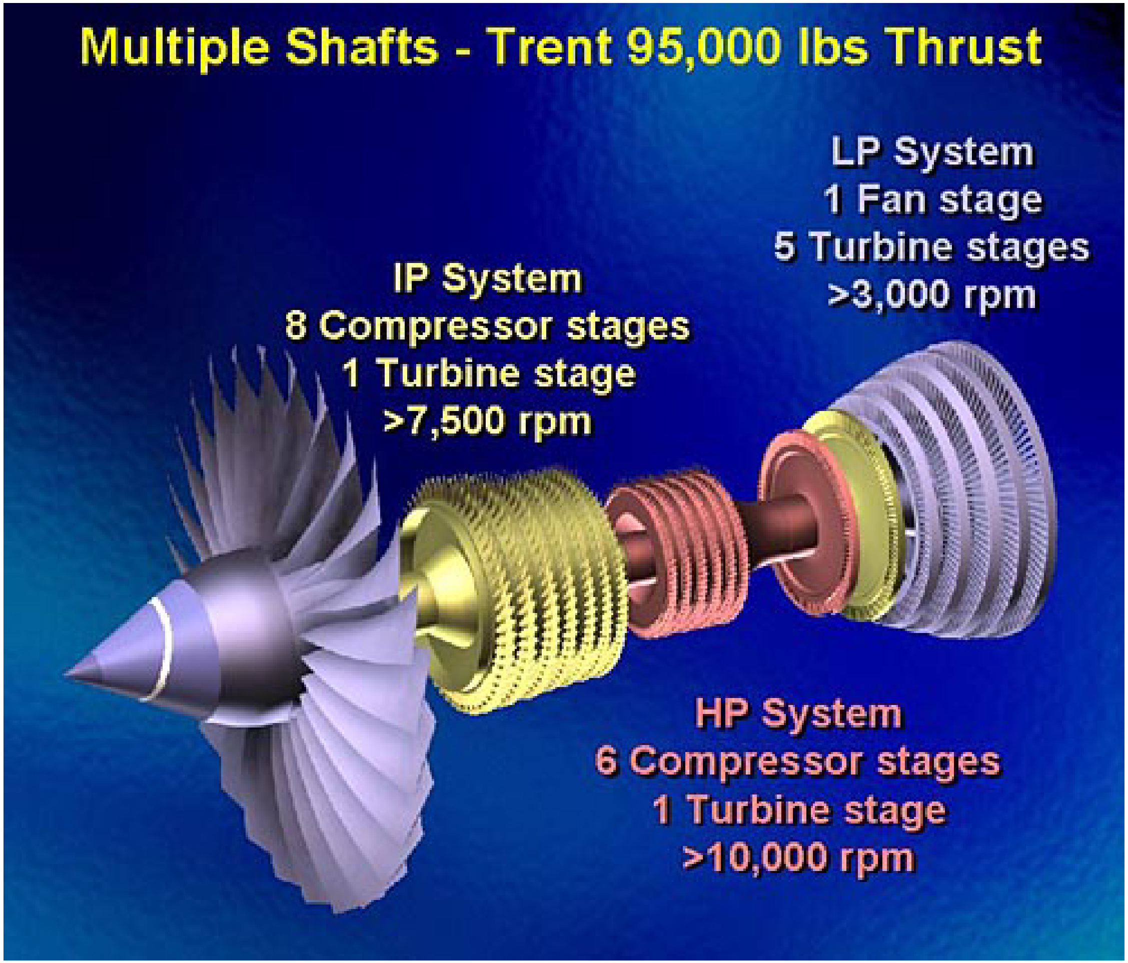


Dart, a classic Turbo prop application

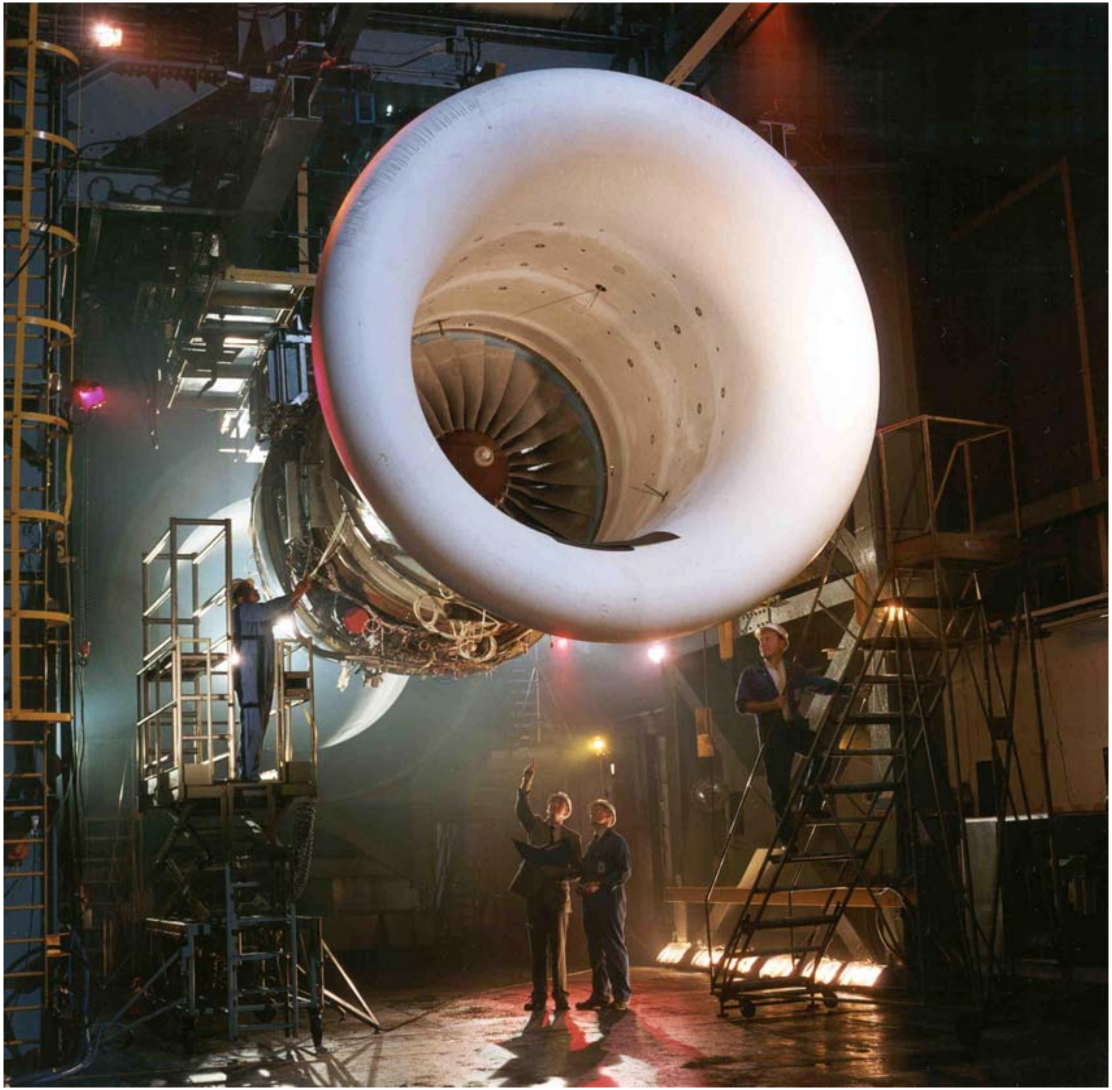
TRENT

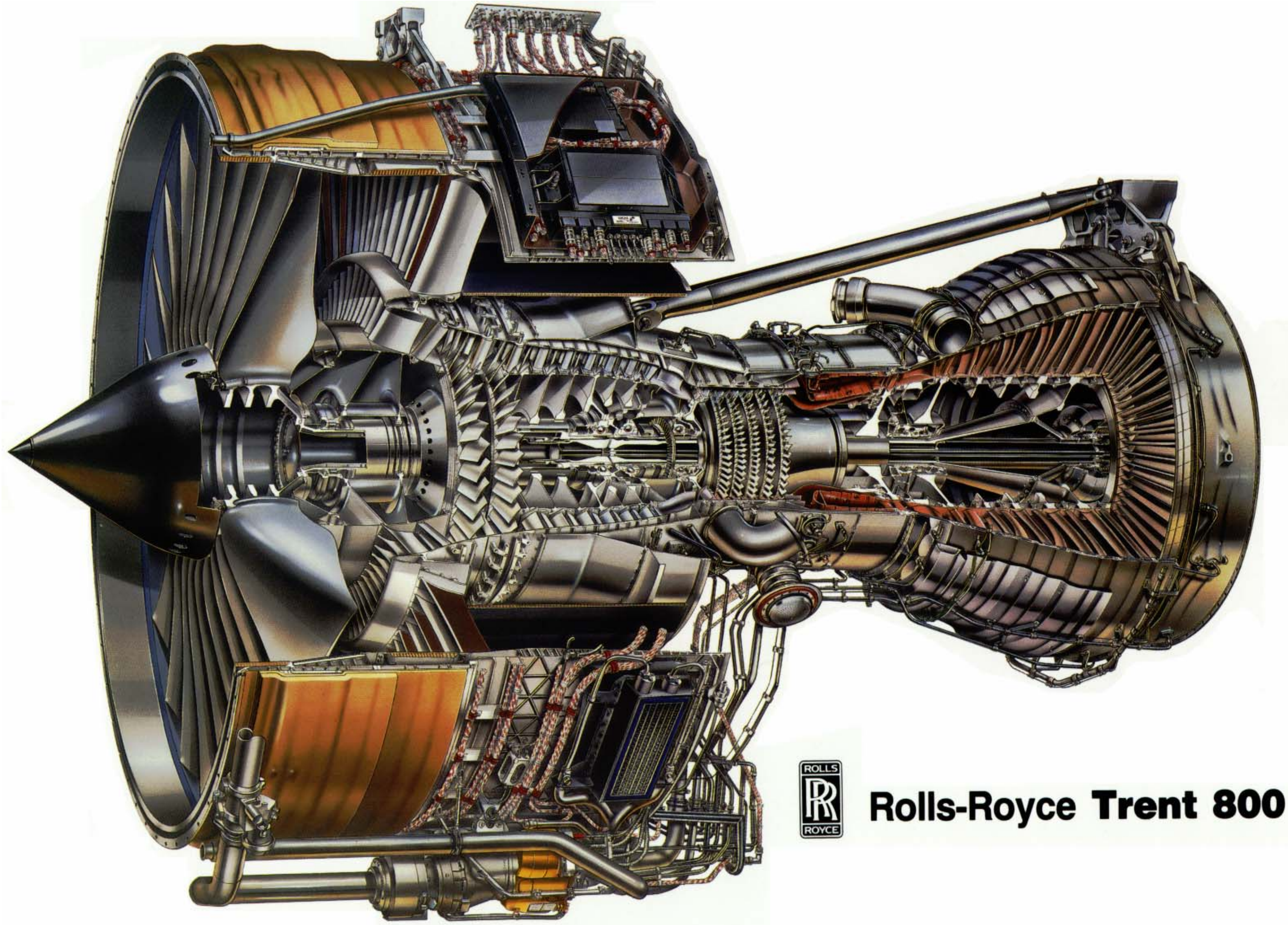


Note the compressor stages

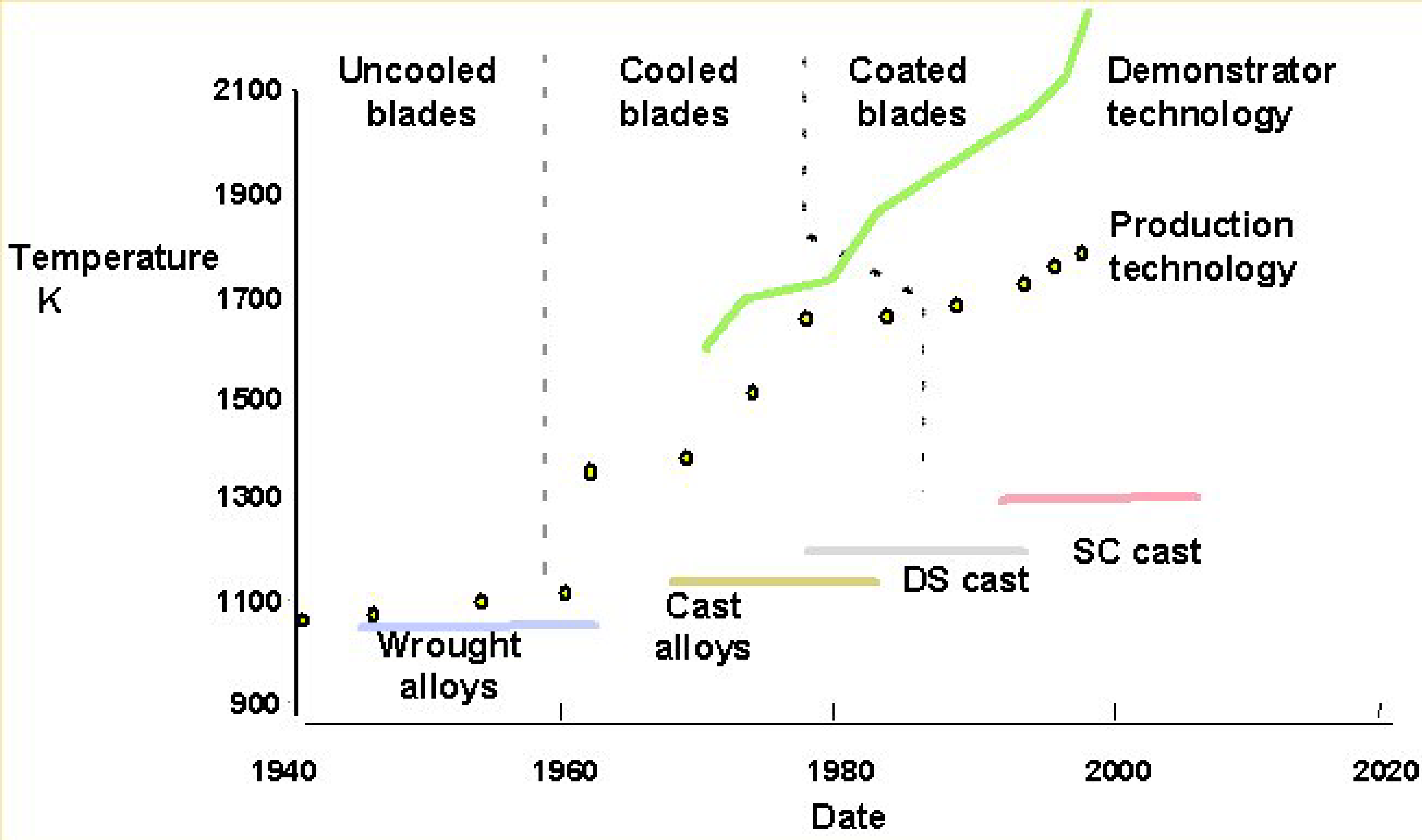


Trent Power unit

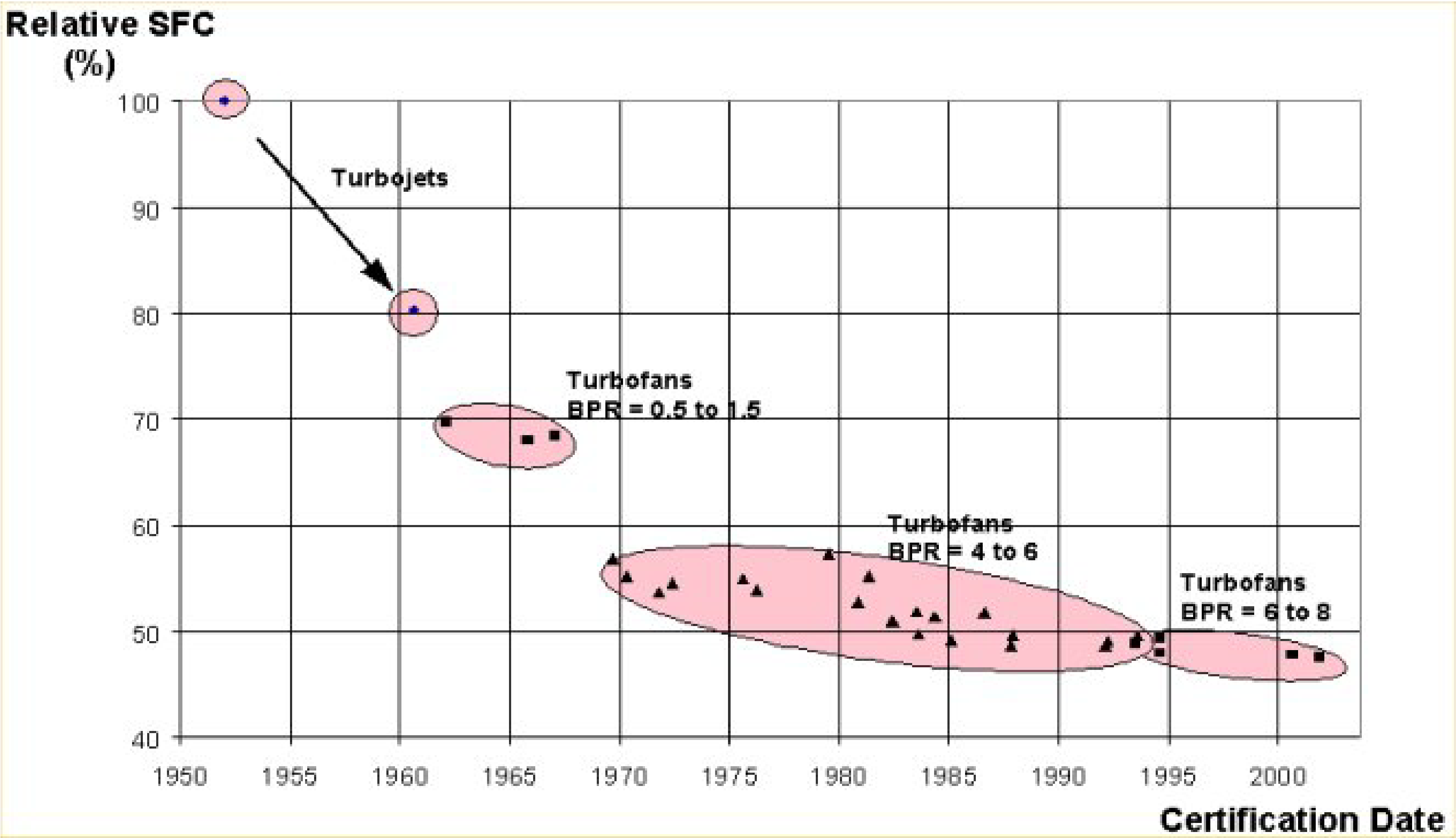



ROLLS
ROYCE
Rolls-Royce Trent 800

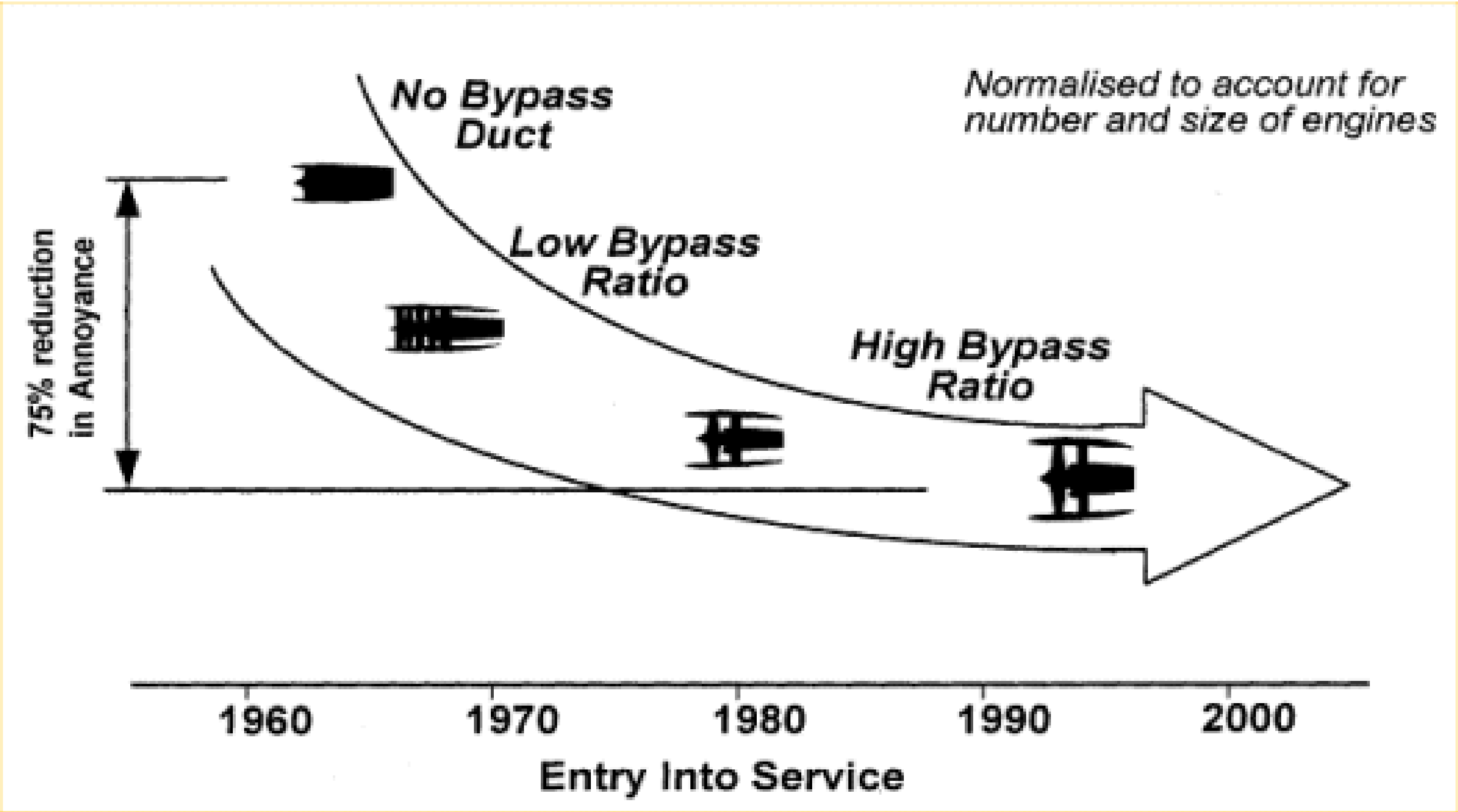
Progress In Materials And Turbine Entry Temperature



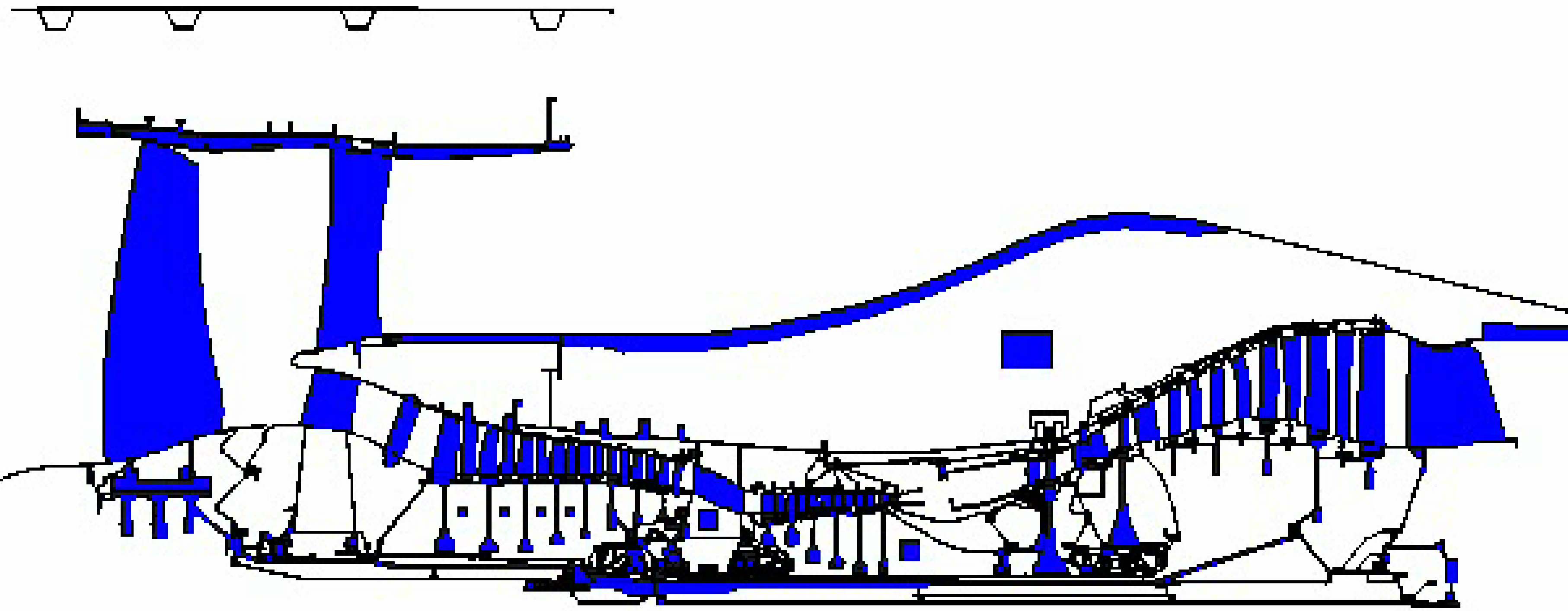
Progress In Reducing Fuel Consumption



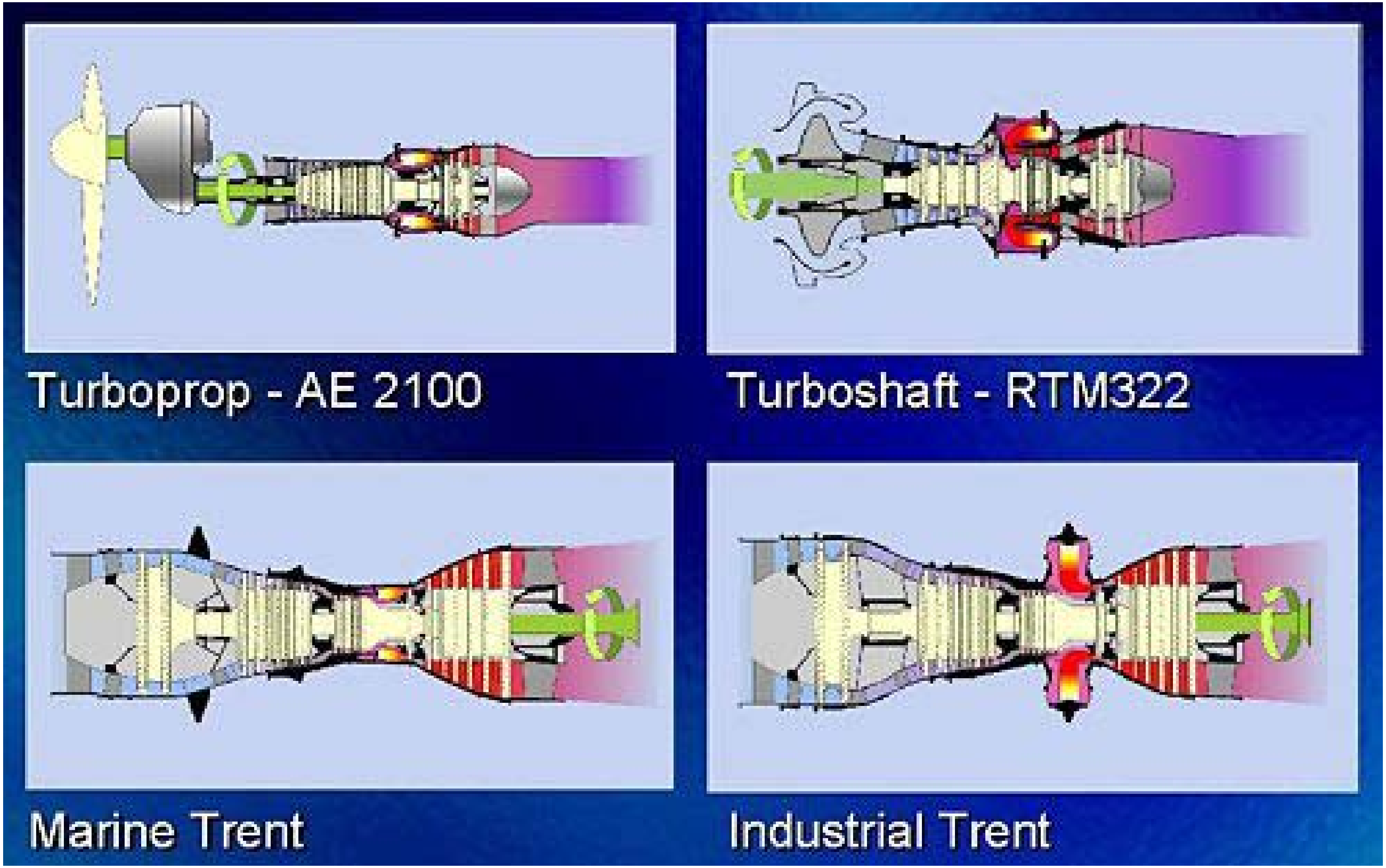
Progress In Reducing Total Aircraft Noise

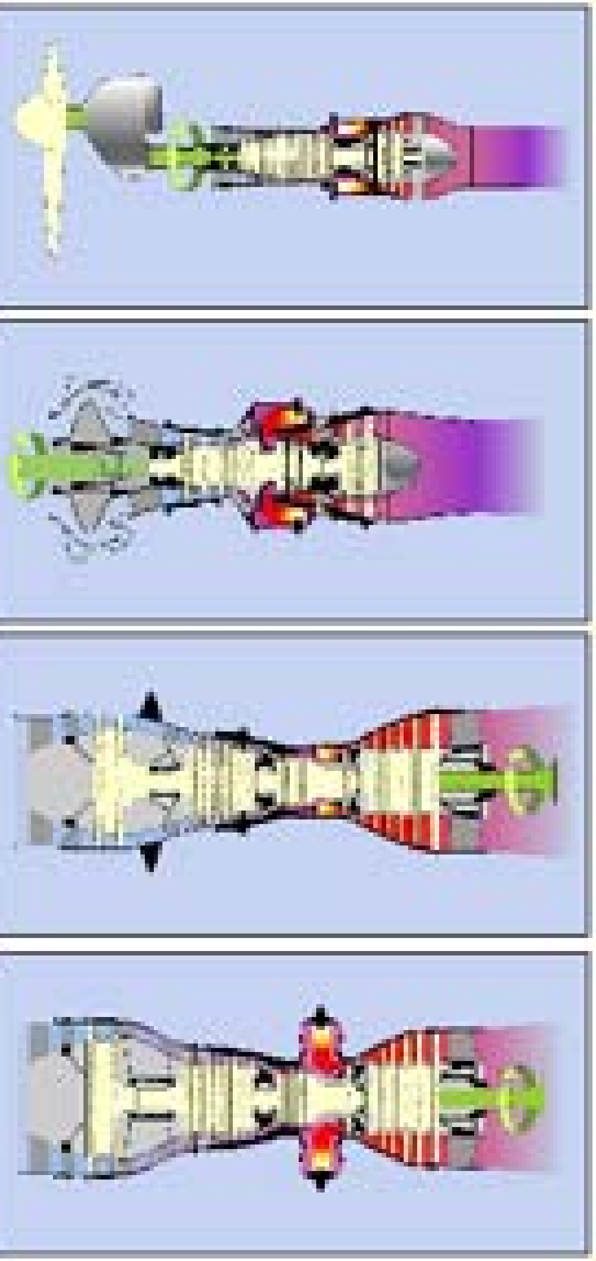


Thermo-Mechanical Model Of Trent 500 For A340

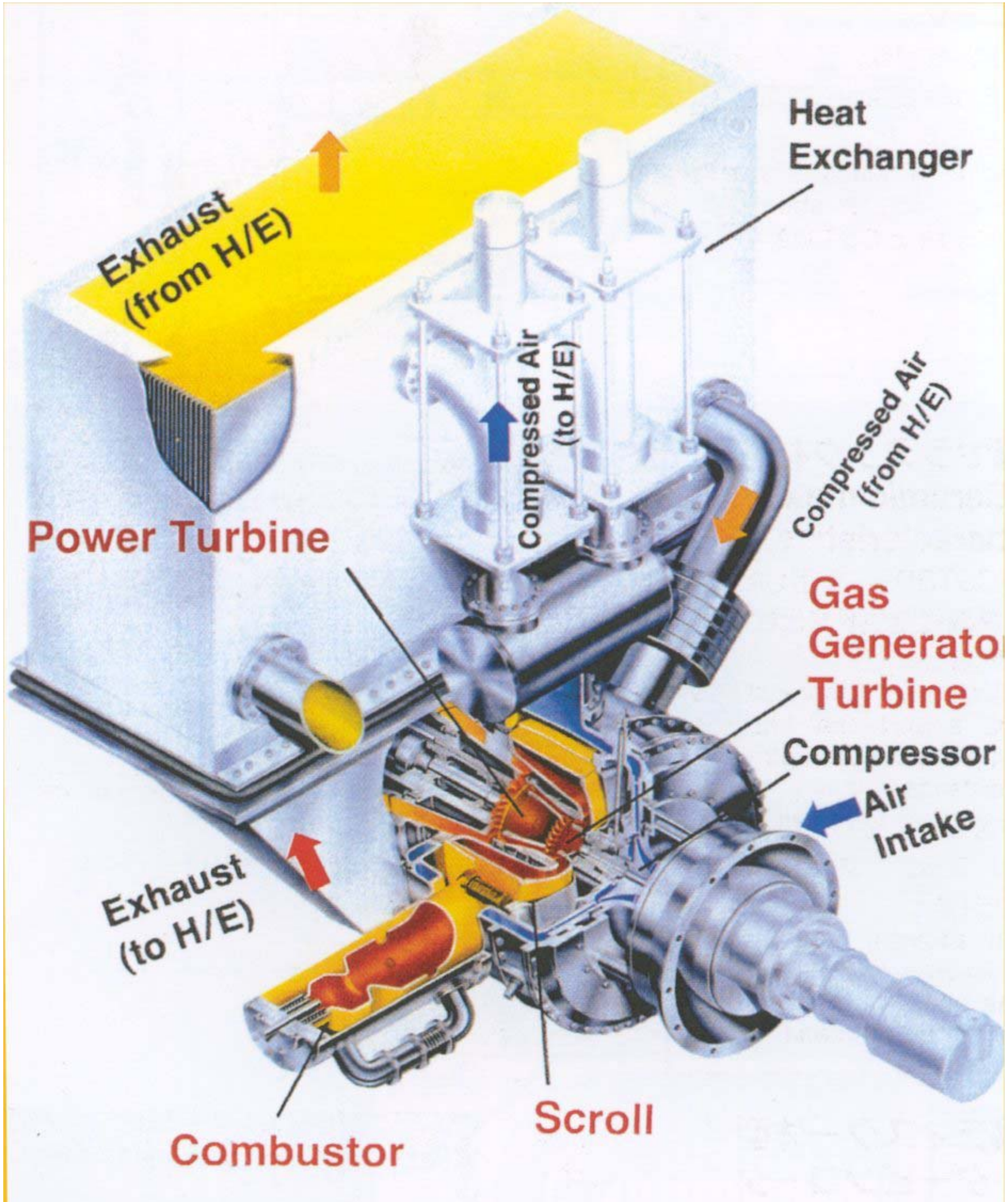


Same basic unit, different applications





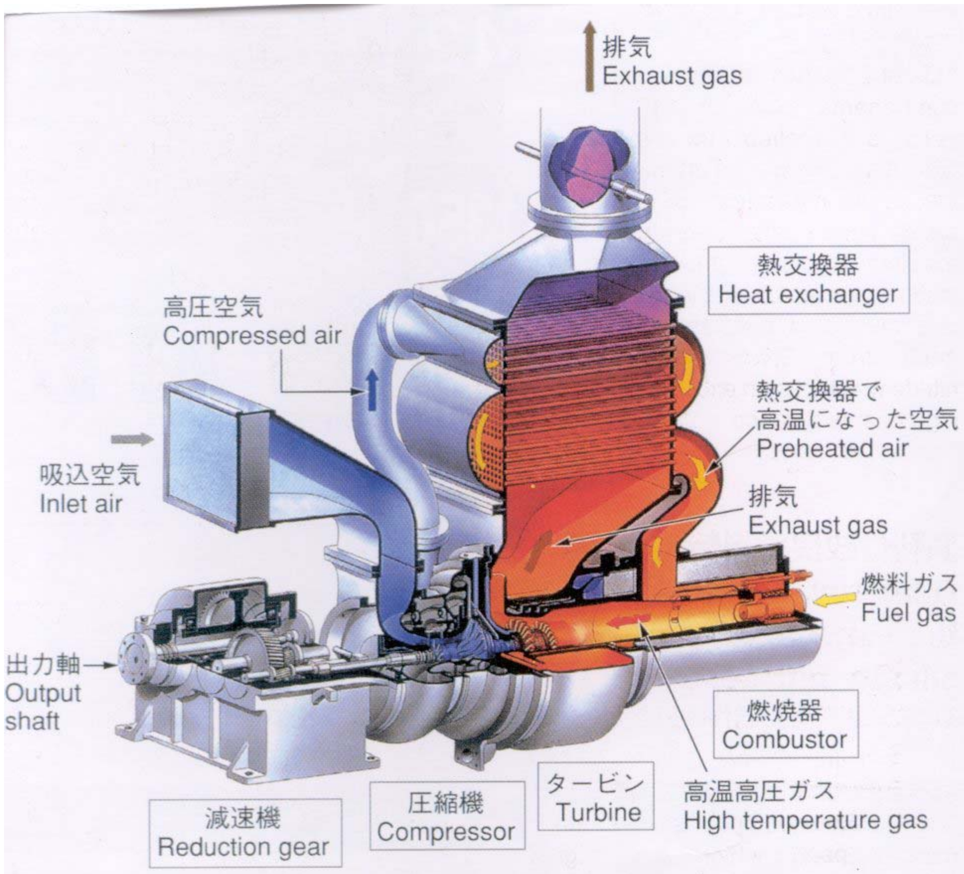
Mechanical configurations



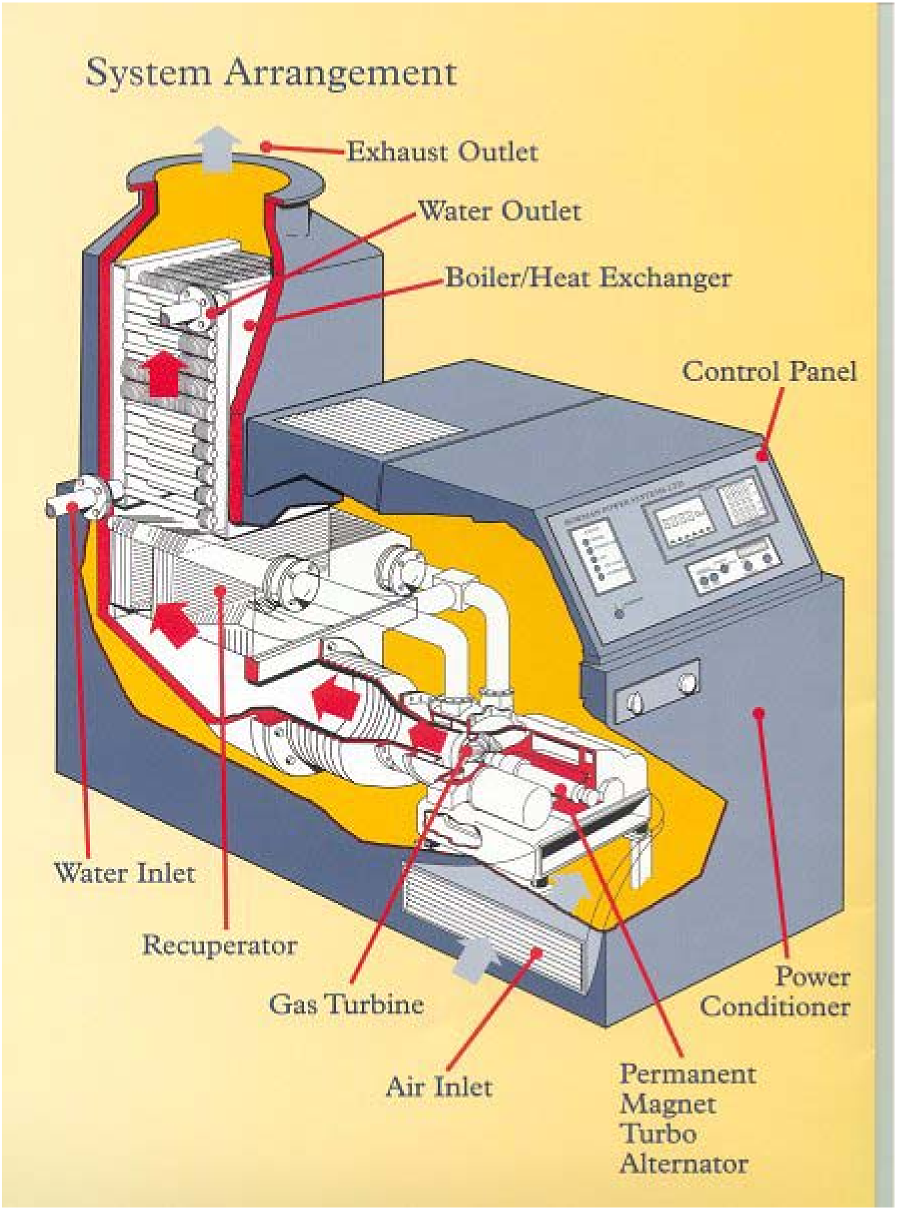
Cut View of CGT302 Ceramic Gas Turbine

300 kW Ceramic Gas Turbine For Co-generation

300 kW Ceramic Gas Turbine



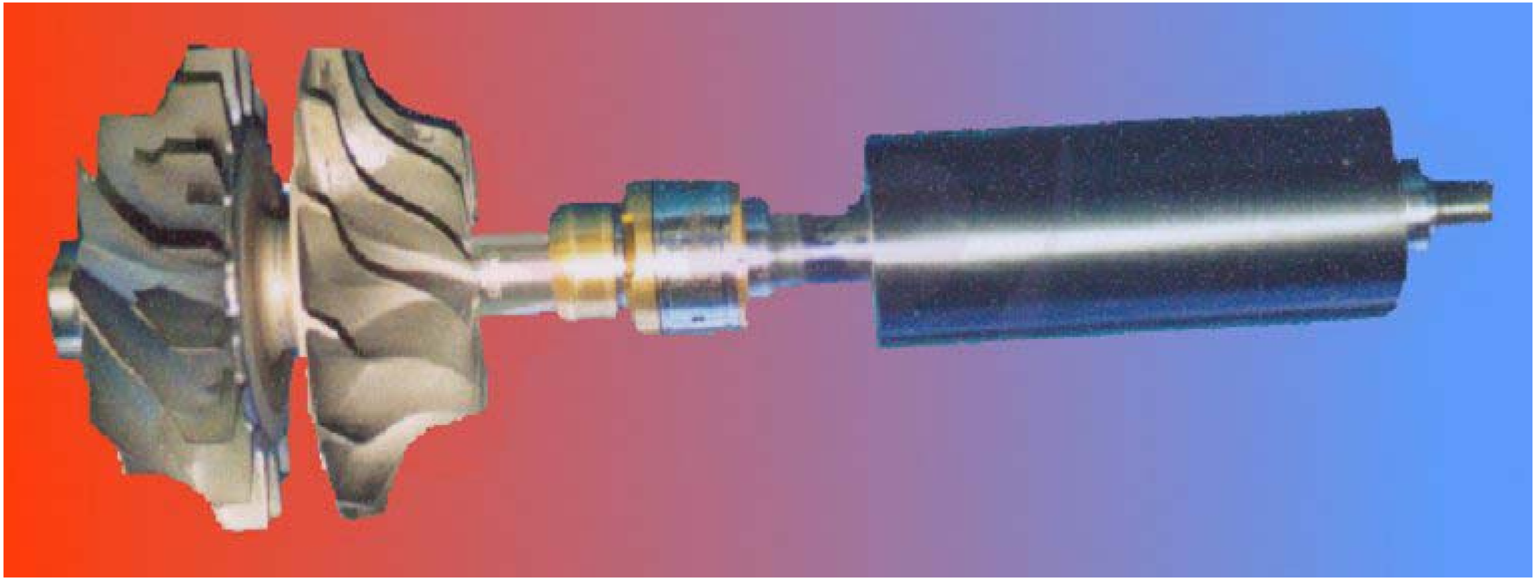
CGT301の概念図
(Conceptual plan of CGT301)



Small Gas Turbine Cogen System 80 kW

80 kW Gas Turbine Alternator

- Permanent Magnet
- Rare Earth Samarium Cobalt Magnets
- Composite Sleeve
- High Temperature Capability



F18 Hornet Just Supersonic Close to Sea Level

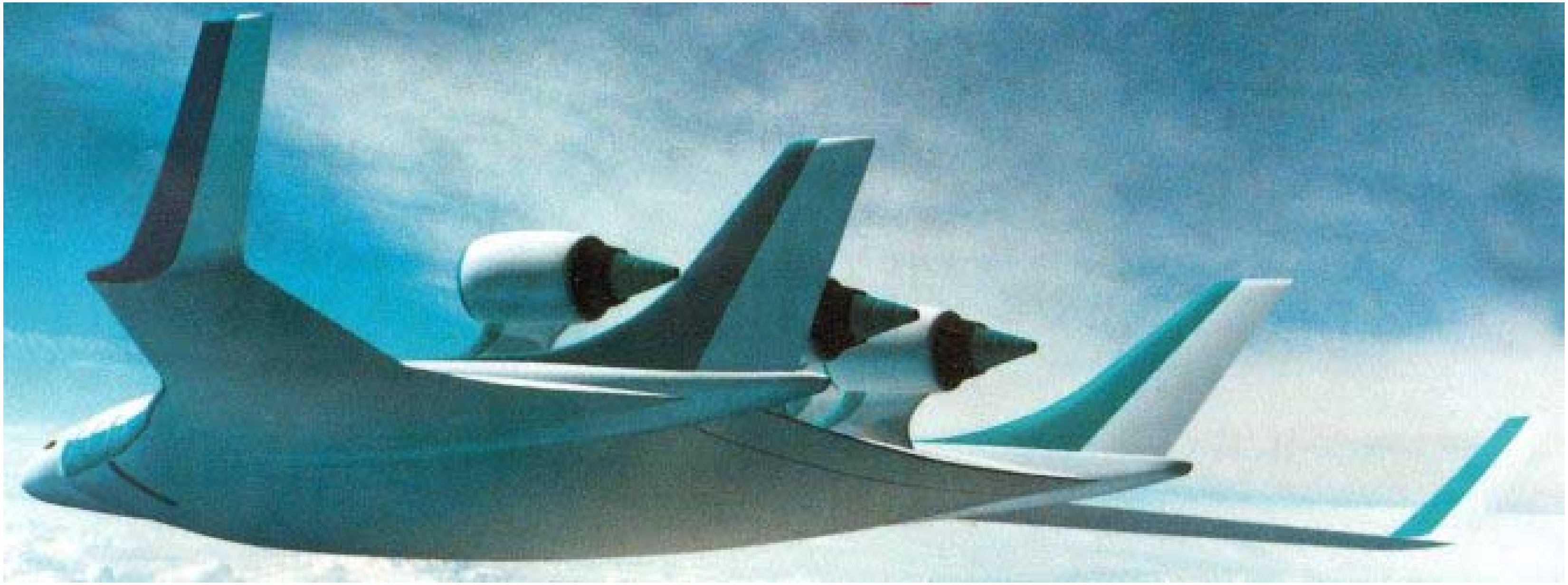
Boeing B2 Bomber Transonic

SR-71B Showing Shock Diamonds

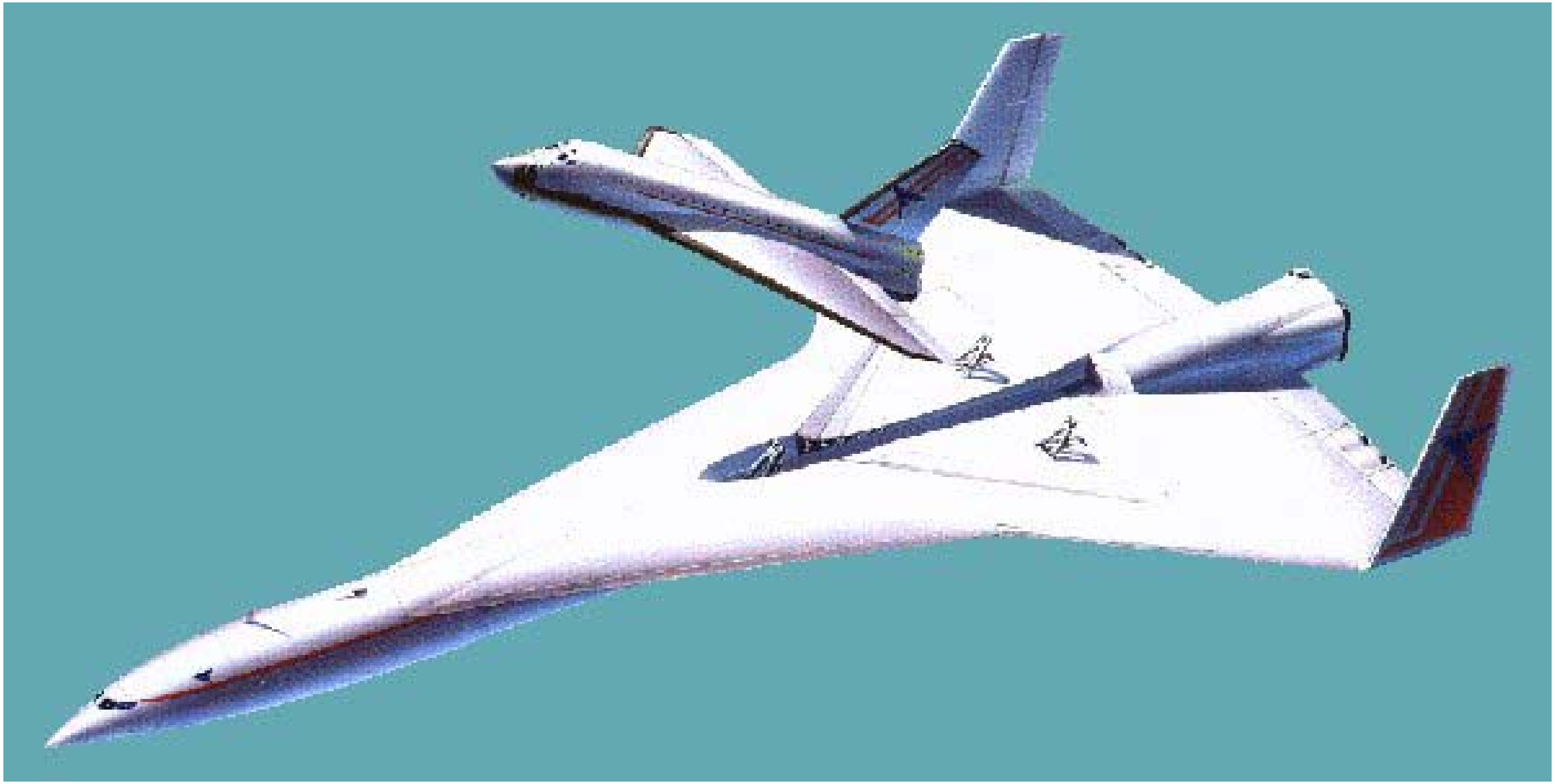
Dryden Flight Research Center EC92-1284 Photographed 1992
SR-71B take-off with "shock diamonds" in the exhaust. NASA photo

A3XX Double-Decker

Flying Wing Idea

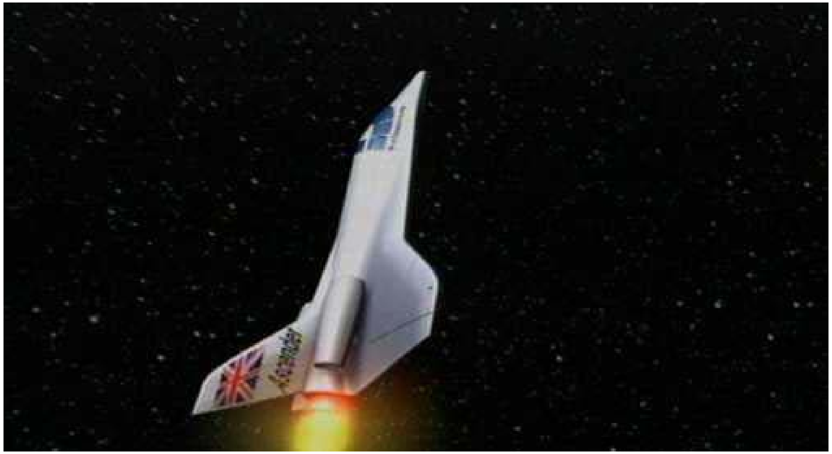


Space Bus Launch



Sub-orbital Craft Launch

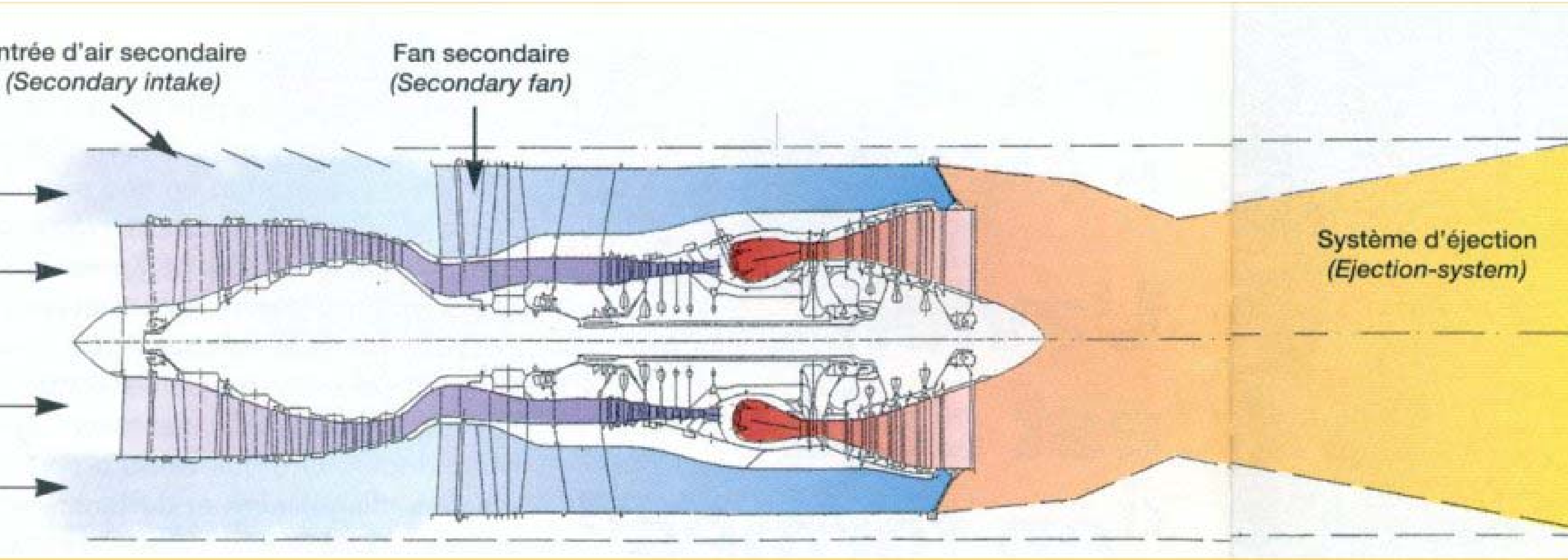
Ascender Space Plane



Space Plane in Sub-orbit

Boeing SST

Proposed SST Engine
(Super Sonic Transport)



Apache Attack Helicopter

Observational UAV

Israelian Drone (Eagle)

Electronic War Drone (UAV)

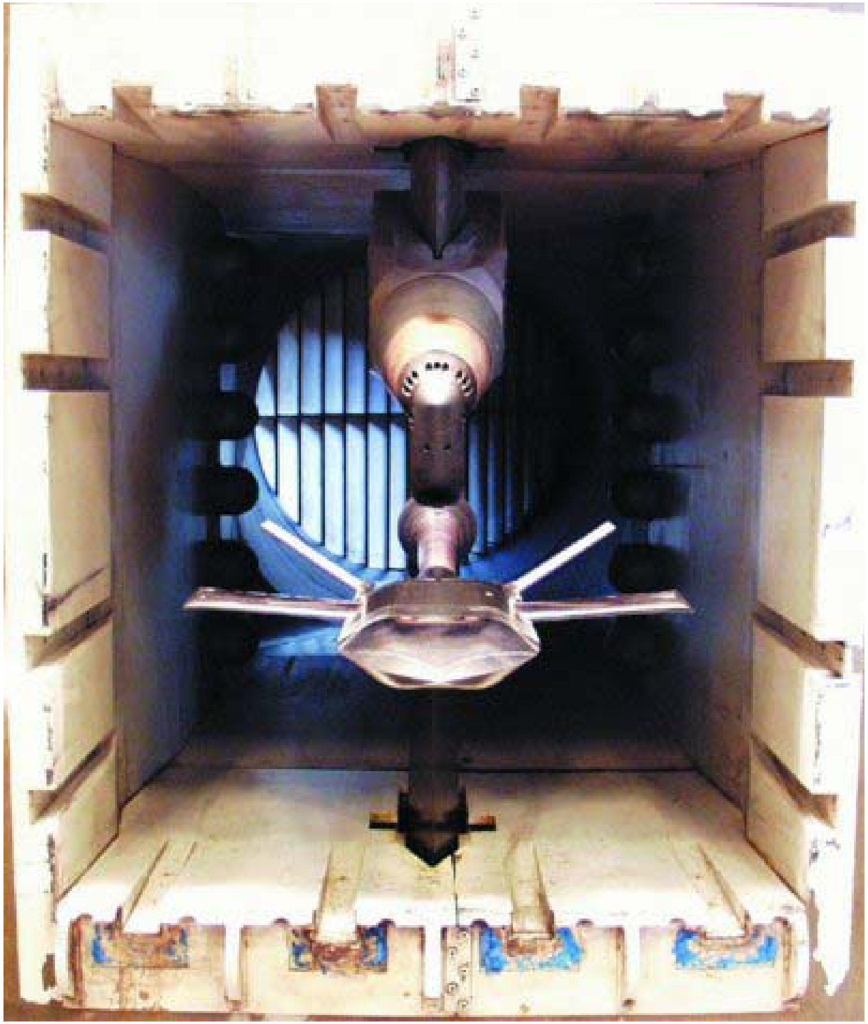
Saab UAV

NASA UAV (DAST)

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC80-14090 Date: 1980 Photo by: NASA

DAST in Flight

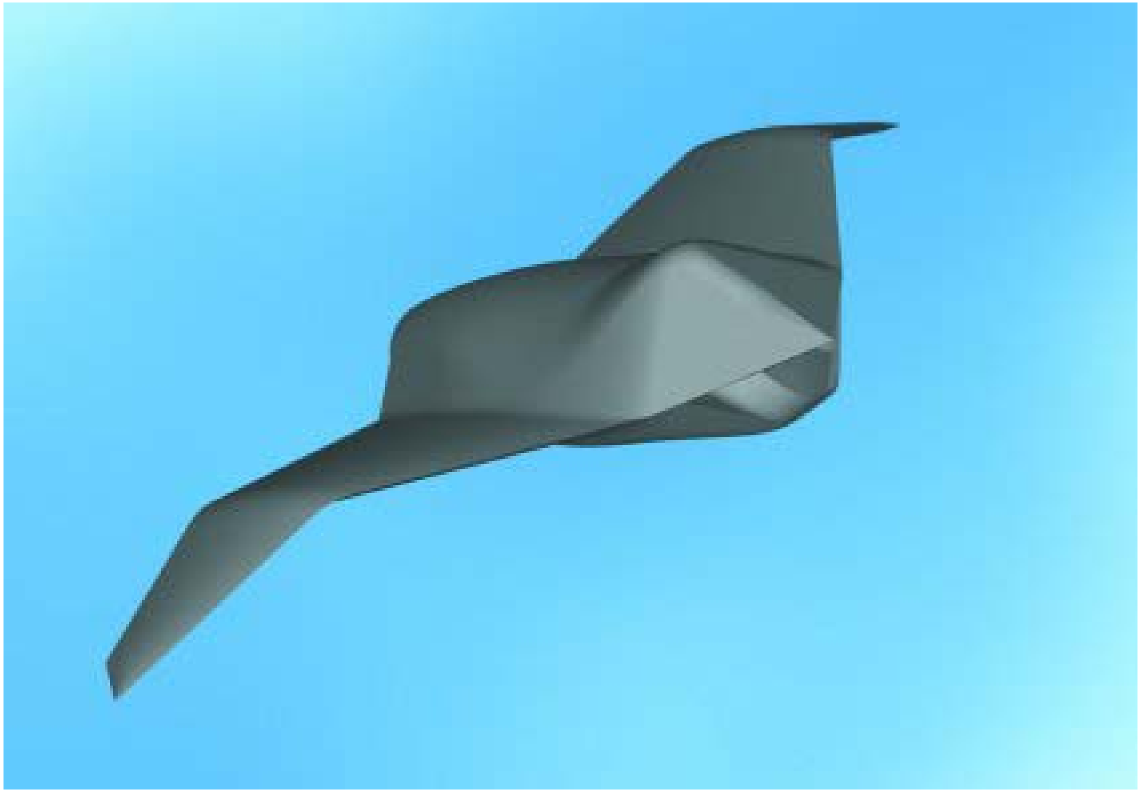
UAV Saab Sharc



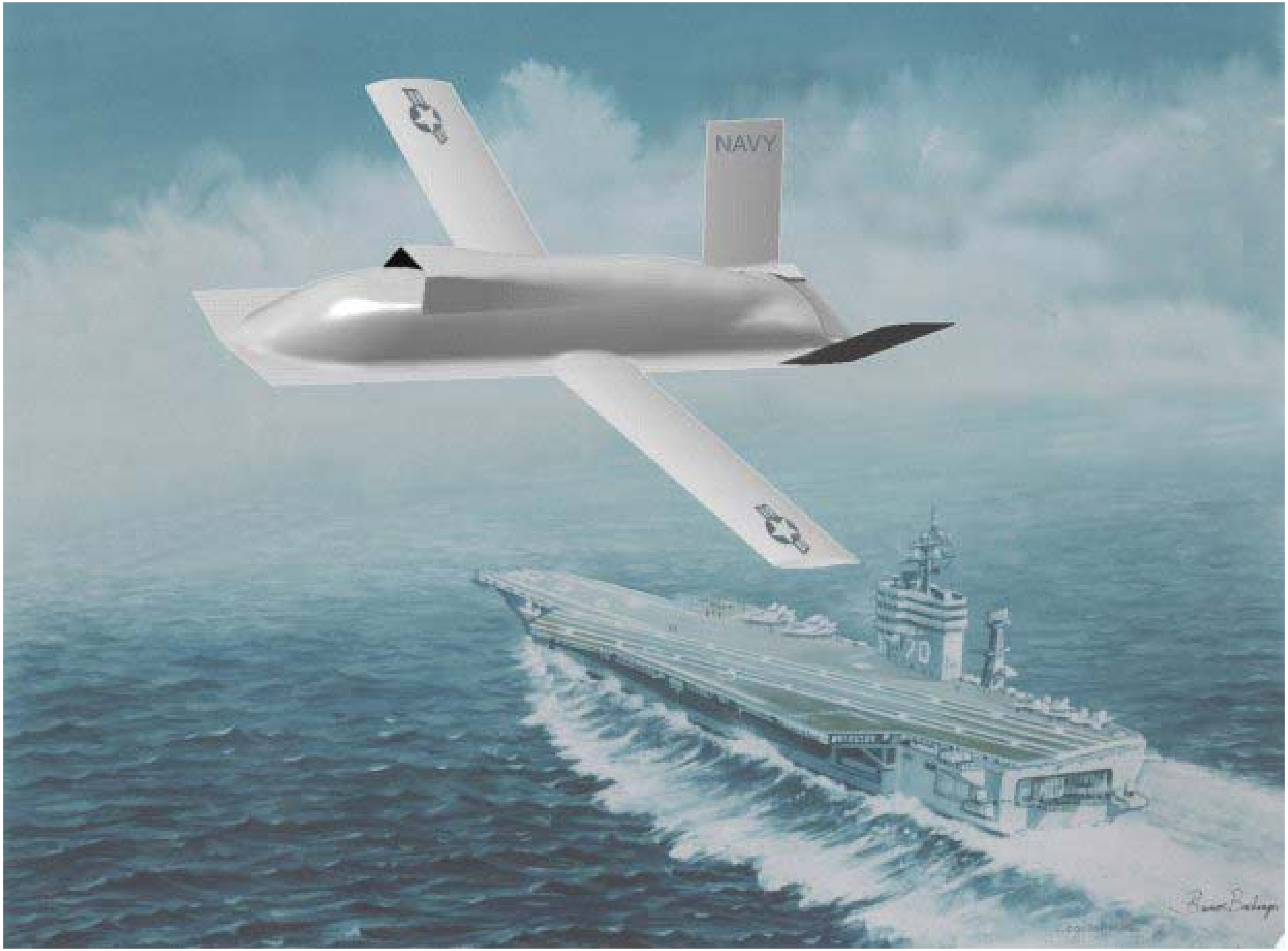
UAV Microdrone

Boeing X-45 Combat UAV

Dassault UAV

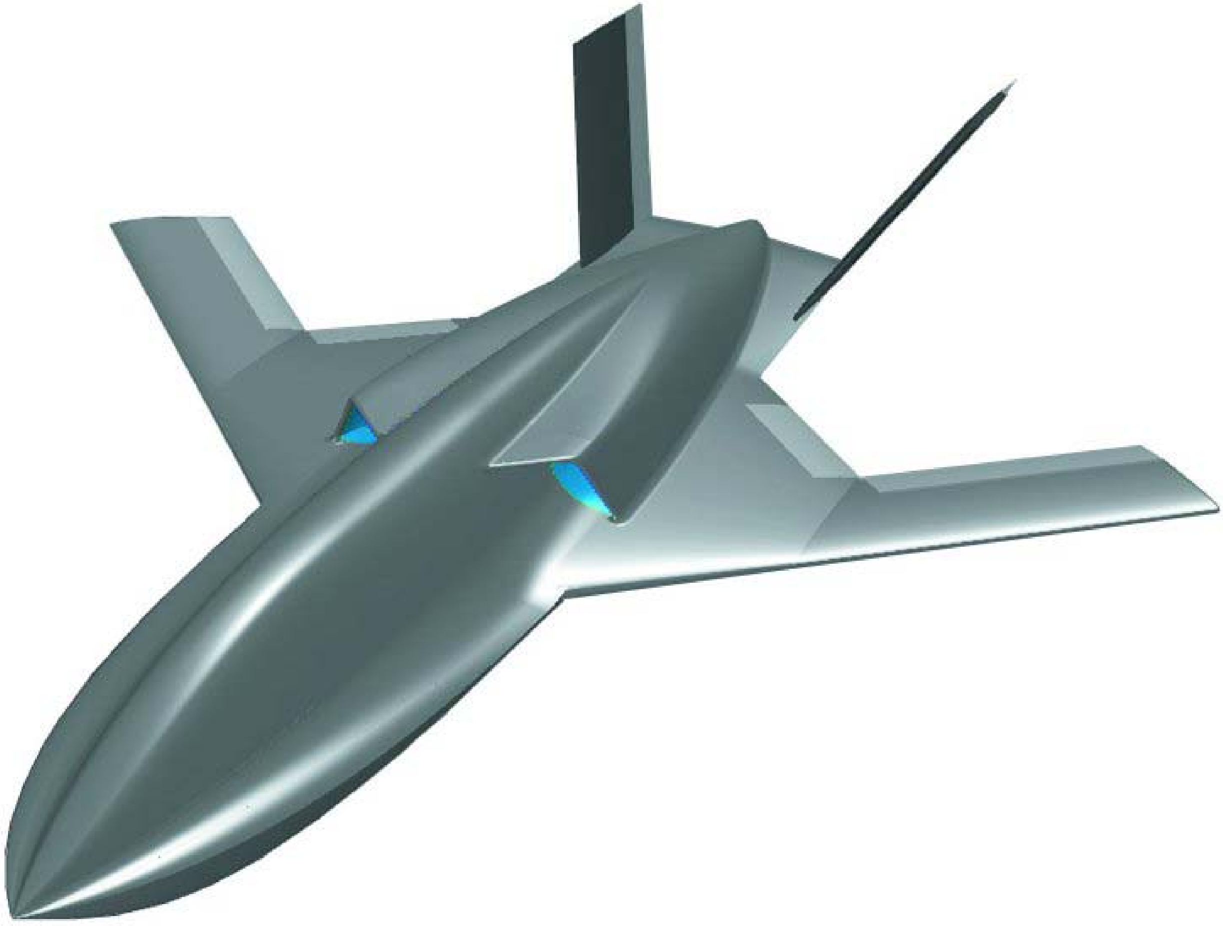


Boeing UAV MRE



UAV Dassault Aeronef

UAV Attack Drone



Hydrogen Plane

Aircraft Can Be Very Reliable, but!