



沈阳航空航天大学
SHENYANG AEROSPACE UNIVERSITY



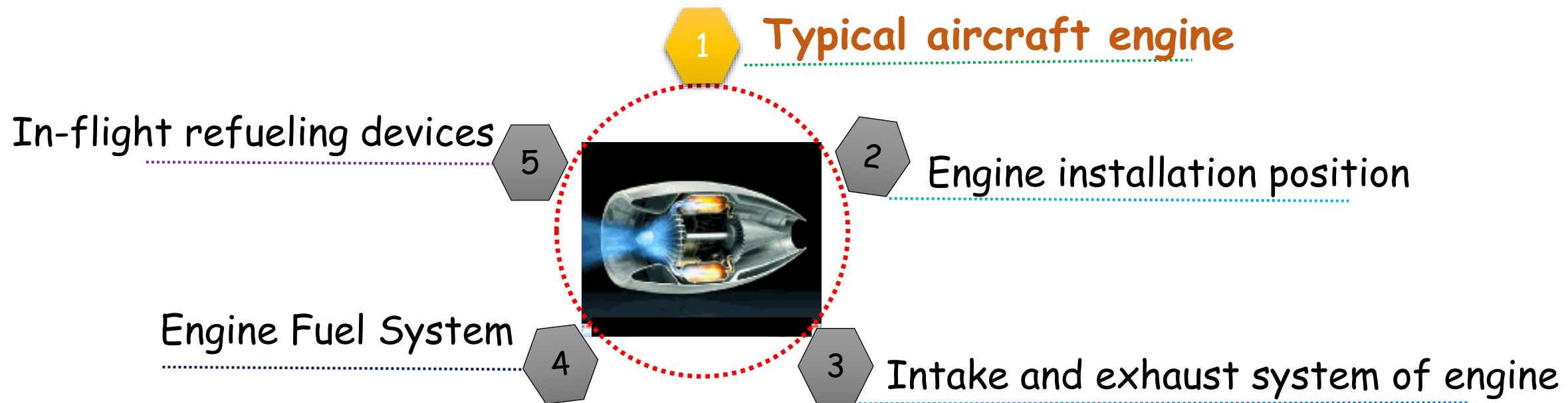
INTRODUCTION TO AEROSPACE ENGINEERING

WANG GONG DONG

FACULTY OF AEROSPACE ENGINEERING



Lecture 4 Propulsion system

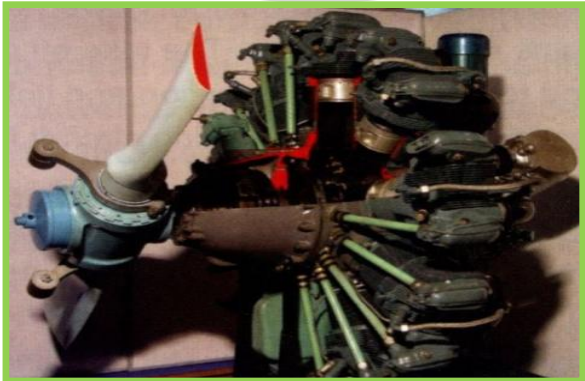




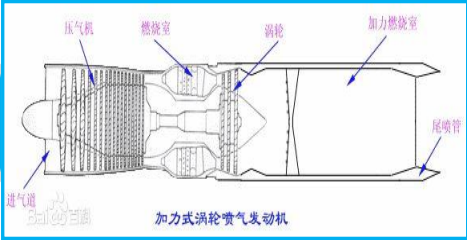
5.1 Typical aircraft engine type

Reciprocating engine

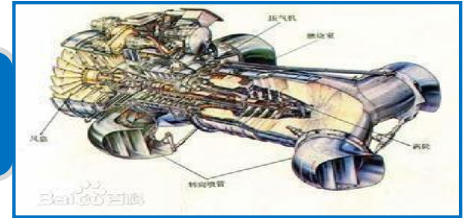
Jet engine



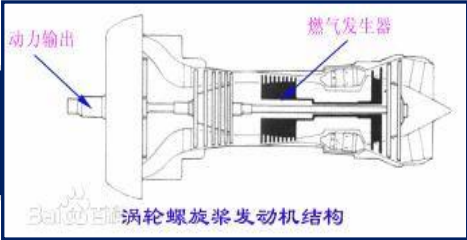
Turbojet engine



Turboshaft engine



Turboprop engine



Turbofan engines





5.2.1 Reciprocating engine

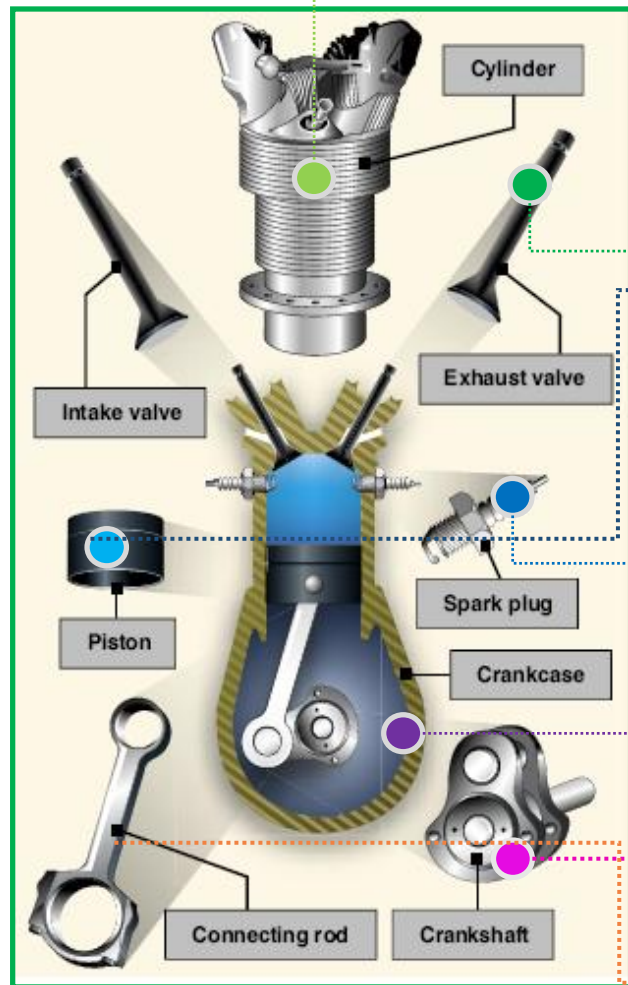
Most small aircraft are designed with piston engines. The name is derived from the back-and-forth, or reciprocating, movement of the pistons which produces the mechanical energy necessary to accomplish work.

The Reciprocating engine usually uses gasoline as the fuel to drive the propeller work. The spin of the propeller provides the thrust of the aircraft. As well, when we choose the Reciprocating engine as the aircraft power unit, it must work with the propeller.





Reciprocating engine components



Cylinder

Intake/exhaust
valve

Piston

Spark plug

Crankcase

Crankshaft

Connecting rod

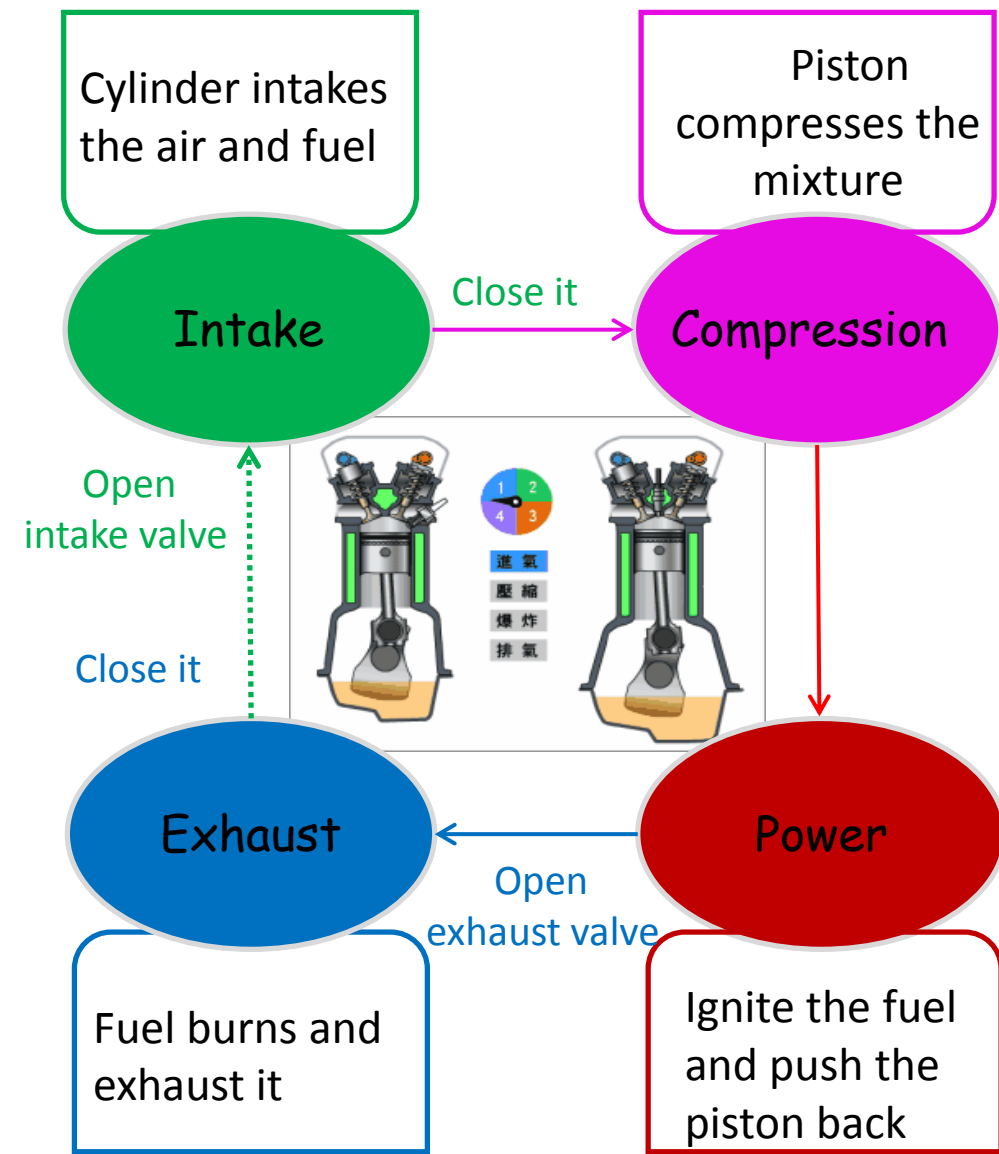
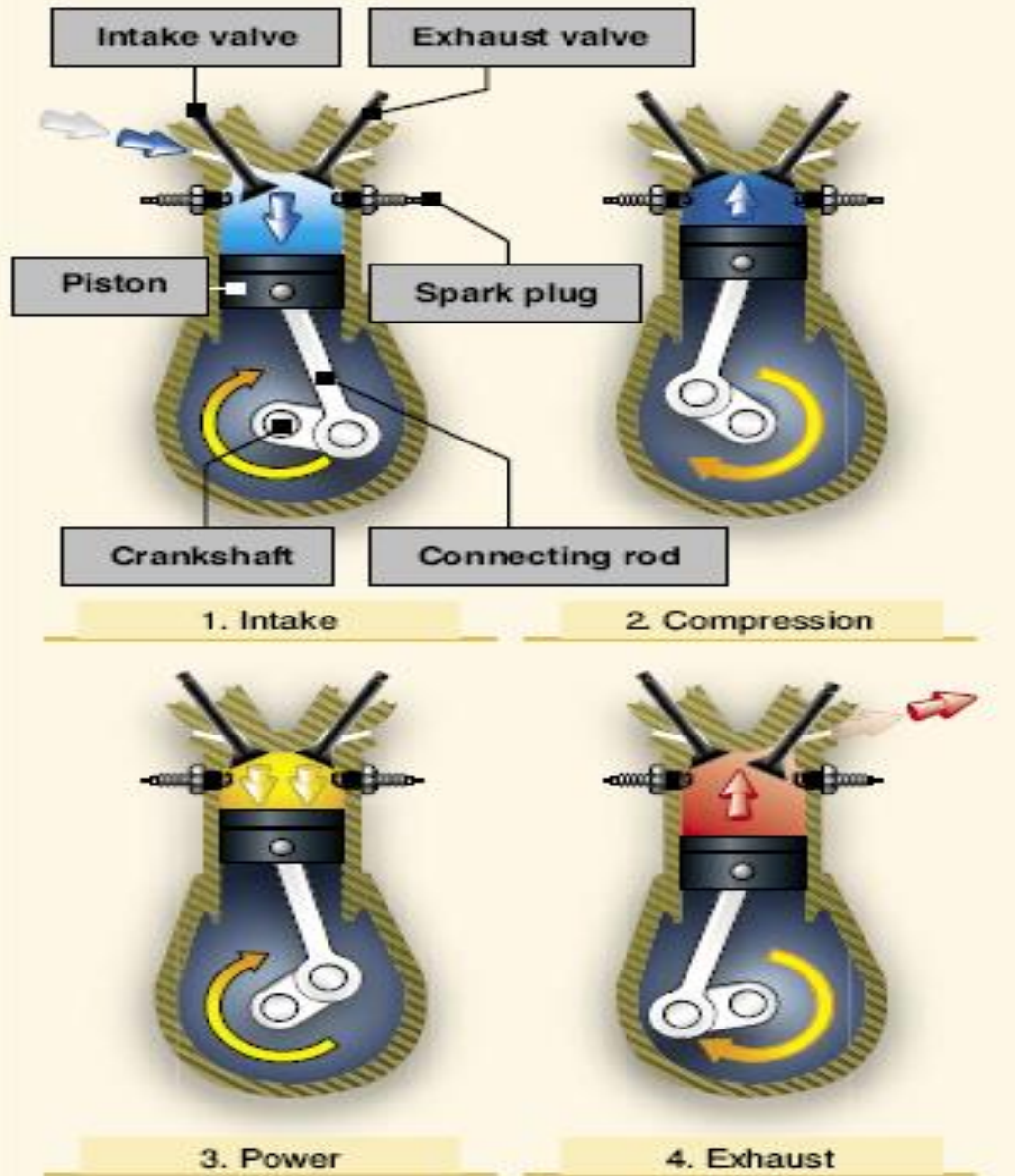


2 Reciprocating engine working principle

Reciprocating engine works by acting on the air, which Inhales the mixture of air and fuel, then compresses it by pistons ,when the mixture is compressed mostly serious (which means that the pressure is max) ignites the fuel ,the explosion of the mixture will push the pistons as well as the piston will drive crankshaft to rotate and the crankshaft will drive propeller.



Most Reciprocating aviation engine is a four-stroke engine, which means that a cylinder completes a cycle should finish four-stroke. The piston in the cylinder goes through a four-stroke divided into an intake stroke, a compression stroke, an expansion stroke and an exhaust stroke.



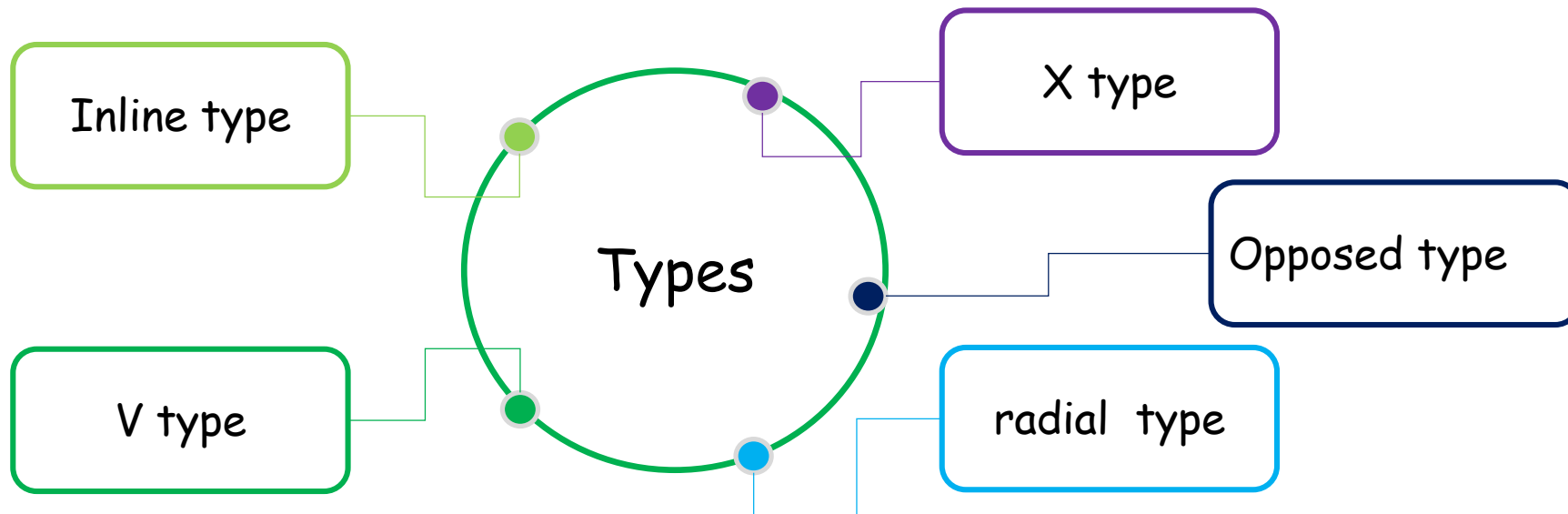


Cylinder Arrangement

In order to fulfil the requirements of power and ensure the Reciprocating engine have a smooth operation, one piston engine usually have multiple cylinders.

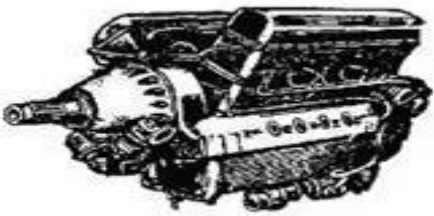
According to the different of cylinder arrangement , Reciprocating engine can be divided into inline type, V type , opposed type , X type , radial type.

In every type ,one Reciprocating engine can owns different number of cylinders. Such star type ,the number of cylinder maybe 5、 7、 9、 14、 18、 24 and so on.



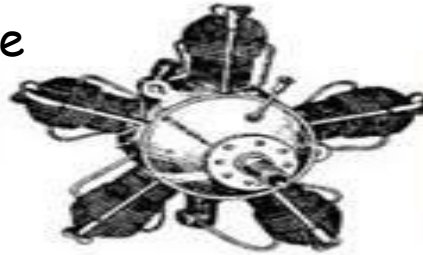


V type



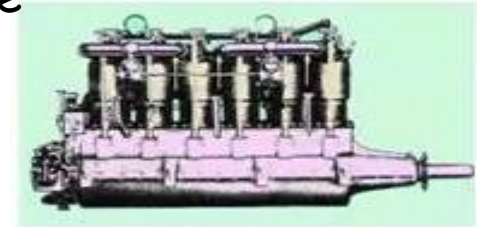
a) V型

radial type



b) 星型

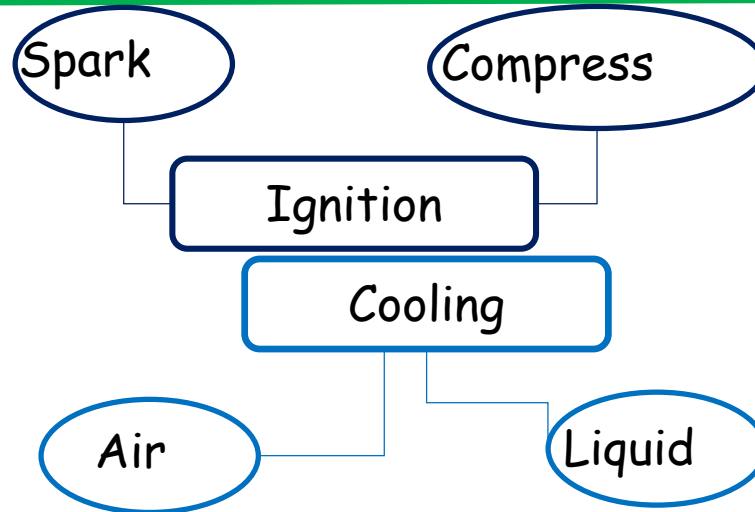
inline type



c) 直列式

Fuel and air mixture ratio

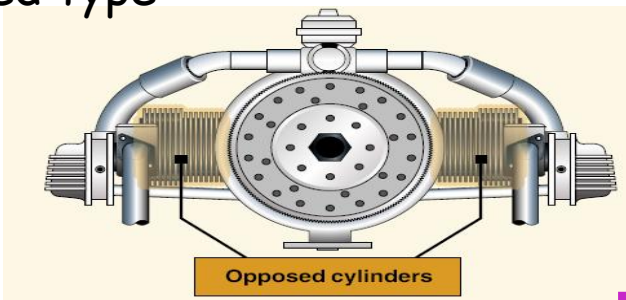
1:15



Compression ratio

5-8

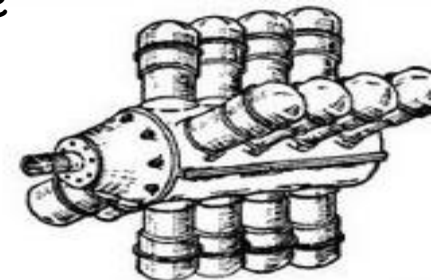
Opposed type



W type

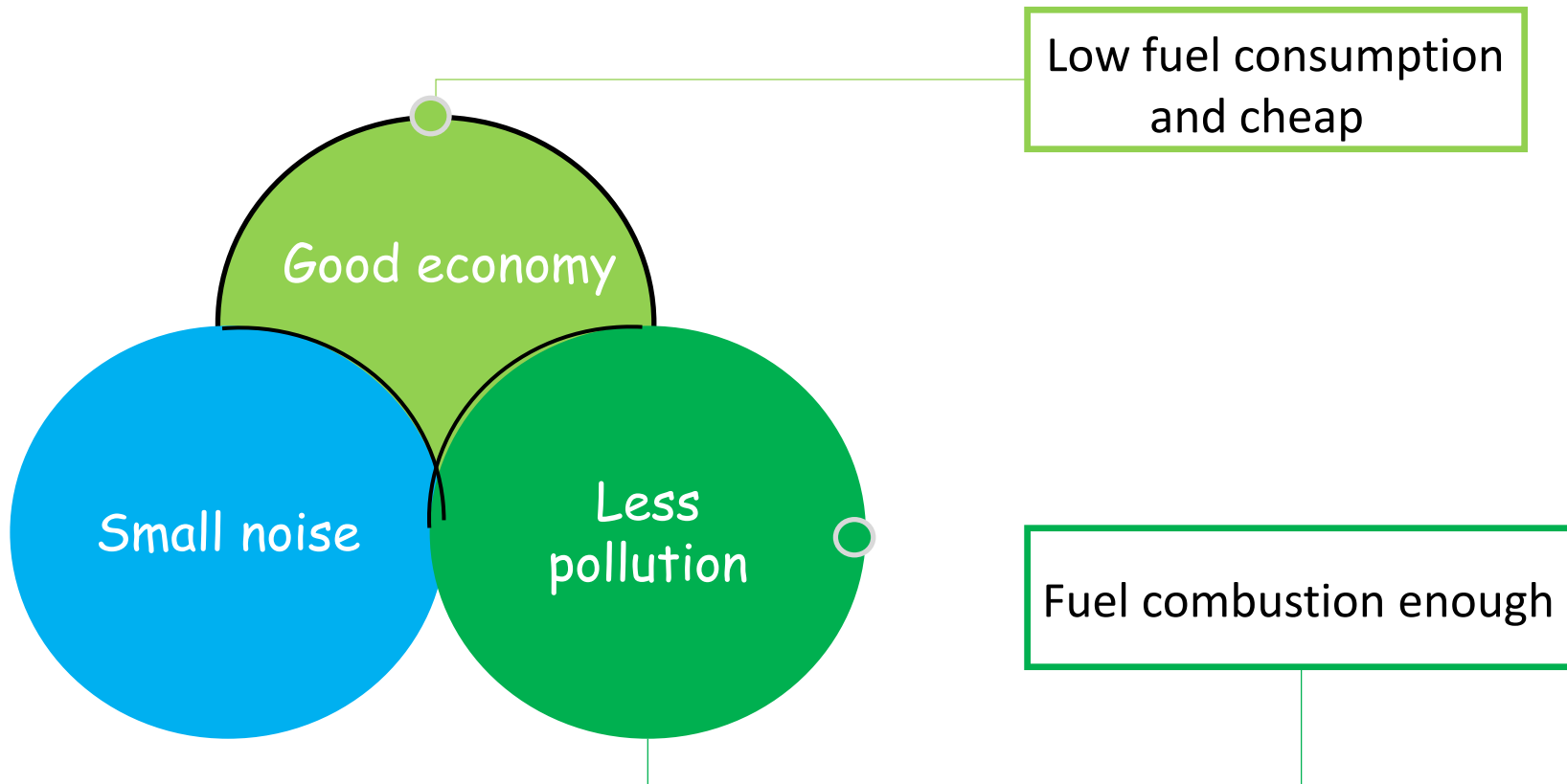


X type





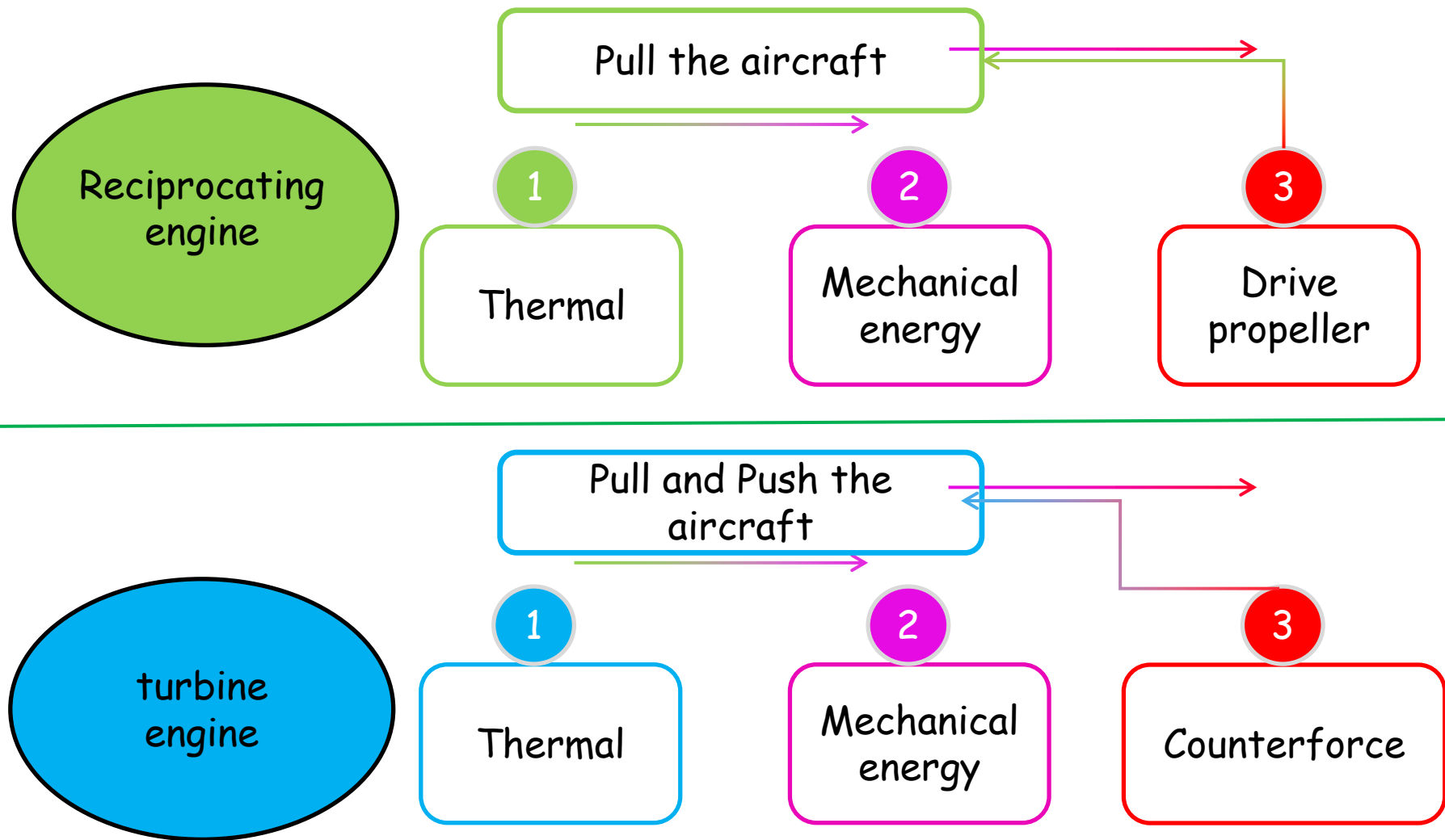
Advantage



Used in small and low speed aircraft

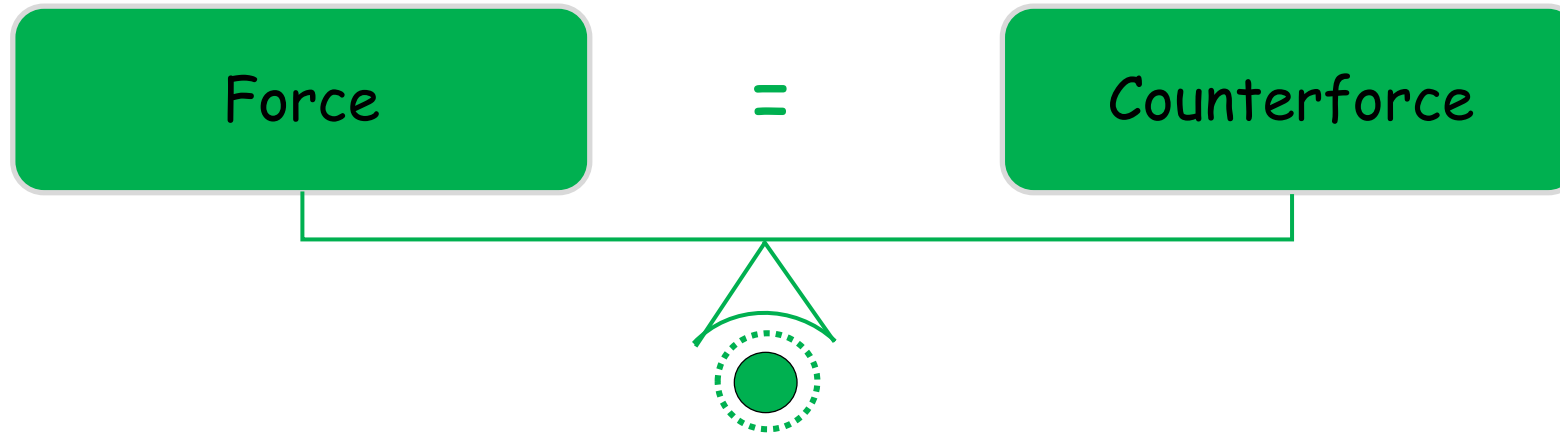


5.2 turbine engine



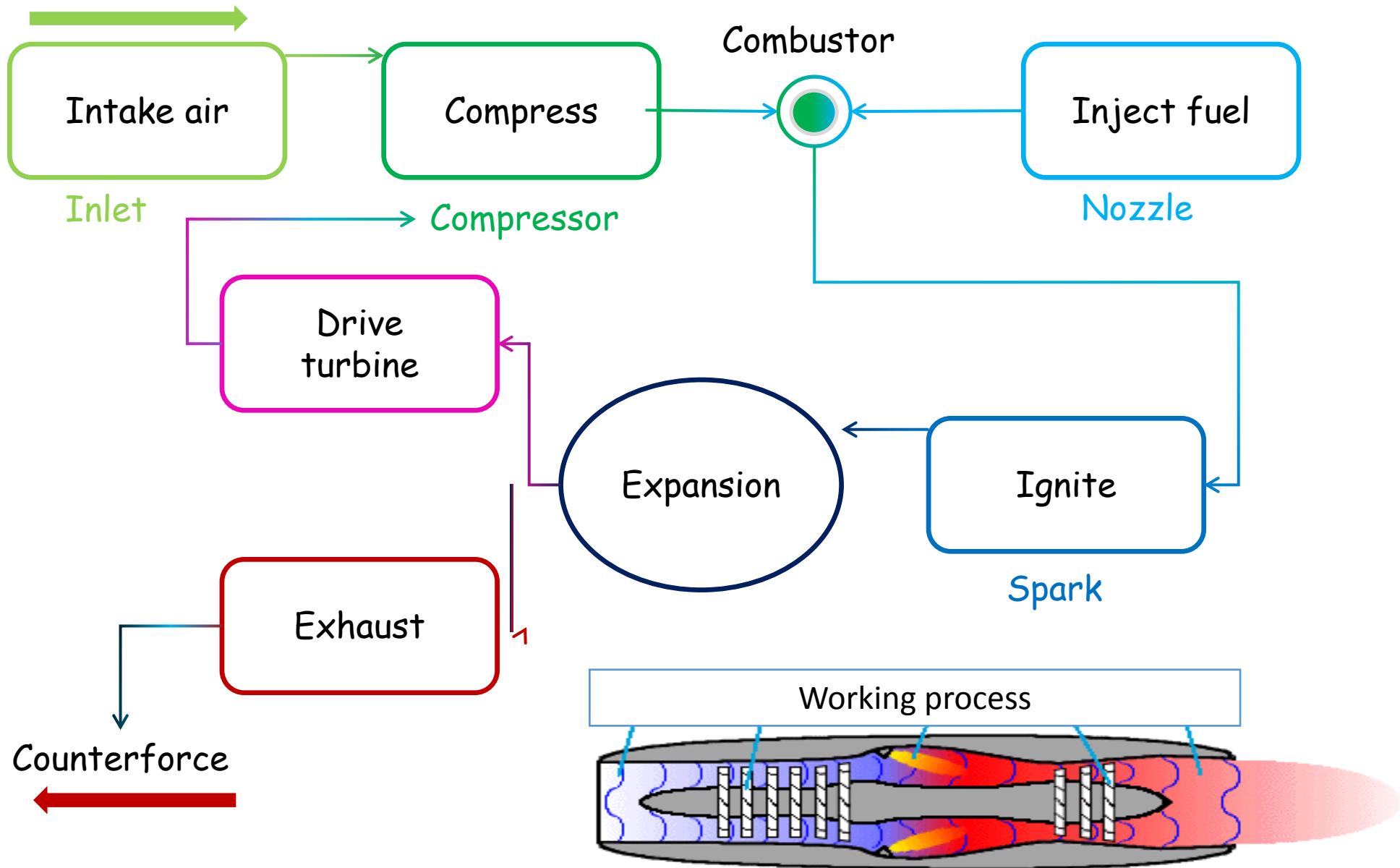


Working principle



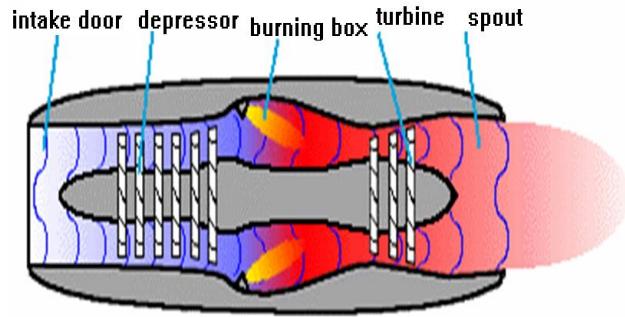
Jet engine is also acting on the air. First which intakes numerous air and compress it ,when the air is coming to the combustor, injects fuel and ignites the mixture of fuel and air, with burning of the mixture, pressure is increased sharply and exhausted the air out of the combustor with great high speed.

So, the jet engine is pushed by the exhaust air with high speed and high pressure. As well , jet engine push the aircraft go ahead with the counterforce.

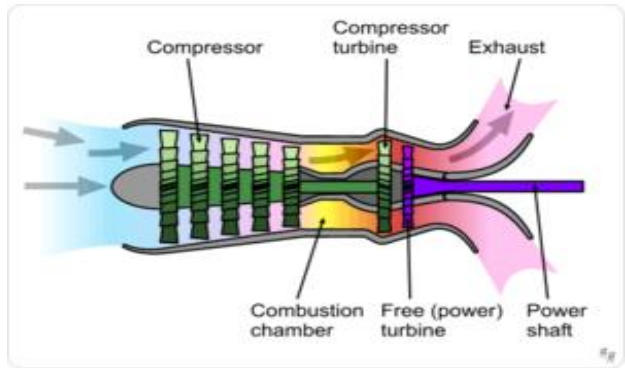
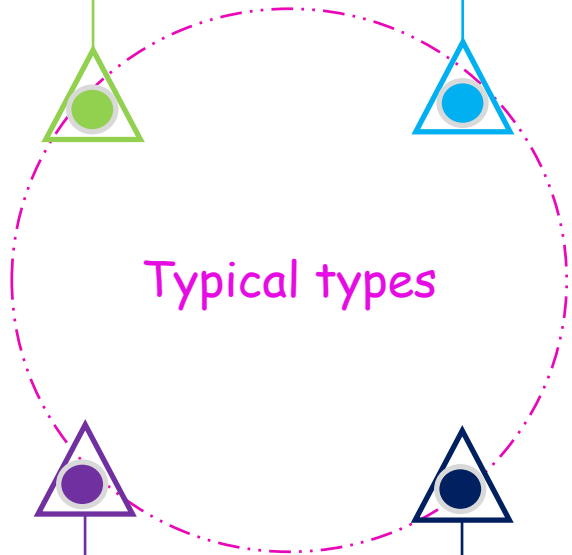
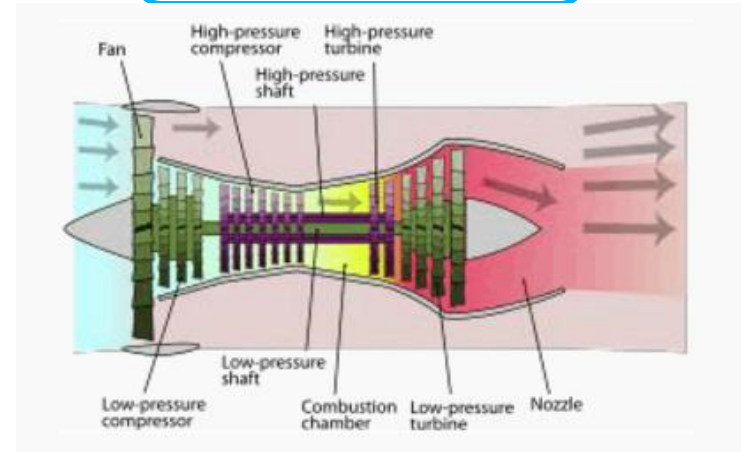




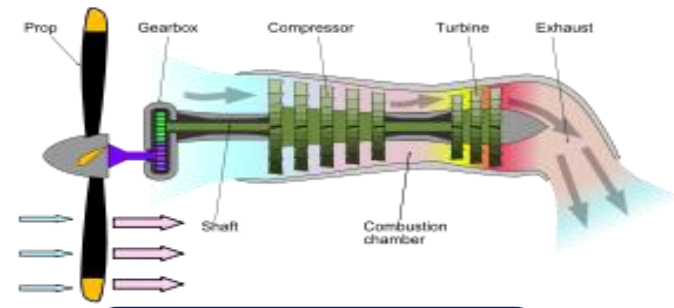
Turbojet



Turbofan



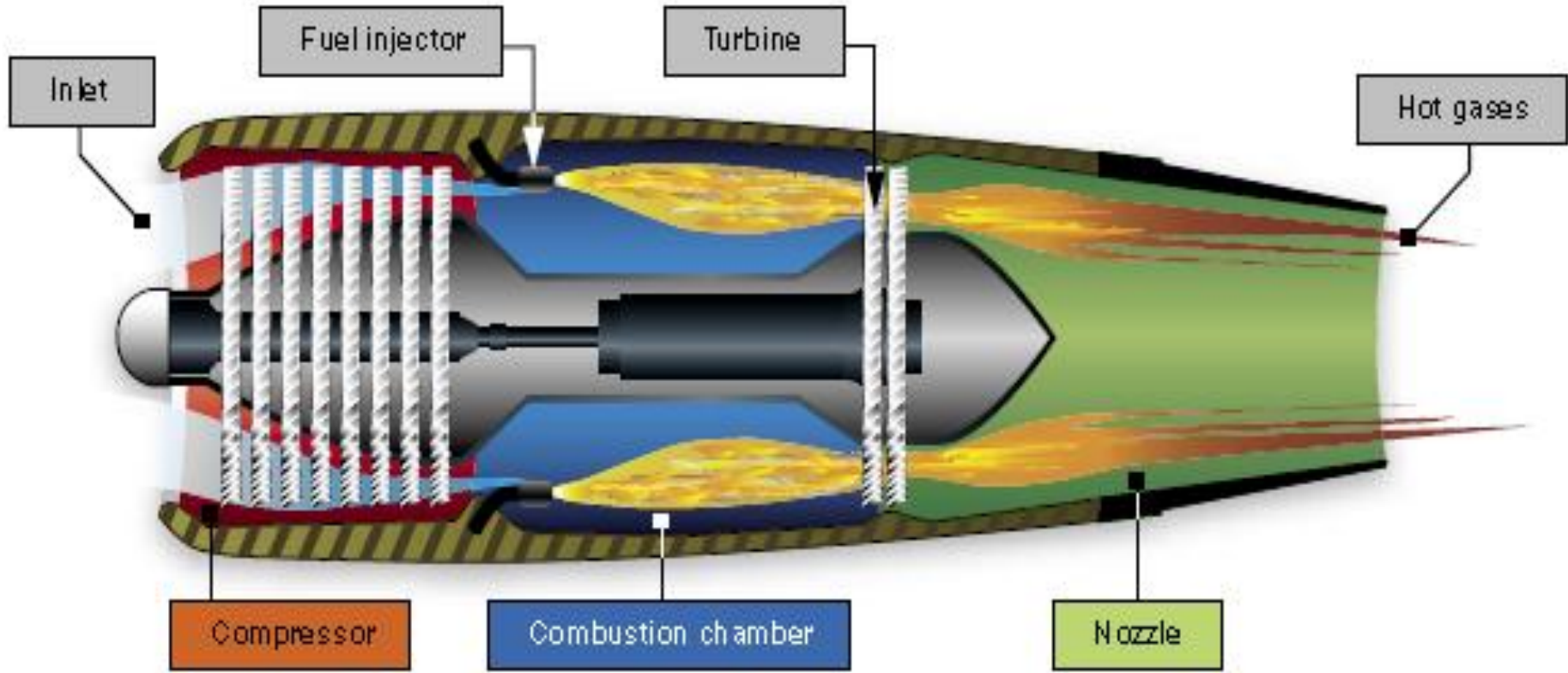
Turboshaft



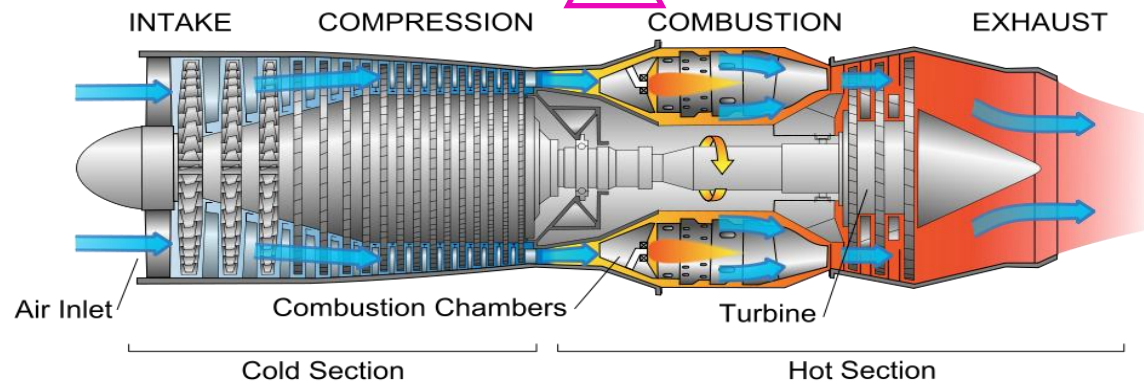
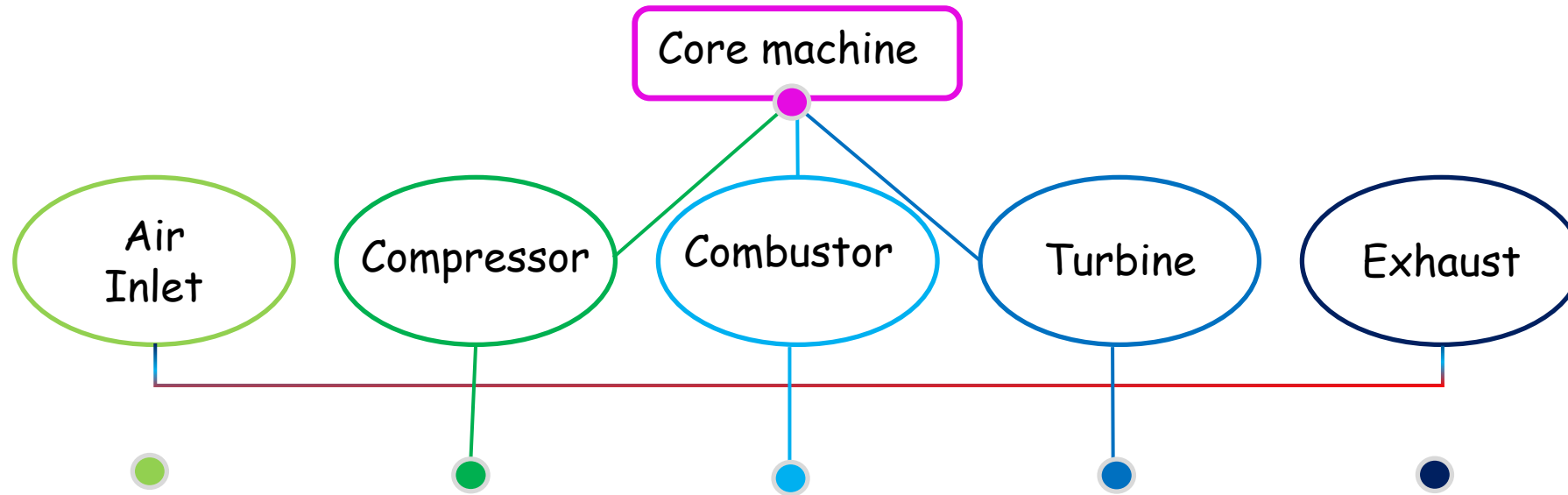
Turboprop



1 Turbojet engine



Components of turbojet engine

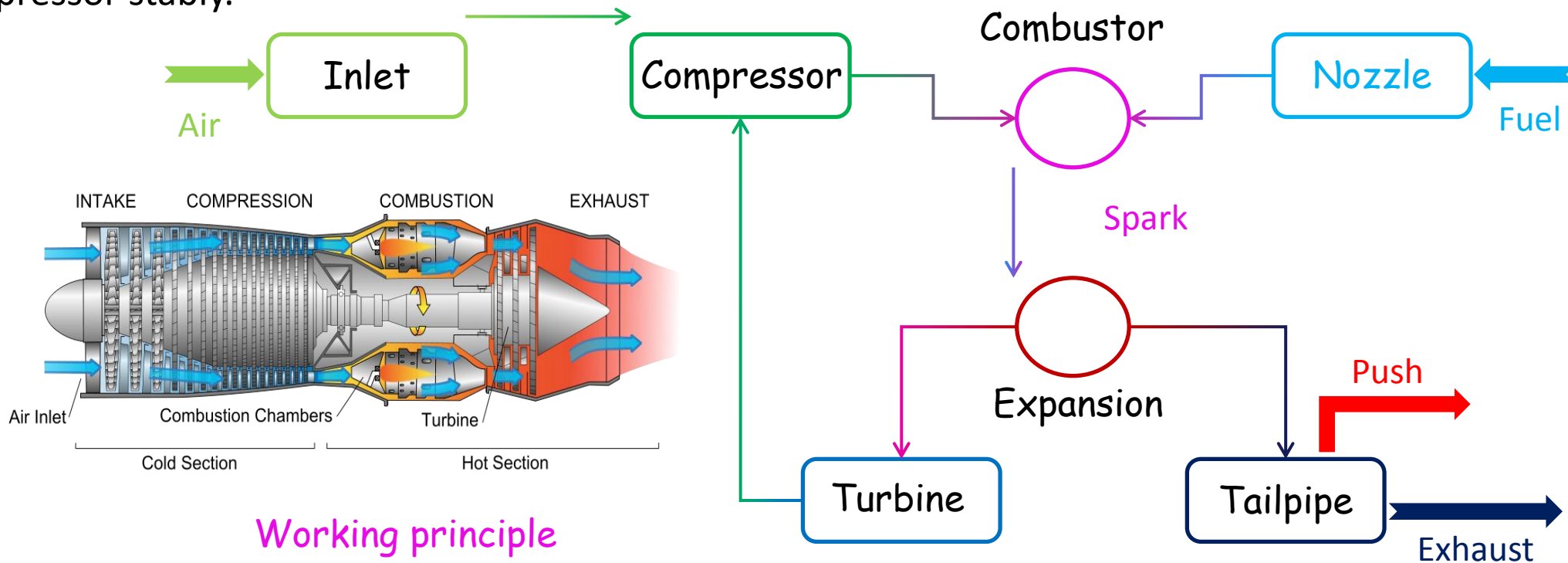


Components



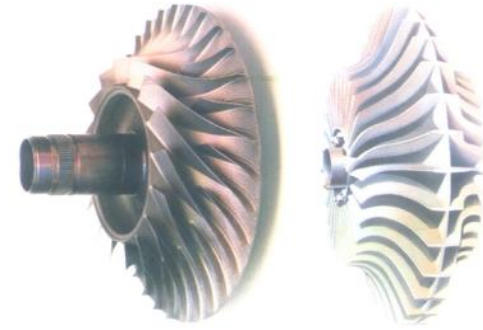
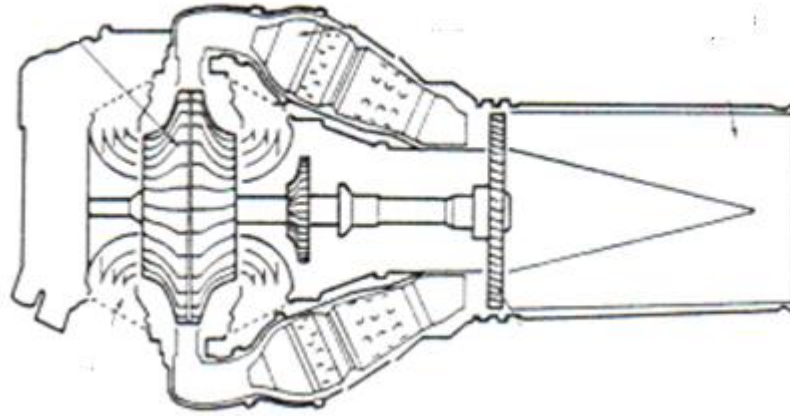
Compressor and turbine are connected on the same axis. When the high speed and pressure mixture of fuel and gas expand, which push the turbine to rotate with the axis as well as drive the compressor to rotate with the same speed.

So, the turbine and compressor rotation makes a cycle. When the mixture expand, which push the turbine and compressor rotates at the same time. When the mixture exhaust out of combustor, new air is intaked by the compressor stably.

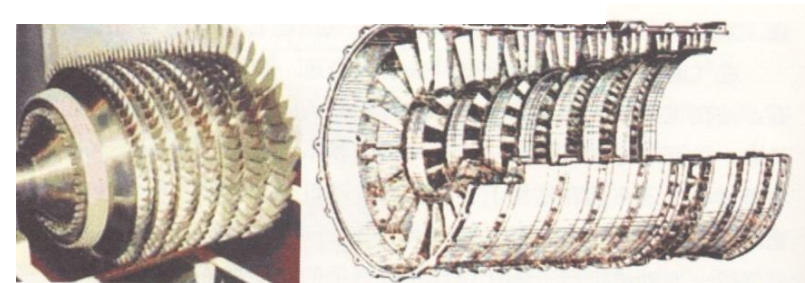
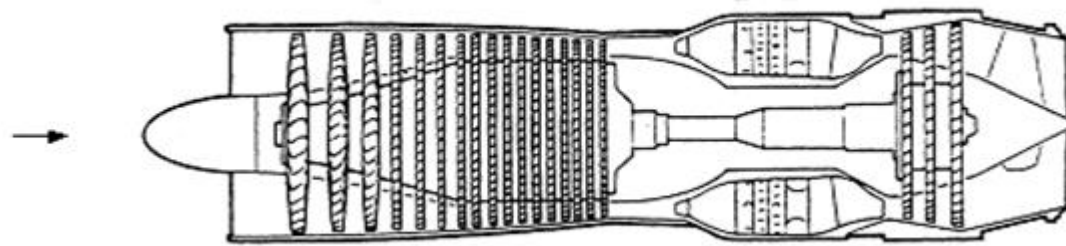




Centrifugal
Compressor



Axial
Compressor





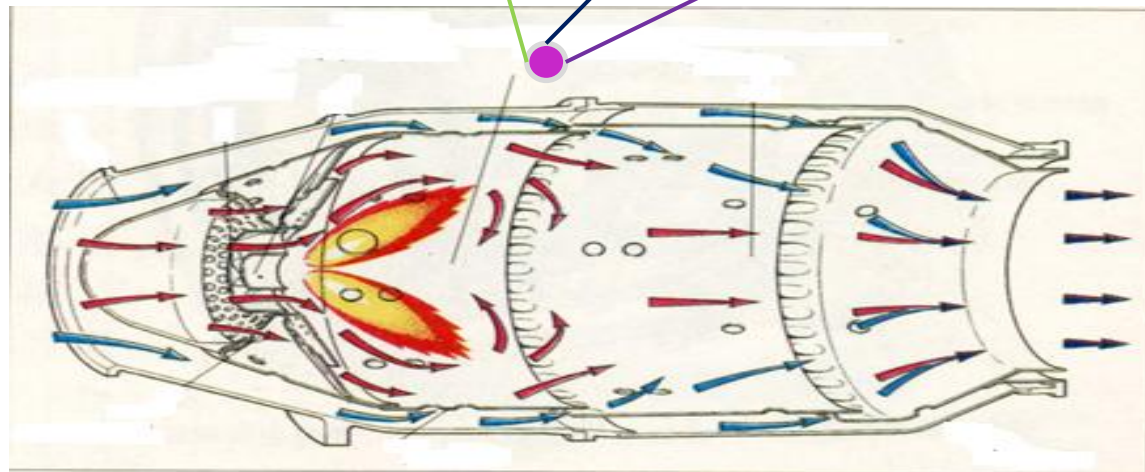
Combustor

Exhaust

combustion chamber

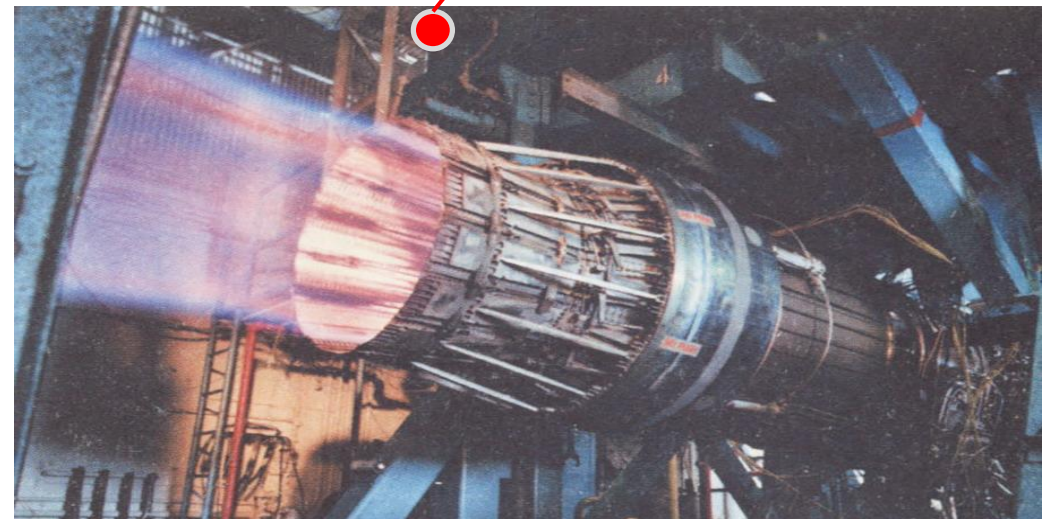
Turbine

Nozzle



Diffusion convergent type

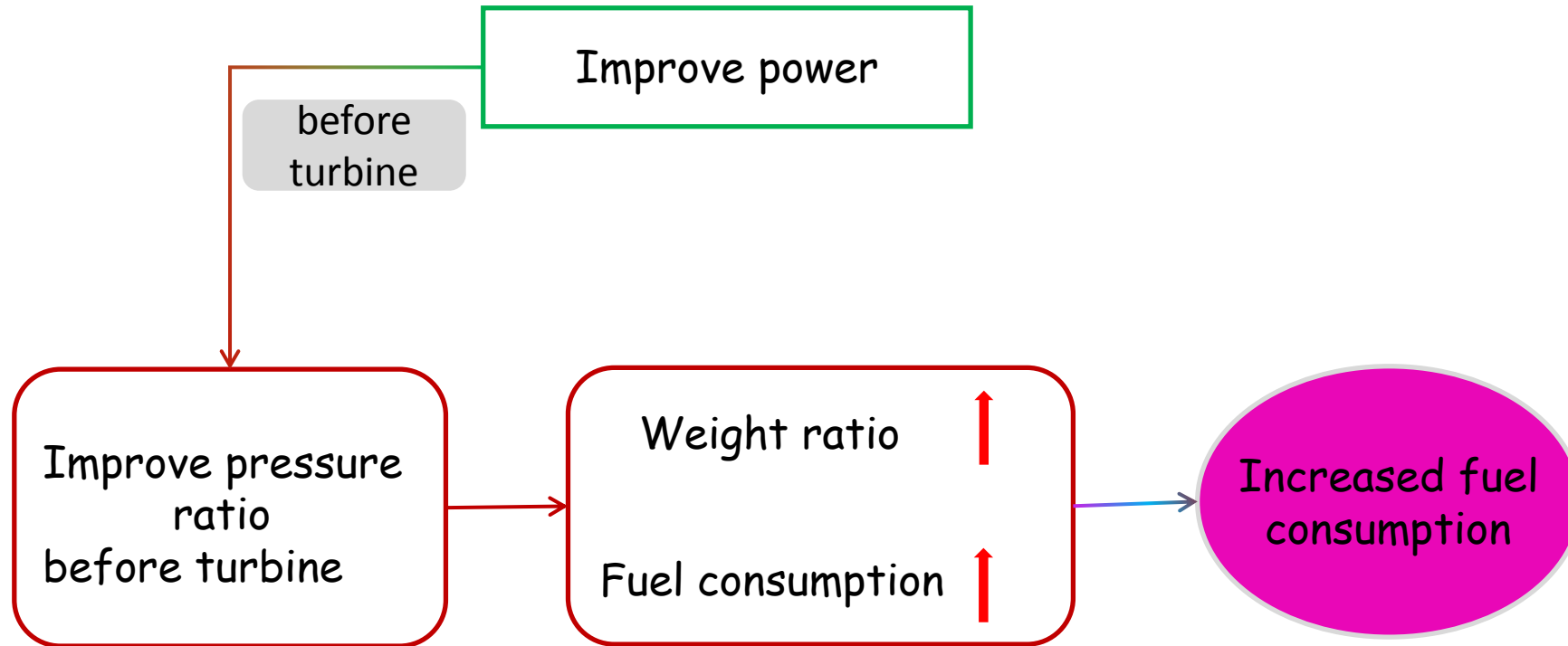
Vector type





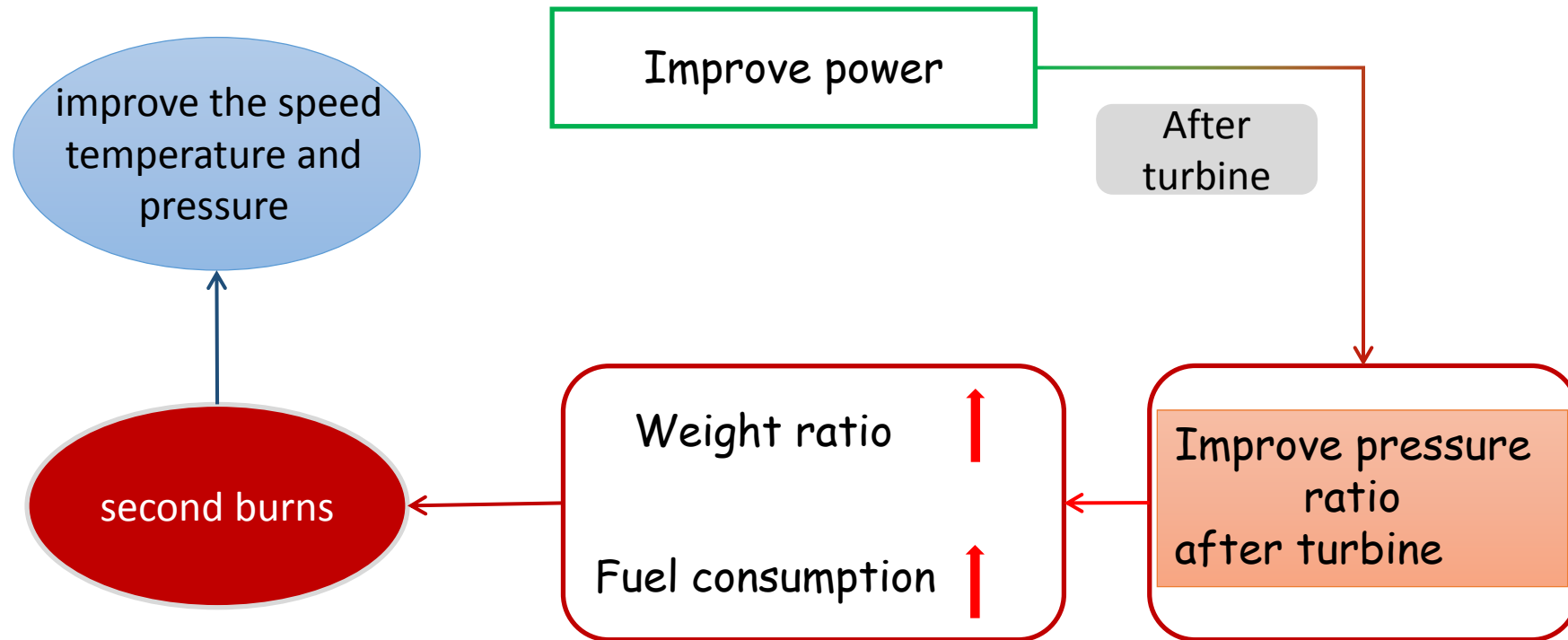
In order to improve the power of turbojet engine ,there usually has two different kinds of measures.

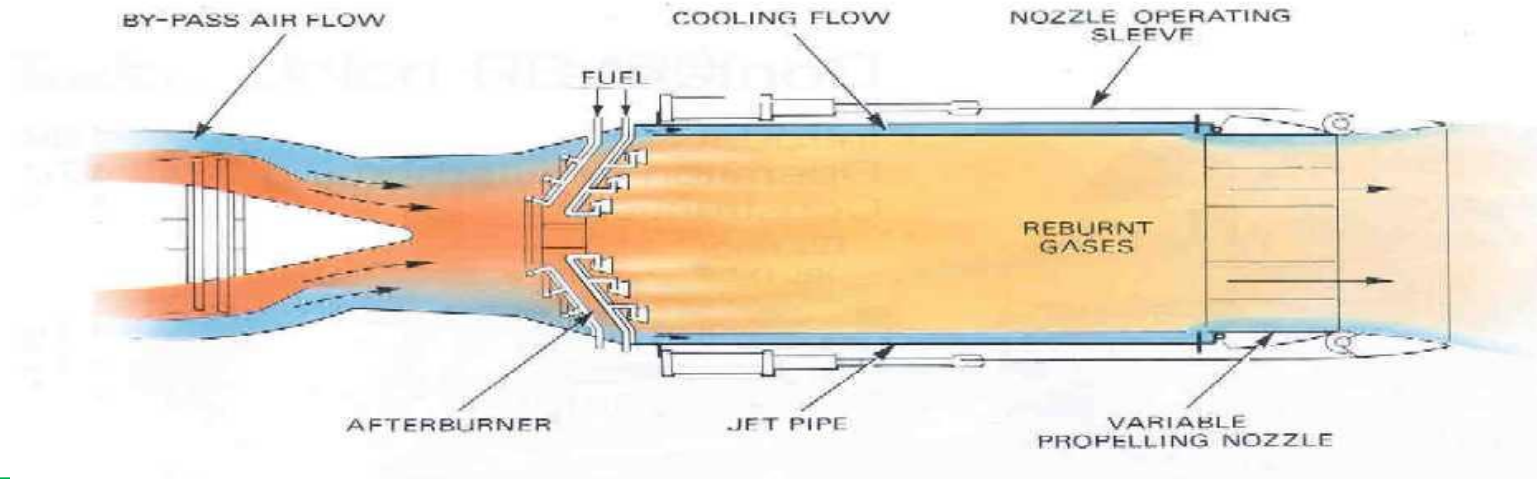
One is improve the temperature and pressure of mixture before the turbine. But when the temperature and pressure of mixture is too high, exhaust speed will also improve which will loss more and more kinetic energy. The process lead to a contradiction of weight ratio and fuel consumption.





The other is improve the temperature and pressure after the turbine. In this way we can arrange afterburner after the turbine, when the burned mixture exhaust out of the combustor and comes into the afterburner, we inject fuels into the afterburner and make the second burns to improve the speed、temperature and pressure.





Turbojet engine

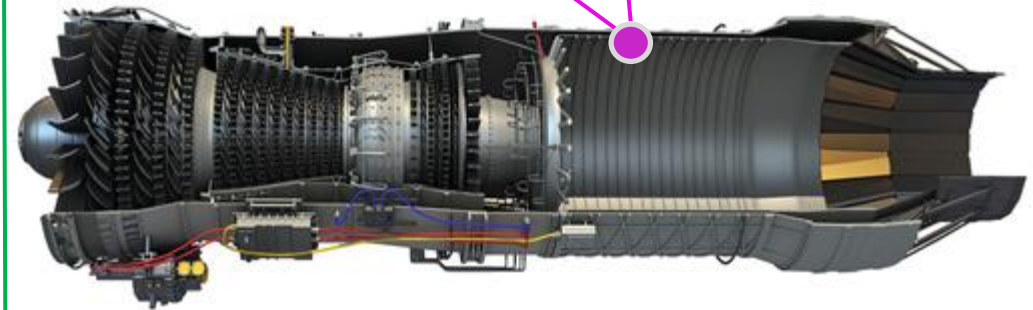
Advantage

- Accelerated fast
- Simple design

Disadvantage

- Increased fuel consumption

F100 Afterburner

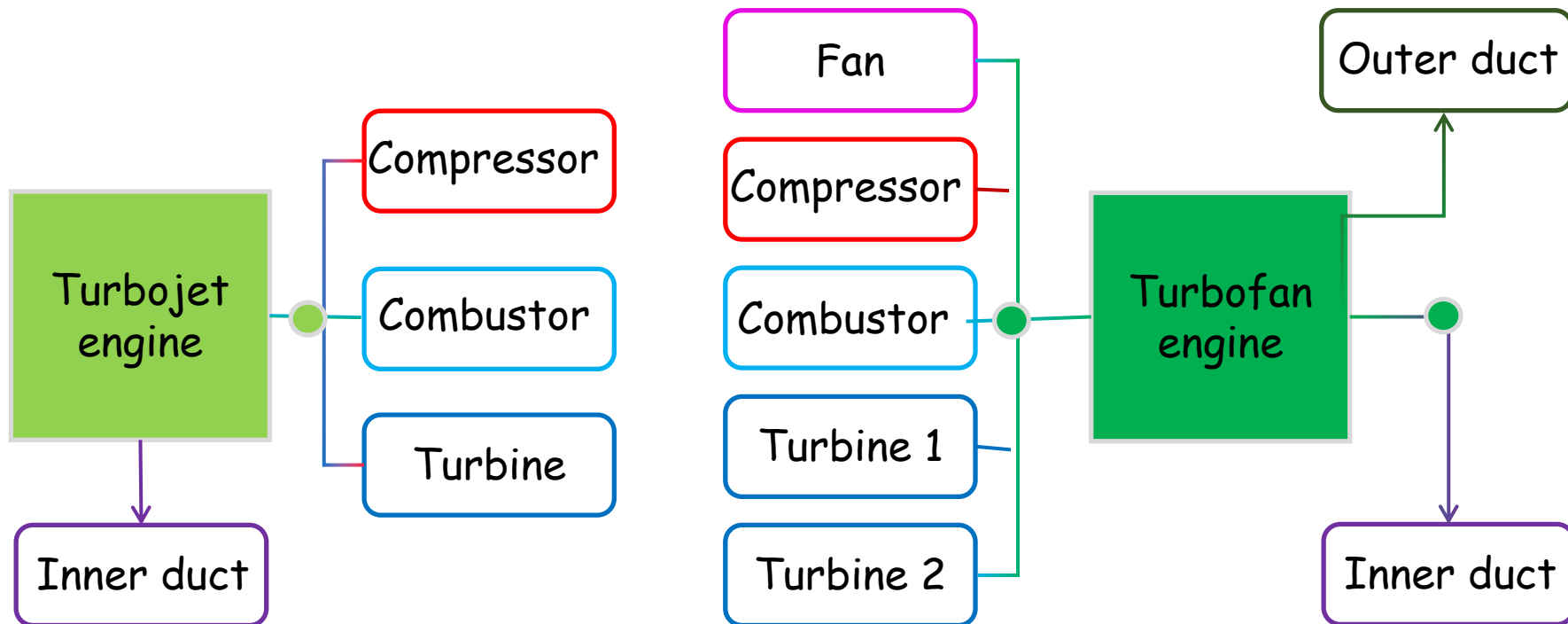


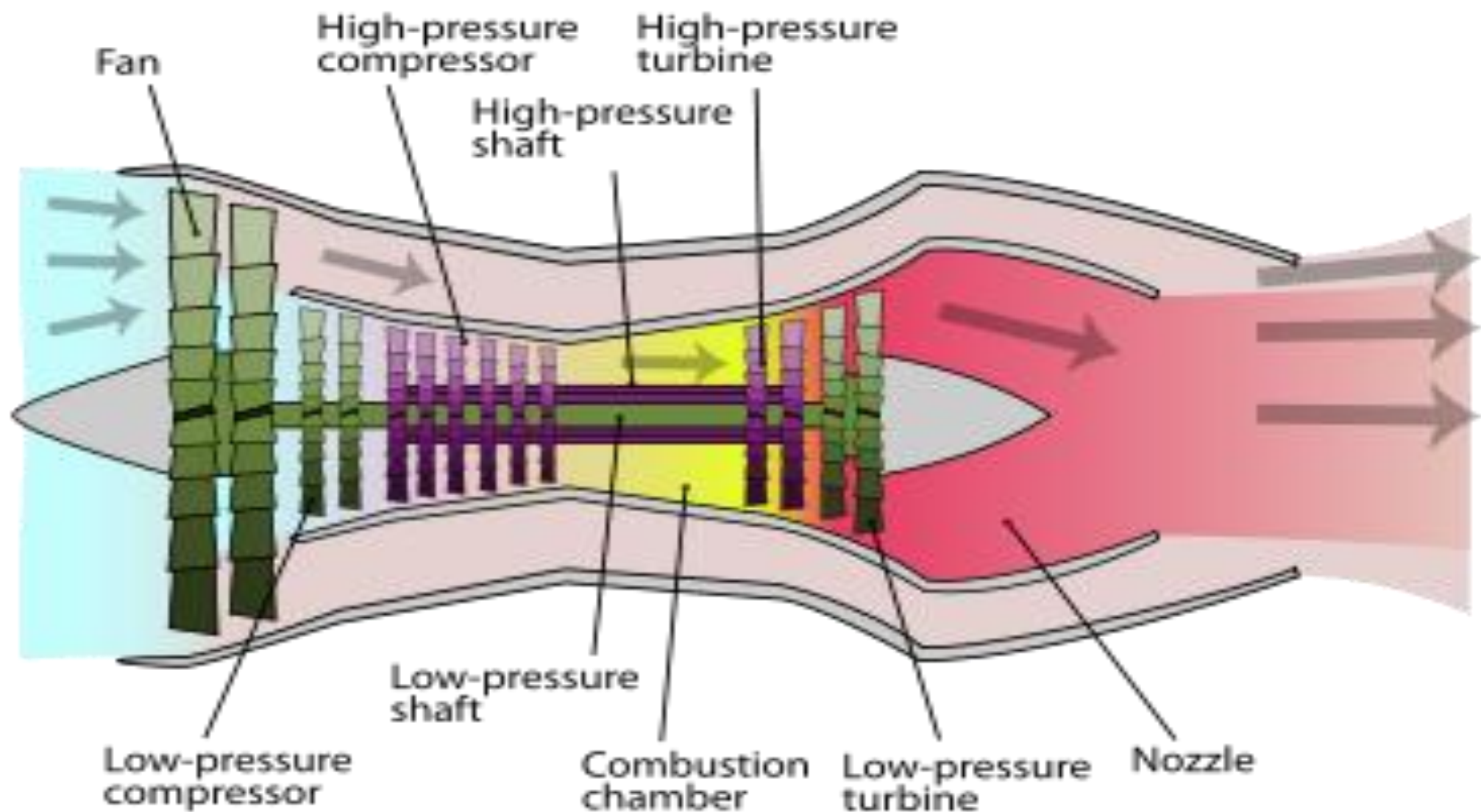


2 Turbofan engine

With the shortcomings, we know the turbojet engine can not improve power without increasing the fuel consumption .

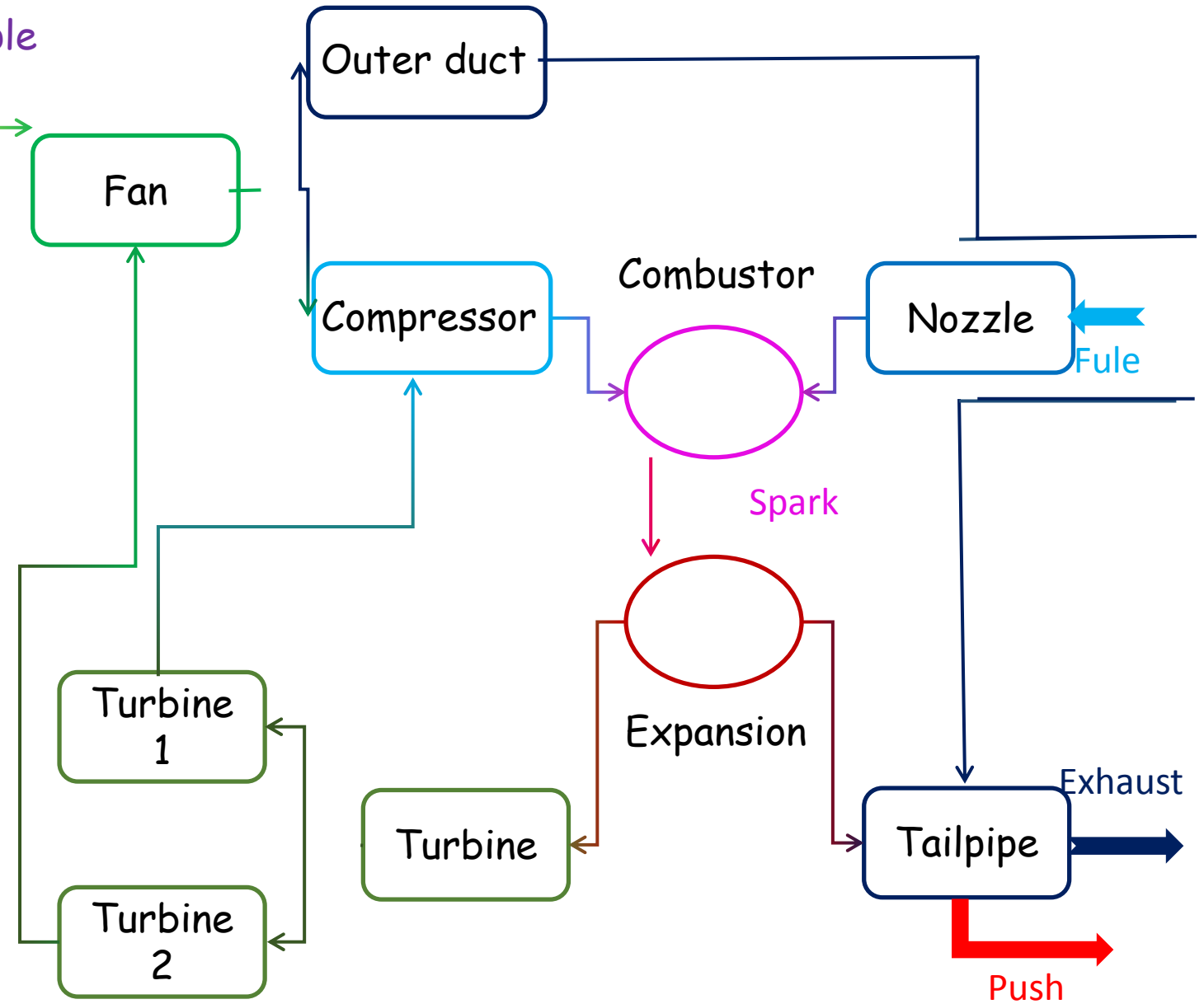
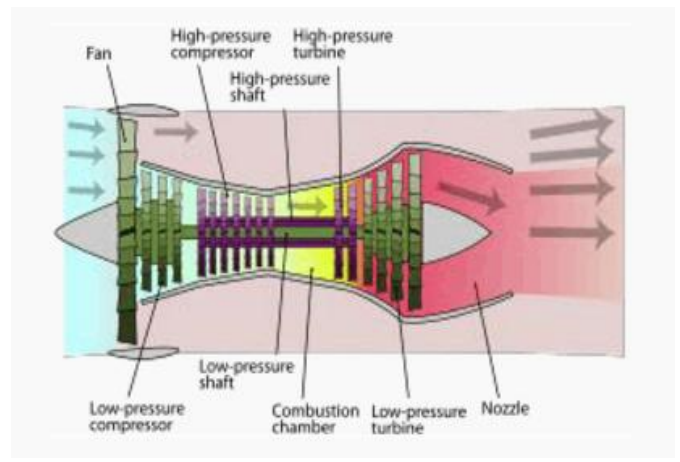
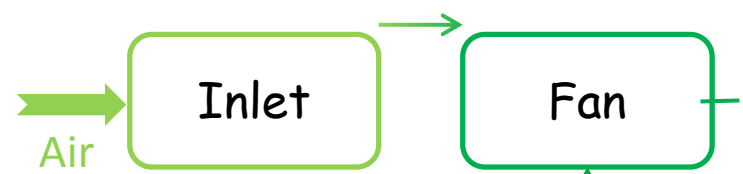
In order to deal with the problem, the turbofan engine occurs on the basis of the turbojet engines.







Working principle





The measure used to deal with the problem is that add fans before the compressor.

When the air is intaked into the engine, first it passes fans, the fans will improve the temperature and pressure of air.

Portion of air comes into the compressor just as in the turbojet engines, after compressor the air is mixed with fuel and burned,the mixture expand and flow by turbine and exhaust out.

The other air do not come into compressor ,but just flow with the aisle outside of the compressor(turbojet engine) and exhaust out of the engine.

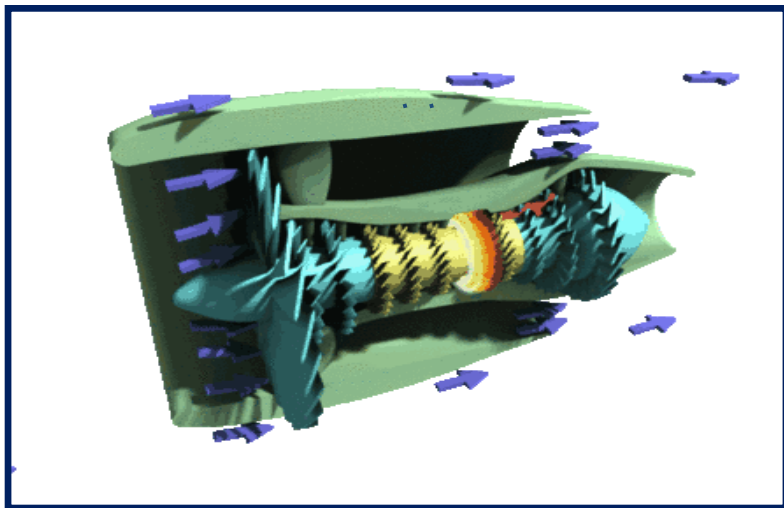
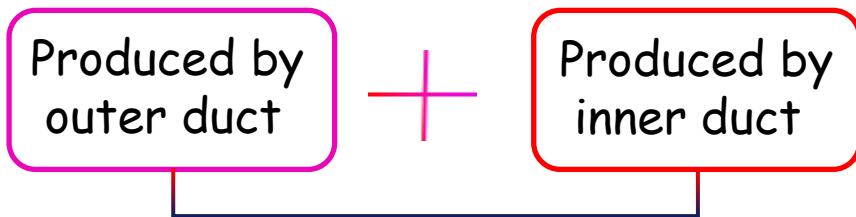
So, if we want improve the temperature and pressure of air before compressor ,we just need improve the diameter of fans or change the structure of fans and compressor .We need not add more fuel in the combustor.

With turbofan engines ,we can achieve the goal that the balance of weight ratio and fuel consumption

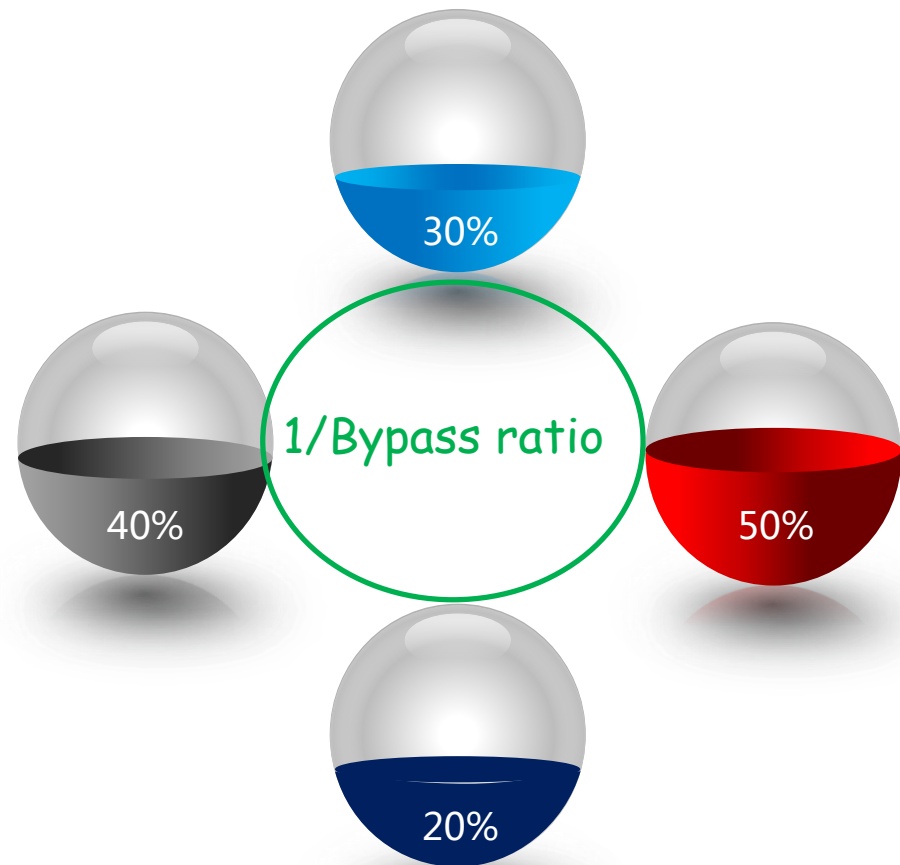


Turbofan engine power is composed with the counterforce of outer and inner duct airflow.

Outer duct and inner duct gas flow ratio is called bypass ratio.



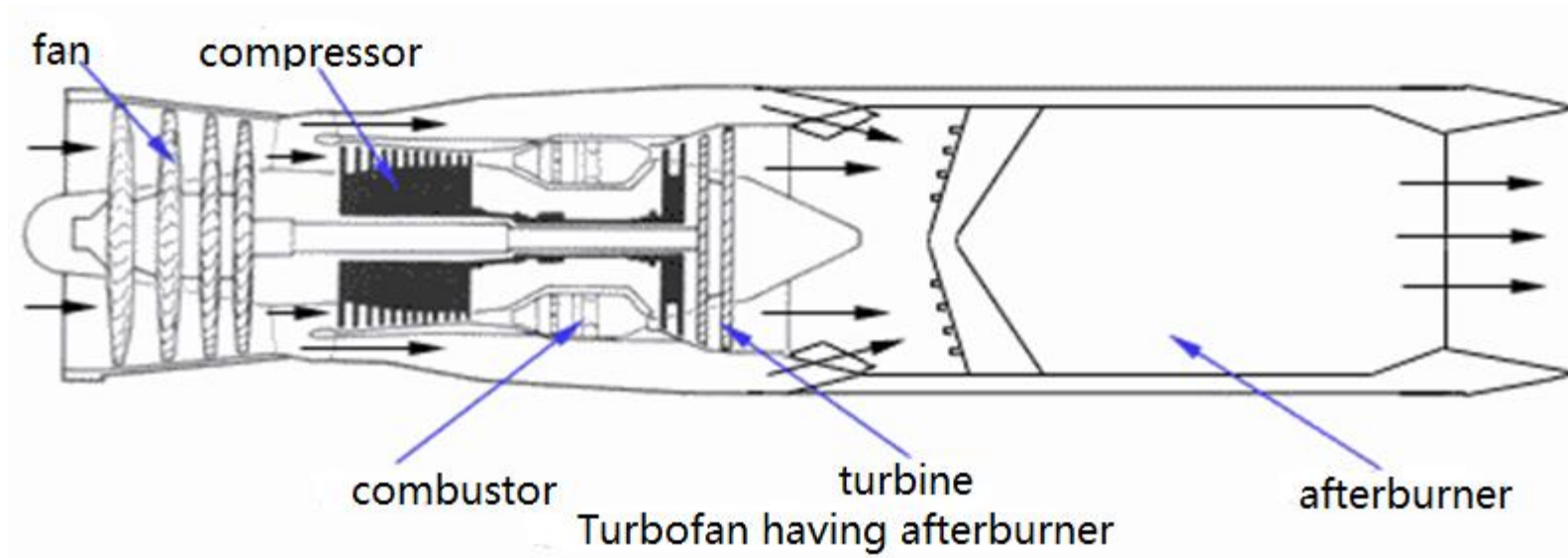
Thrust





In order to further improve the power of the turbofan engine ,we can also add the afterburner .When the burned mixture with high pressure and temperature comes into the afterburner , inject fuel and make the second expansion.

Afterburning turbofan engine has the excellent ability. In the low speed ,which has a low fuel consumption. In the high speed, which can get a high weight ratio.





Turbofan engine

Advantage

Low fuel consumption

High weight ratio

Small noise



Disadvantage

Technical complexity

Difficult fabrication

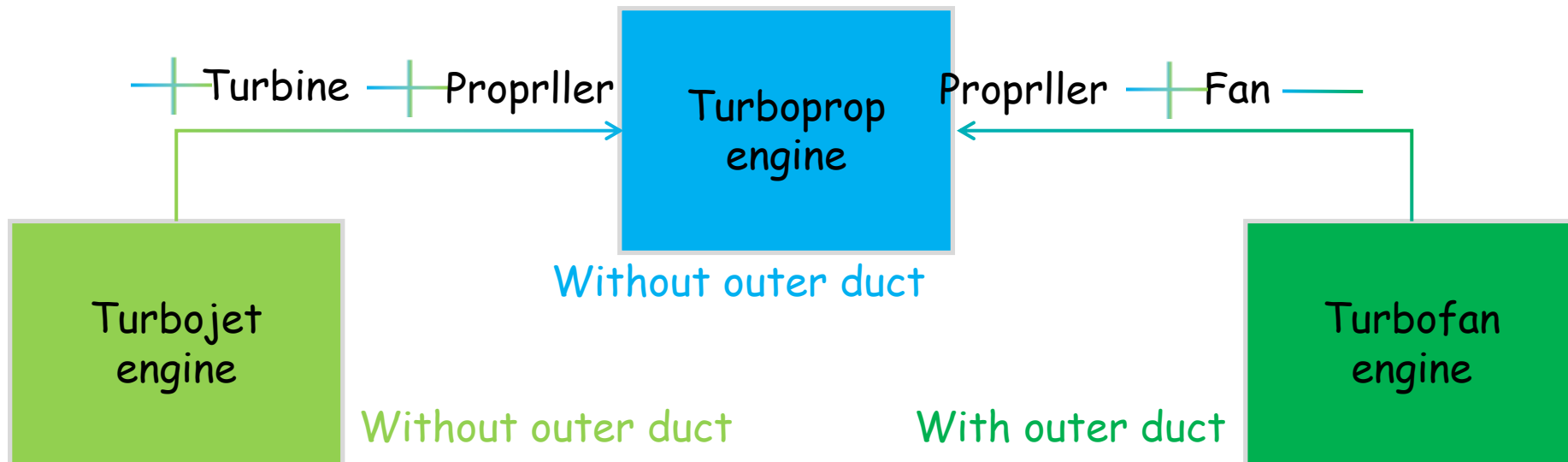
Widely used in the large passenger airplane and new fighter.



3 Turboprop engine

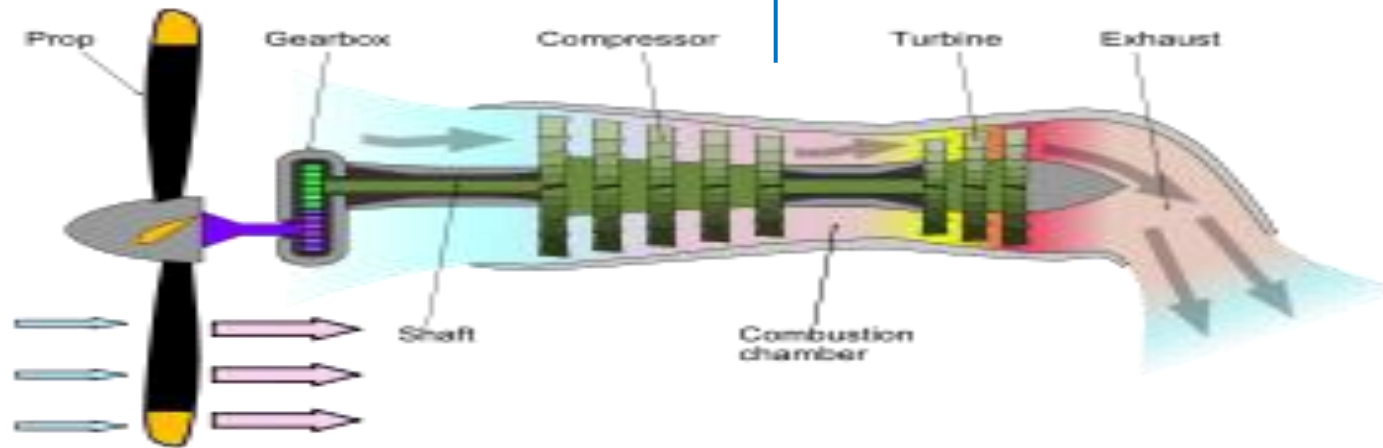
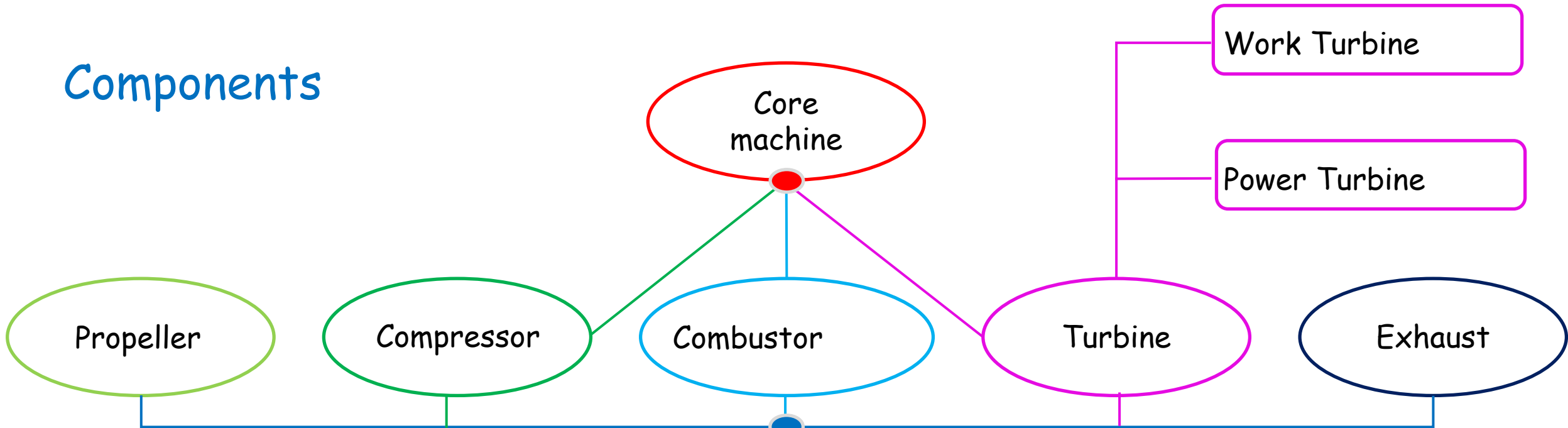
Evolved from the turbofan engine, the power turboprop engine provides for the aircraft is pull of propeller not the counterforce of air. This is the great difference between turboprop engine and turbo (turbojet) engine.

Compared with the turbofan engine , turboprop engine has not fans but has propeller; compared with turbojet engine ,turboprop engine has one more turbine and propeller.





Components

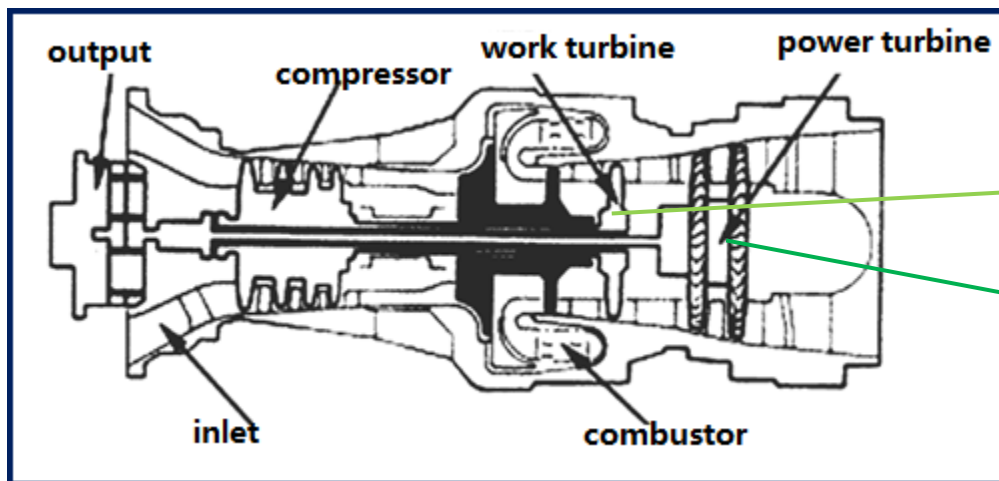




In turboprop engine ,there has two turbines. One is connected with compressor named work turbine. The other is connected with propeller called power turbine or free turbine.

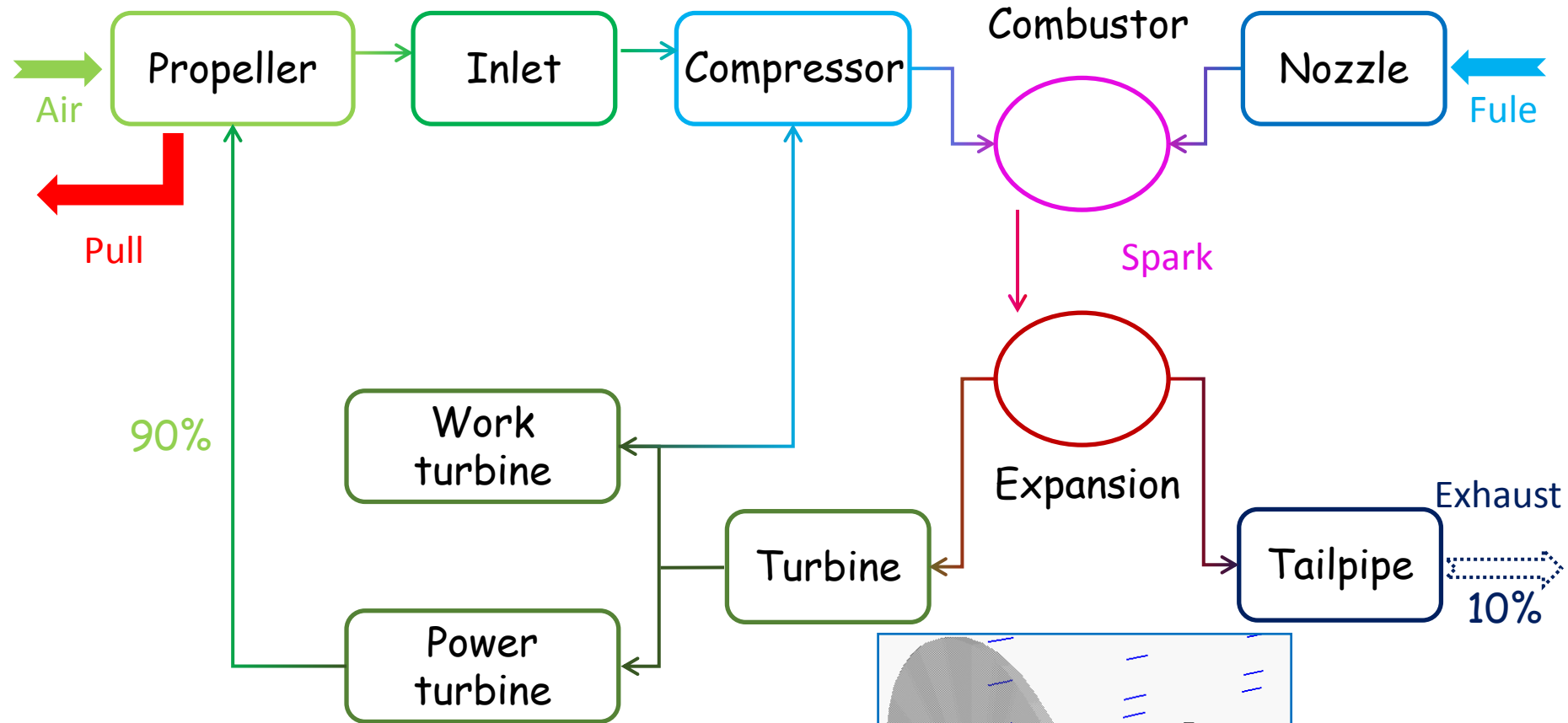
Work turbine has a great speed drive the compressor to compress the new air continuously. Power turbine work with a low speed drive the propeller to provide pull for the aircraft.

Thrust provided by turboprop engine is mostly comes from the propeller. The percent can rank about 90 percent .The exhaust air only account to about 10 percent.

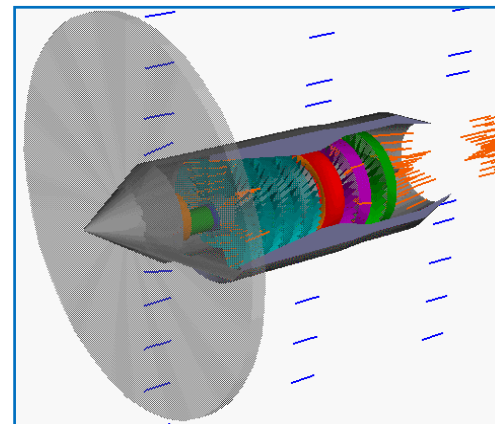


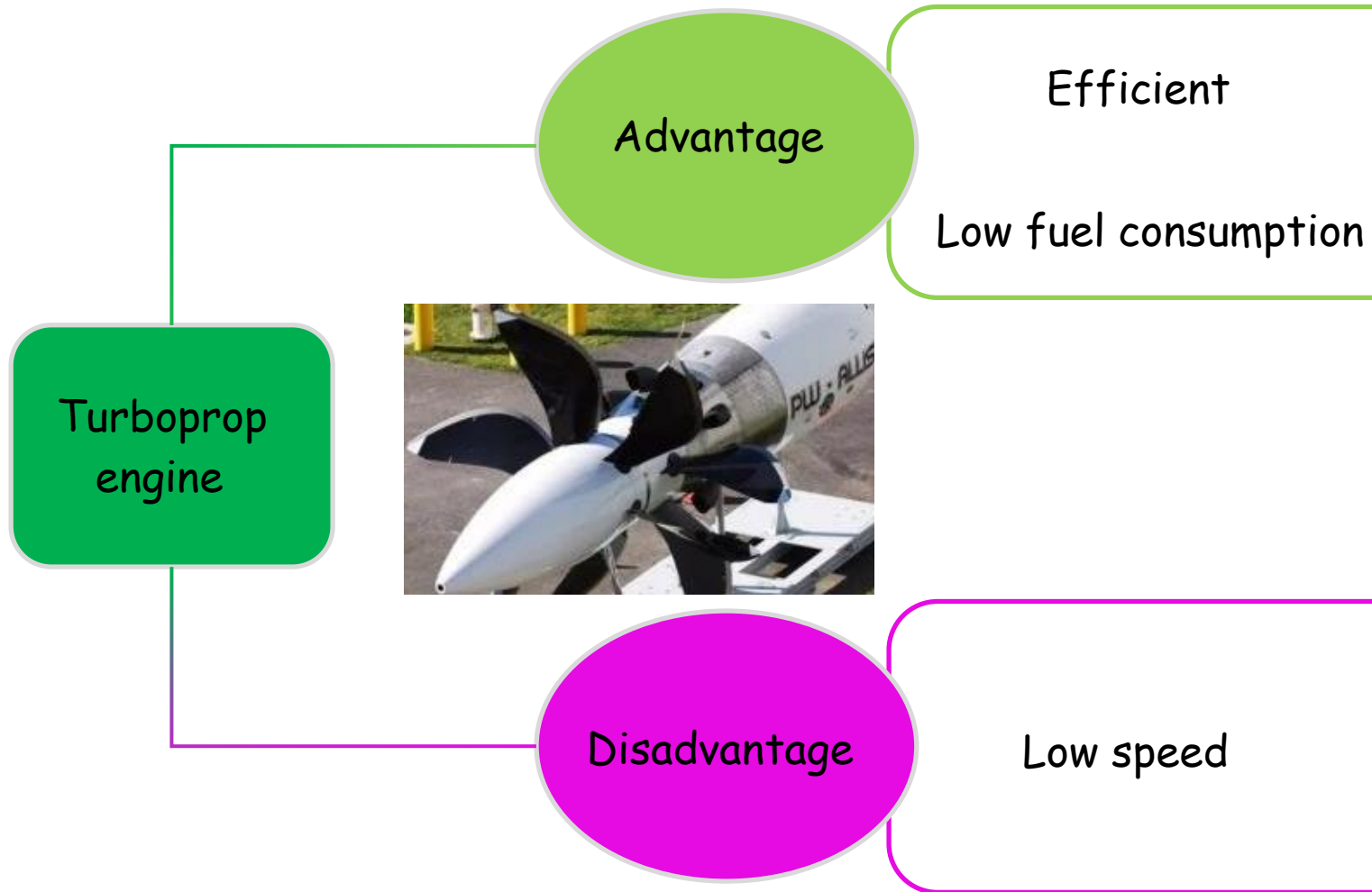
Work Turbine

Power Turbine



Working principle





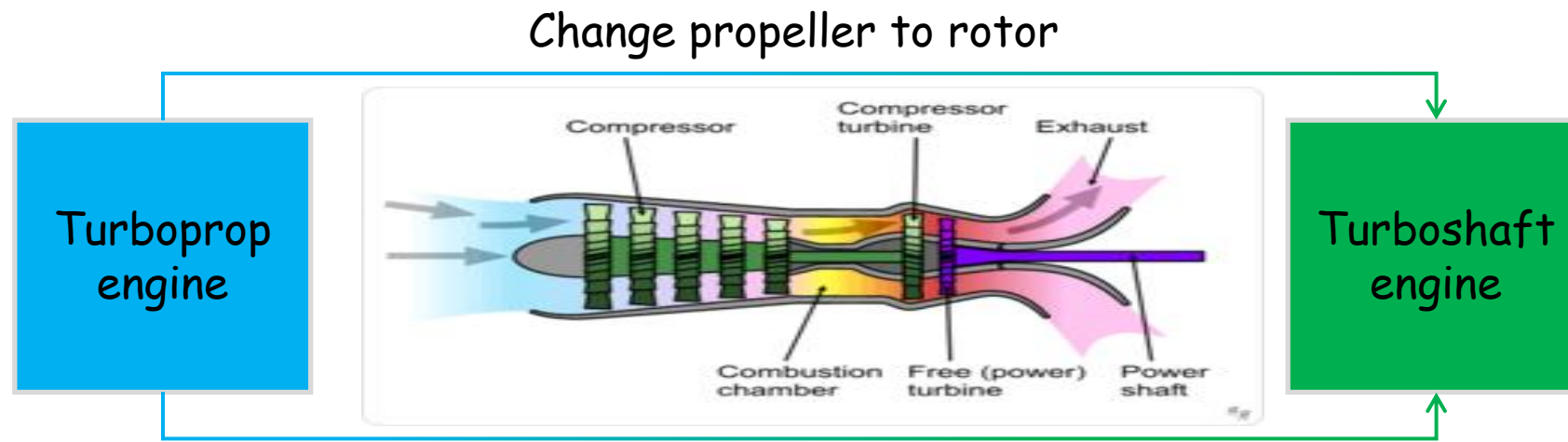
Mostly used in transport aircraft in 1950s and also used in regional aircraft today.



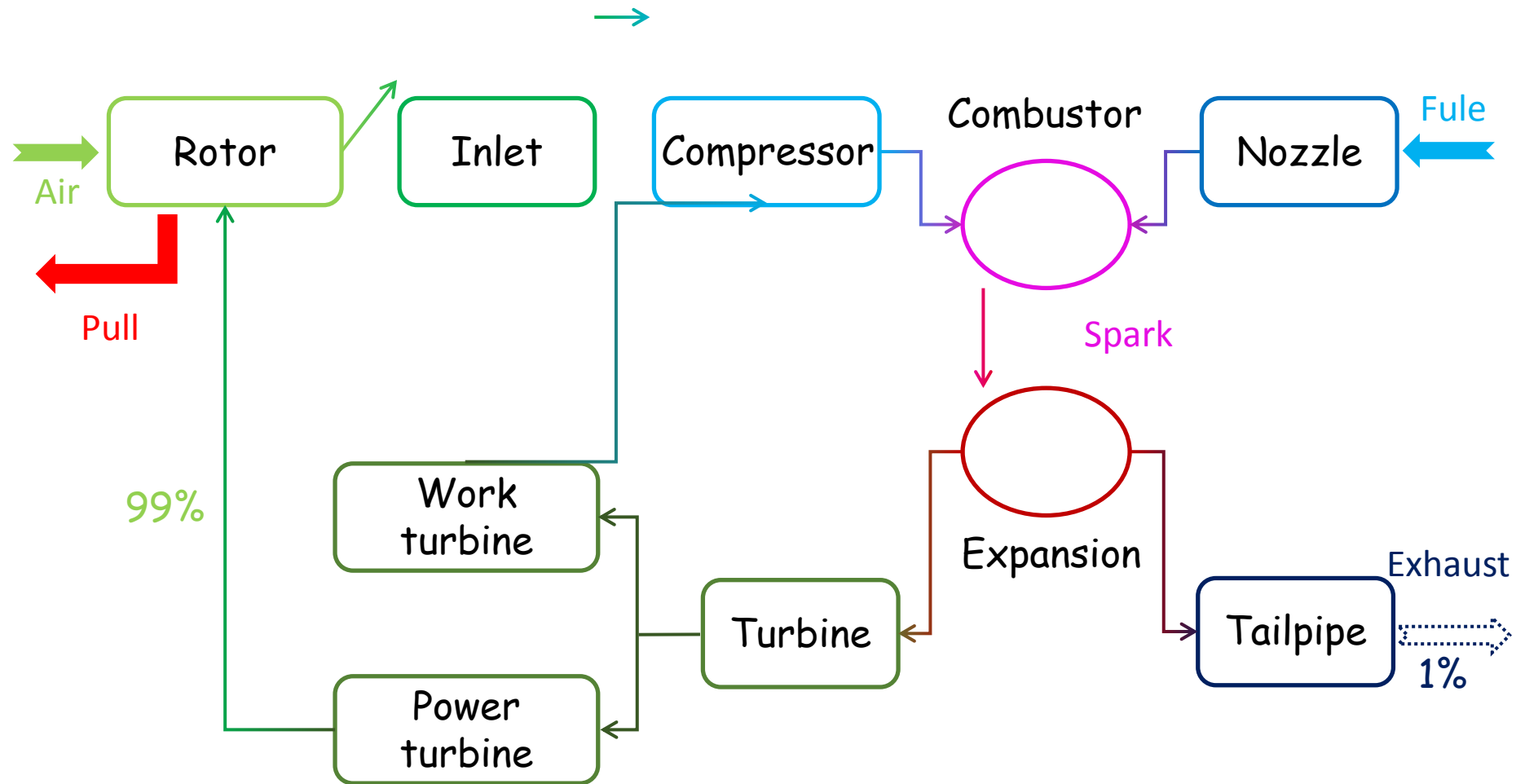
4 Turboshaft engine

Turboshaft engine is the power unit of helicopter or vertical takeoff/short aircraft.

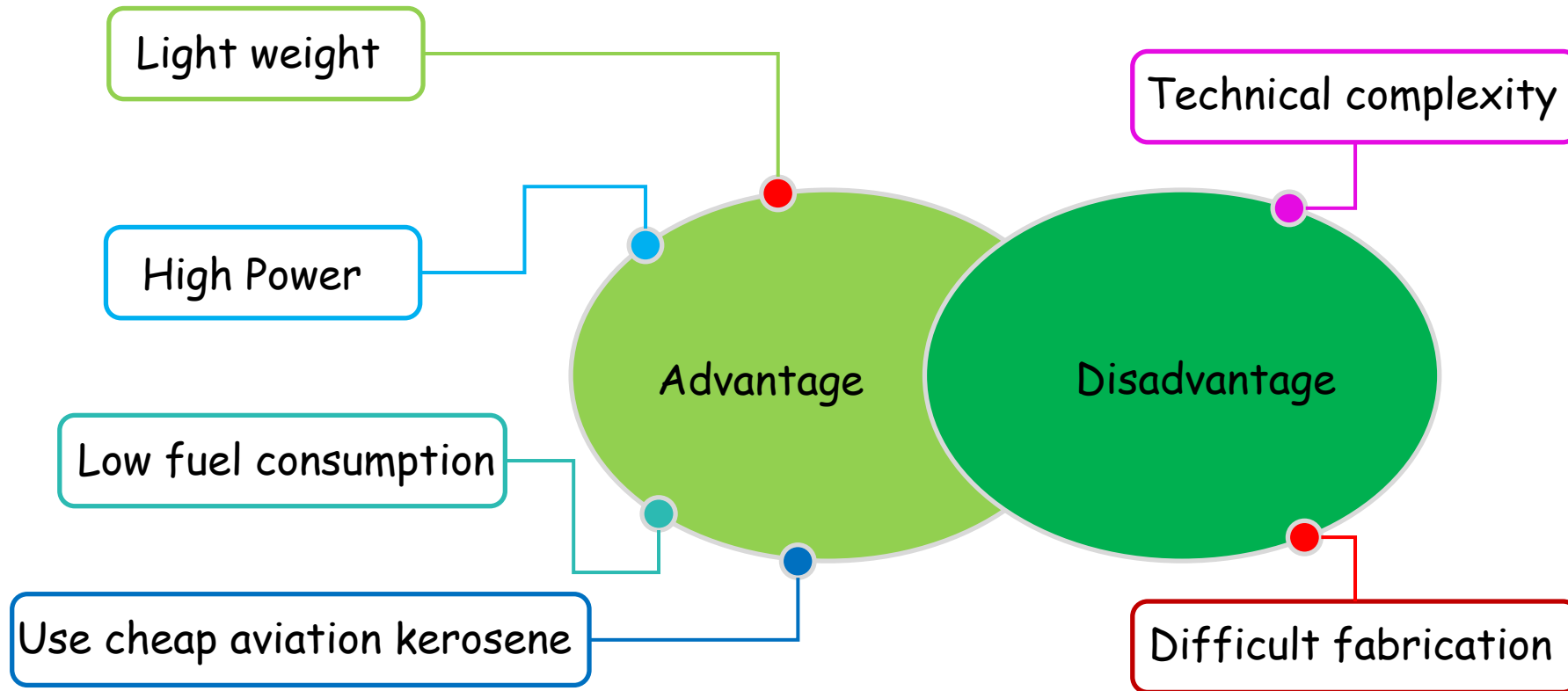
Turboshaft engine has the same structure and same working principle with the turboprop engine. There has two different points, one is turbshaft engine uses nearly all of the air and fuel mixture to work in the power turbine. The other is the turboshaft engine power turbine has a high speed.



Power turbine has a high speed



Working principle



Mostly used in helicopter or vertical takeoff/short aircraft.