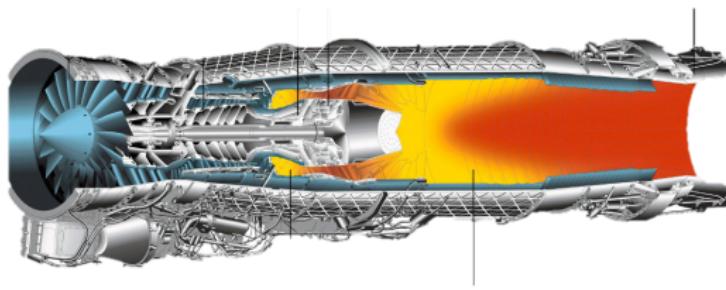


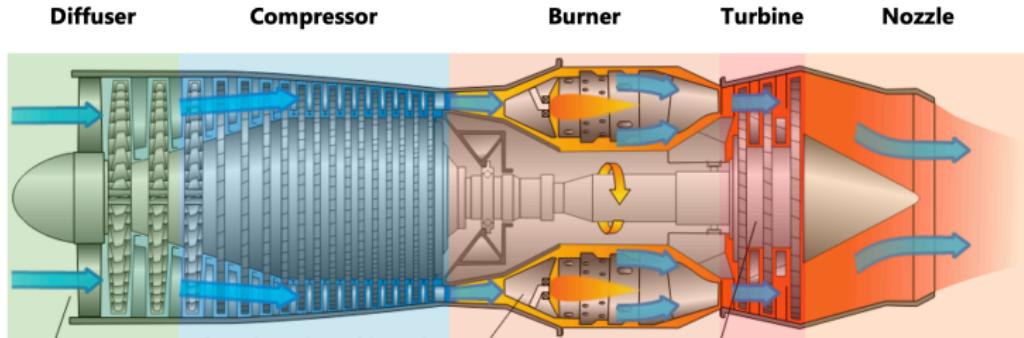
A brief history of jet engines

- ① In 1944, the **first operational jet fighter** in the world was the German ME 262
- ② By 1950, jet engines were the mainstay of all high-performance **military aircraft**
- ③ By 1958, the **commercial airlines** were introducing the jet-powered Boeing 707 and McDonnell-Douglas DC-8
- ④ Today, the jet engine is **the only practical propulsive mechanism** for high-speed subsonic and supersonic flight



Turbojet engine

The configuration of turbojet engine



- ① **Diffuser:** induces a mass of air and decelerates the flow
- ② **Compressor:** compresses and increases the total pressure of the flow
- ③ **Burner:** injects fuel into the airstream and combusts it to raise the gas temperature
- ④ **Turbine:** extracts work from the flowing gas. This work is then transmitted from the turbine through a shaft to the compressor, where it is used to drive the compressor.
- ⑤ **Nozzle:** further expands and exhausts the flow into the atmosphere

Turbojet engine

The thrust equation for turbojet engine

- The mass of fuel added is usually small compared to the mass of air, $\dot{m}_f/\dot{m}_0 \approx 0.05$
- The nozzle is usually designed to make the exit pressure equal to free stream

$$\begin{aligned} T &= (\dot{m}_0 + \cancel{\dot{m}_f}) V_e - \dot{m}_0 V_0 + \cancel{(\rho_e - \rho_0) A_e} \\ &= \dot{m}_0 (V_e - V_0) \\ &= \boxed{\rho_0 A_0 V_0 (V_e - V_0)} \end{aligned}$$

Small Close to zero

Turbojet engine performance

- For turbojet engine, T is mostly increased by increasing $V_e - V_0$
- Thrust does not vary with V_0 : as V_0 increases, \dot{m}_0 increases, $V_e - V_0$ decreases. The two effects tend to cancel each other.
- The altitude effect on thrust: decreases proportionately with a decrease in ρ_∞

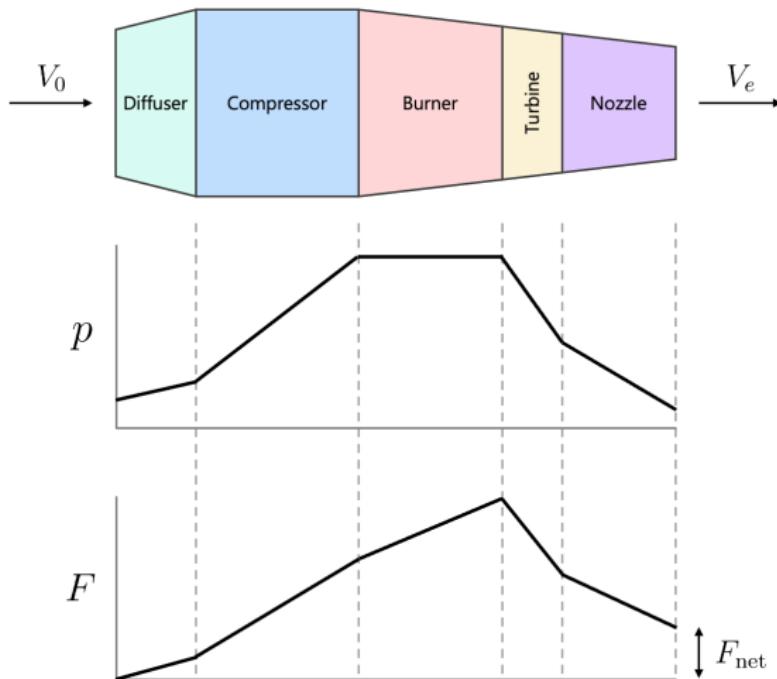
Turbojet engine

Example: Consider a turbojet-powered airplane flying at a standard altitude of 30,000 ft at a velocity of 500 mi/h. The turbojet engine itself has inlet and exit areas of 7 and 4.5 ft^2 , respectively. The velocity and pressure of the exhaust gas at the exit are 1600 ft/s and 640 lb/ ft^2 , respectively. Calculate the thrust of the turbojet with

$$T = \dot{m}_0(V_e - V_0) + (p_e - p_0)A_e$$

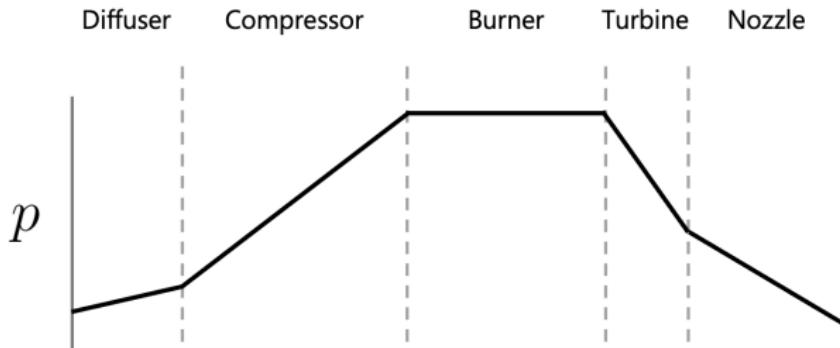
Turbojet engine

Thrust buildup for a turbojet engine



Turbojet engine

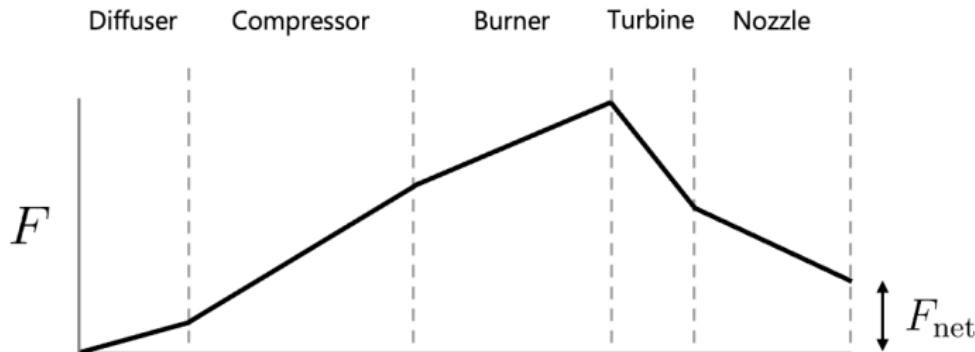
The pressure variation (with axial distance) through a turbojet engine



- ① **Diffuser:** slows down the airflow, pressure increases
- ② **Compressor:** mechanical work compresses the air, pressure increases
- ③ **Burner:** the combustion process takes place at constant pressure
- ④ **Turbine:** expands the high-temperature, high-pressure gases through the turbine, converts pressure to mechanical work, pressure decreases
- ⑤ **Nozzle:** accelerates gas, pressure decreases

Turbojet engine

The thrust variation (with axial distance) through a turbojet engine



- **Main sources of positive thrust:** compressor and burner add energy to the air through compression and combustion, leading to positive momentum change of air, thus increasing thrust
- **Main sources of negative thrust:** turbine extracts energy from the air to drive the compressor, thus reducing thrust
- **Net thrust:** the net accumulative thrust F_{net} is a positive value

Turbojet engine

Thrust distribution of a typical turbojet engine

