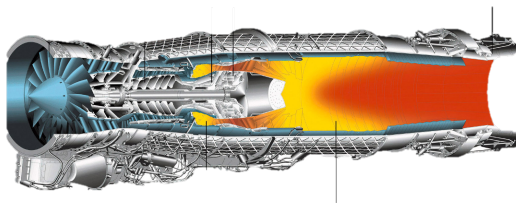
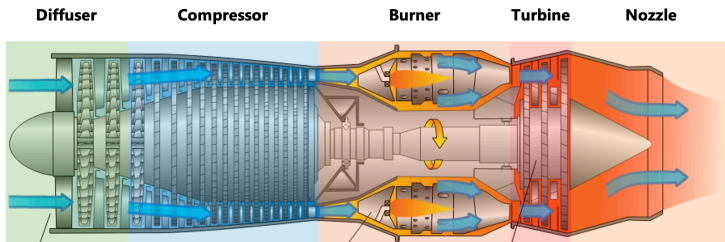


## A brief history of jet engines

- 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



## The configuration of turbojet engine



- 1 **Diffuser:** inducts 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

## 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**

$$\begin{aligned} T &= (\dot{m}_0 + \overset{\text{Small}}{\dot{m}_f}) V_e - \dot{m}_0 V_0 + \overset{\text{Close to zero}}{(p_e - p_0) A_e} \\ &= \dot{m}_0 (V_e - V_0) \\ &= \boxed{\rho_0 A_0 V_0 (V_e - V_0)} \end{aligned}$$

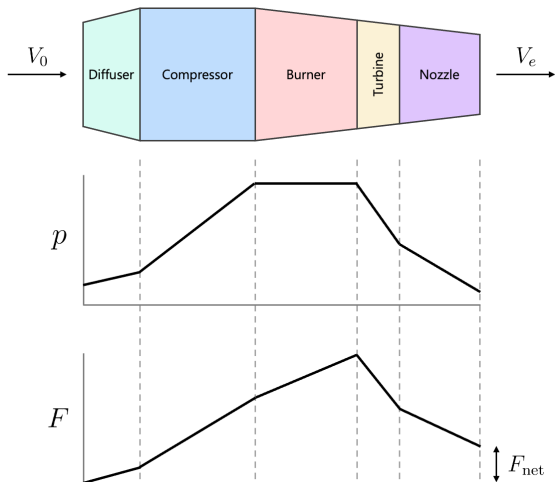
## Turbojet engine performance

- 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  $\rho_\infty$

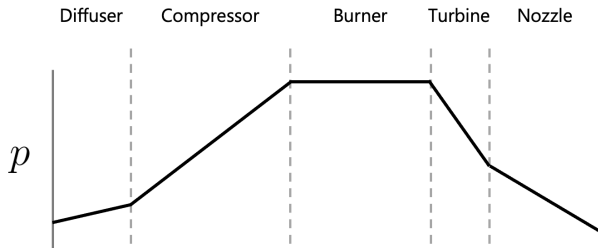
**Example:** Consider a turbojet-powered airplane flying at a standard altitude of 30,000 ft at a velocity of 500 mi/h. The turbojet engine itself has inlet and exit areas of 7 and 4.5 ft<sup>2</sup>, respectively. The velocity and pressure of the exhaust gas at the exit are 1600 ft/s and 640 lb/ft<sup>2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

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

## Thrust buildup for a turbojet engine

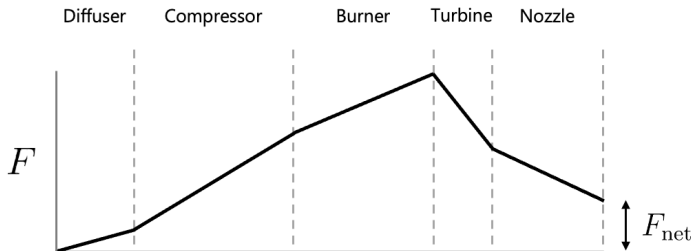


## The pressure variation (with axial distance) through a turbojet engine



- 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

## 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  $F_{\text{net}}$  is a positive value

# Turbojet engine

## Thrust distribution of a typical turbojet engine

