

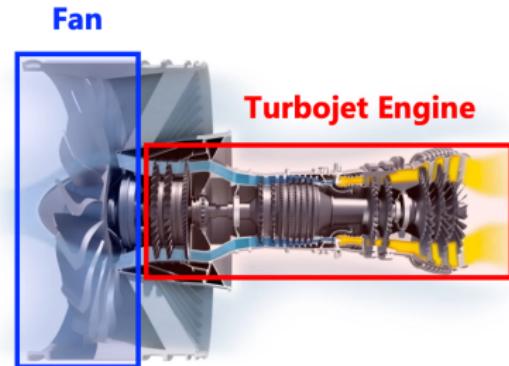
Turbofan engine

What is turbofan engine?

Turbojet engines are inefficient; we will discuss this further later.

Turbofan engine = a turbojet engine + a large ducted fan mounted on the shaft ahead of the compressor. The turbine drives both the fan and the compressor.

- A fan has an enclosed inlet, many blades, and is more efficient at higher speeds.



The thrust of the turbofan is a combination of the thrust produced by the fan blades and jet from the exhaust nozzle.

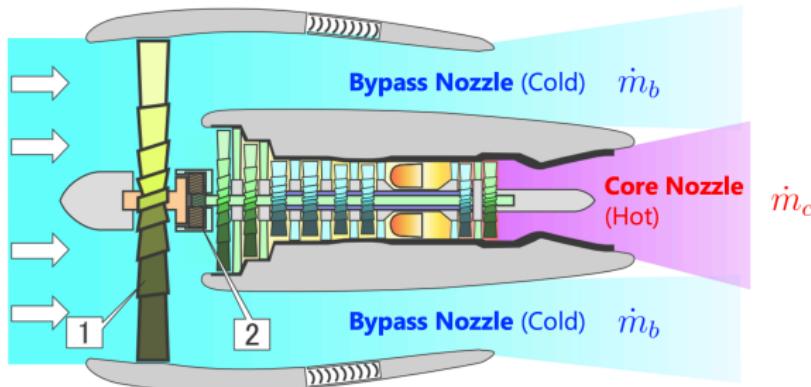
Turbofan engine

Bypass ratio

The ducted fan accelerates a large mass of air that flows through both **the bypass duct** and **the engine core**.

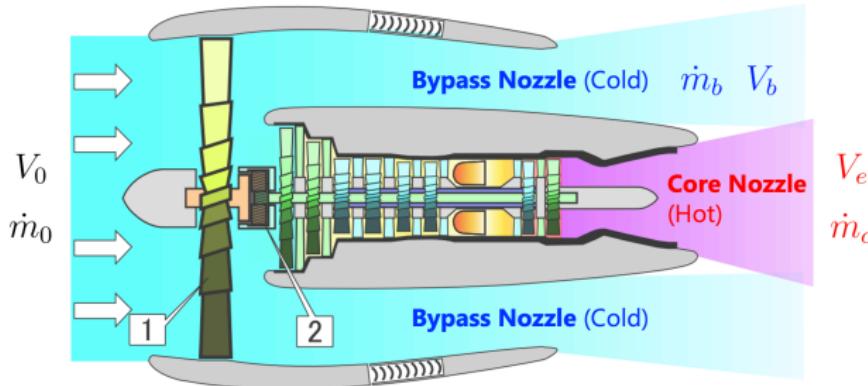
Bypass ratio (BPR): the ratio of the mass flow of air **bypassing the engine core** to the mass flow of air **passing through the core**.

$$\text{BPR} = \frac{\text{Bypass air mass flow } (\dot{m}_b)}{\text{Core air mass flow } (\dot{m}_c)}$$



Turbofan engine

The thrust equation for turbofan engine



Thrust of turbofan engine has two sources:

- ① Thrust from **the core**

$$T_c = \dot{m}_c(V_e - V_0)$$

- ② Thrust from **the bypass (fan)**

$$T_b = \dot{m}_b(V_b - V_0)$$

Turbofan engine

The thrust equation for turbofan engine

The **total thrust** is:

$$\begin{aligned} T &= T_c + T_b \\ &= \dot{m}_c(V_e - V_0) + \dot{m}_b(V_b - V_0) \end{aligned}$$

We also know:

Conservation of mass flow: $\dot{m}_0 = \dot{m}_c + \dot{m}_b$

Bypass ratio: $\text{BPR} = \dot{m}_b / \dot{m}_c$

And the turbofan thrust equation becomes:

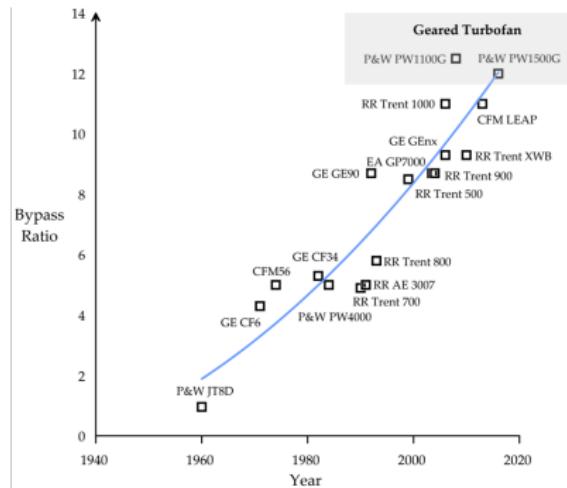
$$\begin{aligned} T &= \dot{m}_c(V_e - V_0) + \dot{m}_b(V_b - V_0) \\ &= \dot{m}_c V_e + \dot{m}_b V_b - \dot{m}_0 V_0 \\ &= \dot{m}_c V_e + \text{BPR} \dot{m}_c V_b - \dot{m}_0 V_0 \\ &= \boxed{\dot{m}_c(V_e + \text{BPR} V_b) - \dot{m}_0 V_0} \end{aligned}$$

Turbofan engine

High-bypass turbofan engine

To further **improve fuel economy** and **reduce noise**, almost all modern jet airliners and military transport aircraft are powered by high-bypass turbofan engines.

Evolution on the turbofan bypass ratio:



Ultra High Bypass Ratio (UHBPR) engine: $BPR > 13:1$, is the turbofan engine frontier