Jet Aircraft Propulsion

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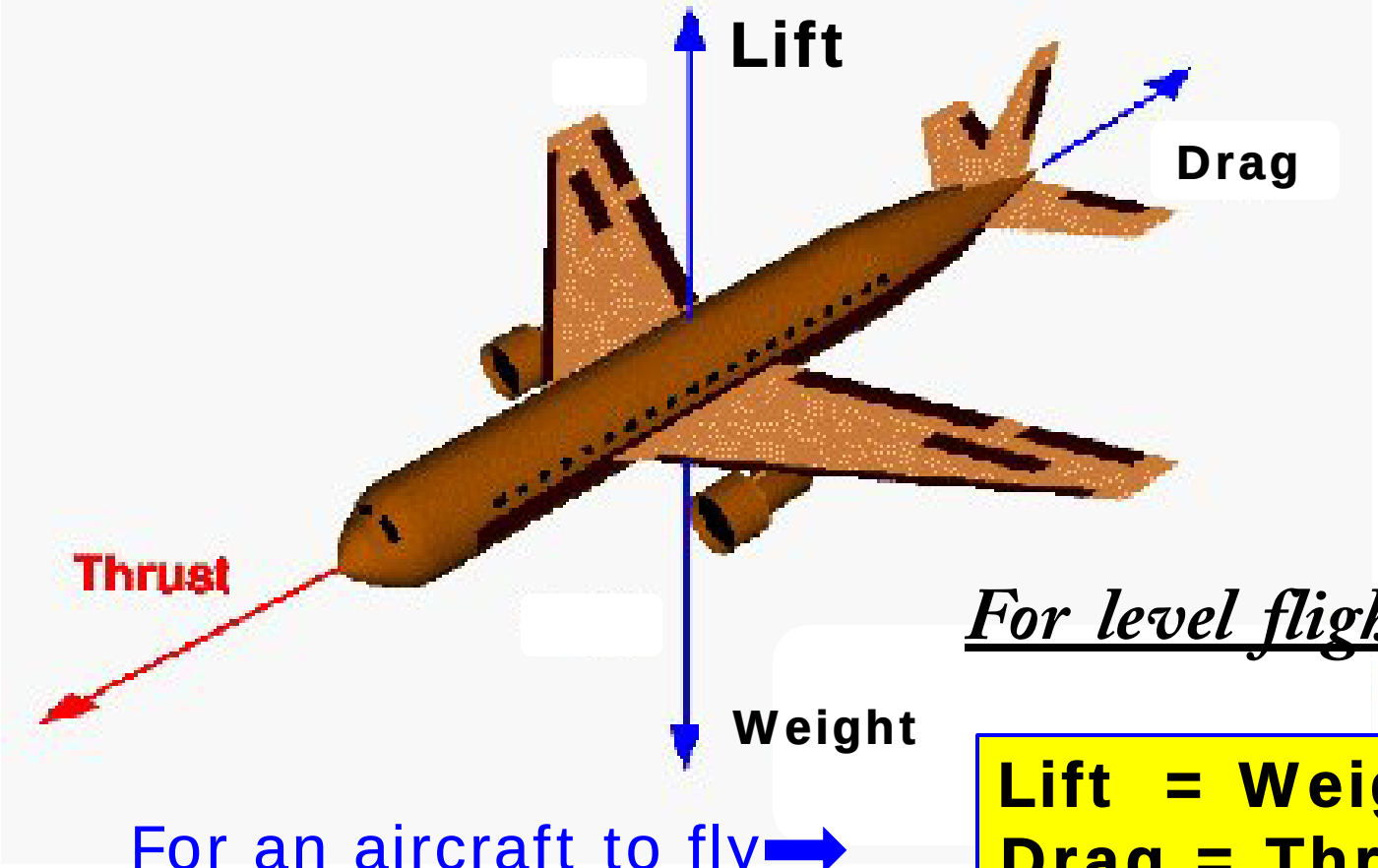
Lect - 2

How the thrust is created for flying

Thrust for flying

- An aircraft does not fly simply by setting it out on the runway and allow strong wind to blow over its wings.
- The aircraft is to be moved forward, forcing it to run through still air at a high speed. Only then necessary lift is created for it to fly. This is a continuous requirement.
- This forward thrust for the aircraft comes from one of two sources: i) a rotating propeller blade powered by an engine or, ii) a pure Jet engine.

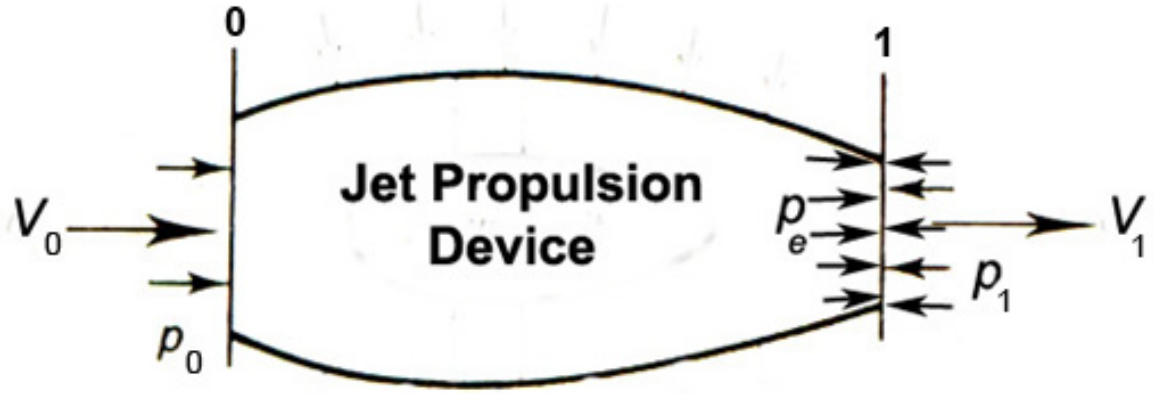
Thrust requirement for aircraft



For level flight

For an aircraft to fly ➡

Lift = Weight
Drag = Thrust



Differential form of thrust generation, $F = \frac{d(mv)}{dt}$

Thrust based on acceleration of mass $F = ma$

Thrust based on velocity change in a time period $F = \frac{m(V_1 - V_0)}{(t_1 - t_0)}$

Acceleration, Velocity, Momentum and Force are vector quantities. They all have specific magnitude & direction

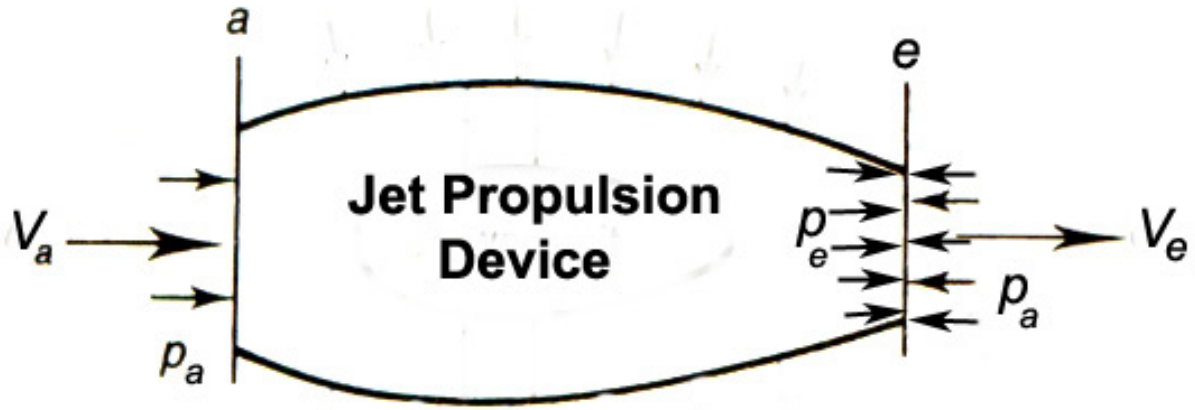
• Thrust is a mechanical **force** which is generated through the **reaction** of accelerating a mass of gas, as explained by Newton's III Law of motion.

• A gas or air, used as a **working fluid** is accelerated to the rear and the engine attached to the aircraft are accelerated in the forward direction.

• To accelerate the gas, we need some kind of propulsion system. We assume that a propulsion system is a machine which accelerates a gas/ air.

- But if we are dealing with a fluid (liquid or gas) and particularly if we are dealing with a moving fluid, keeping track of the mass gets tricky. For a moving fluid, the important parameter is the mass flow rate.

- Since the mass flow rate already contains the time dependence (mass/time), we can express the change in momentum across the propulsion device as the change in the mass flow rate times the velocity.

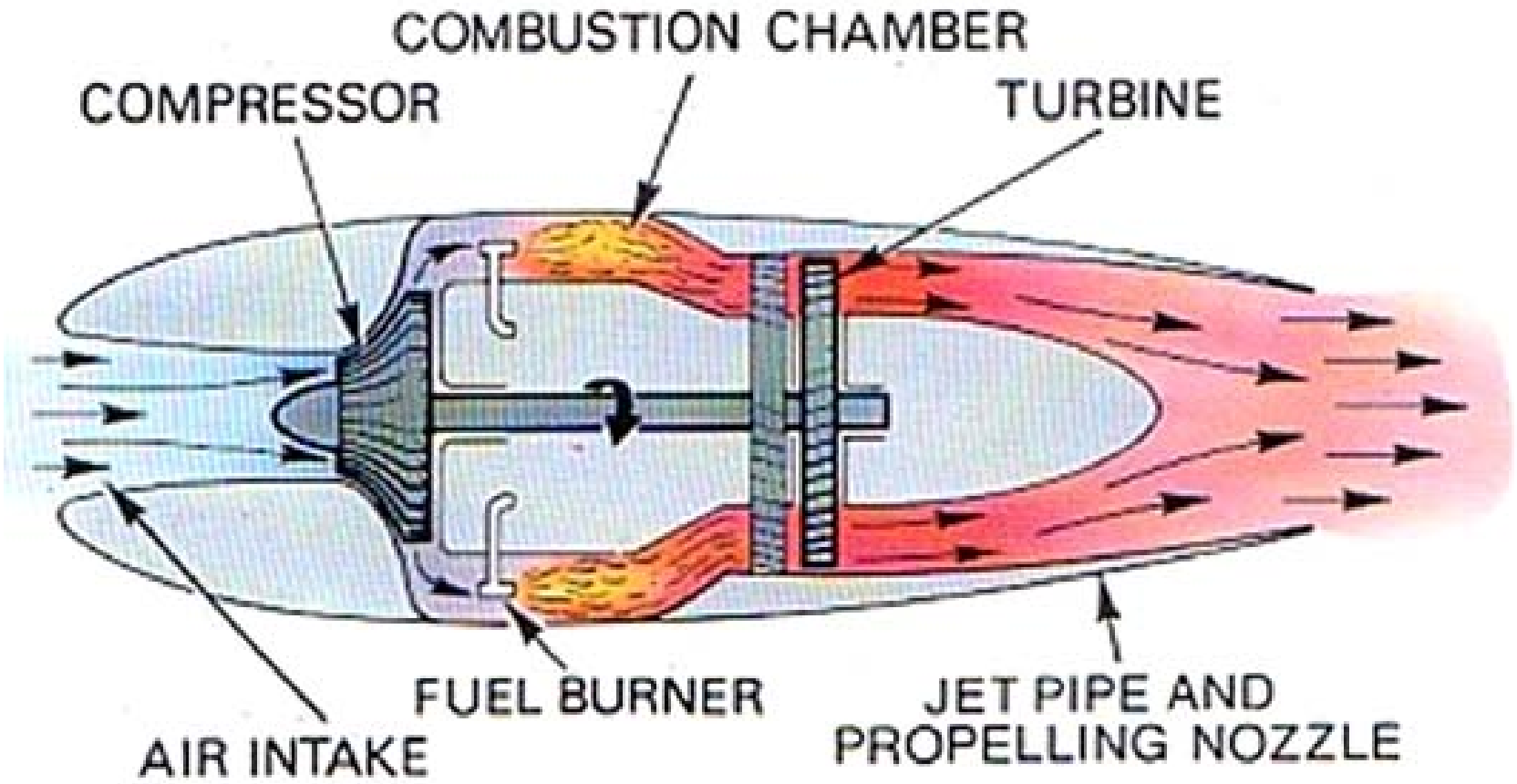


The **general thrust equation** is then given by:

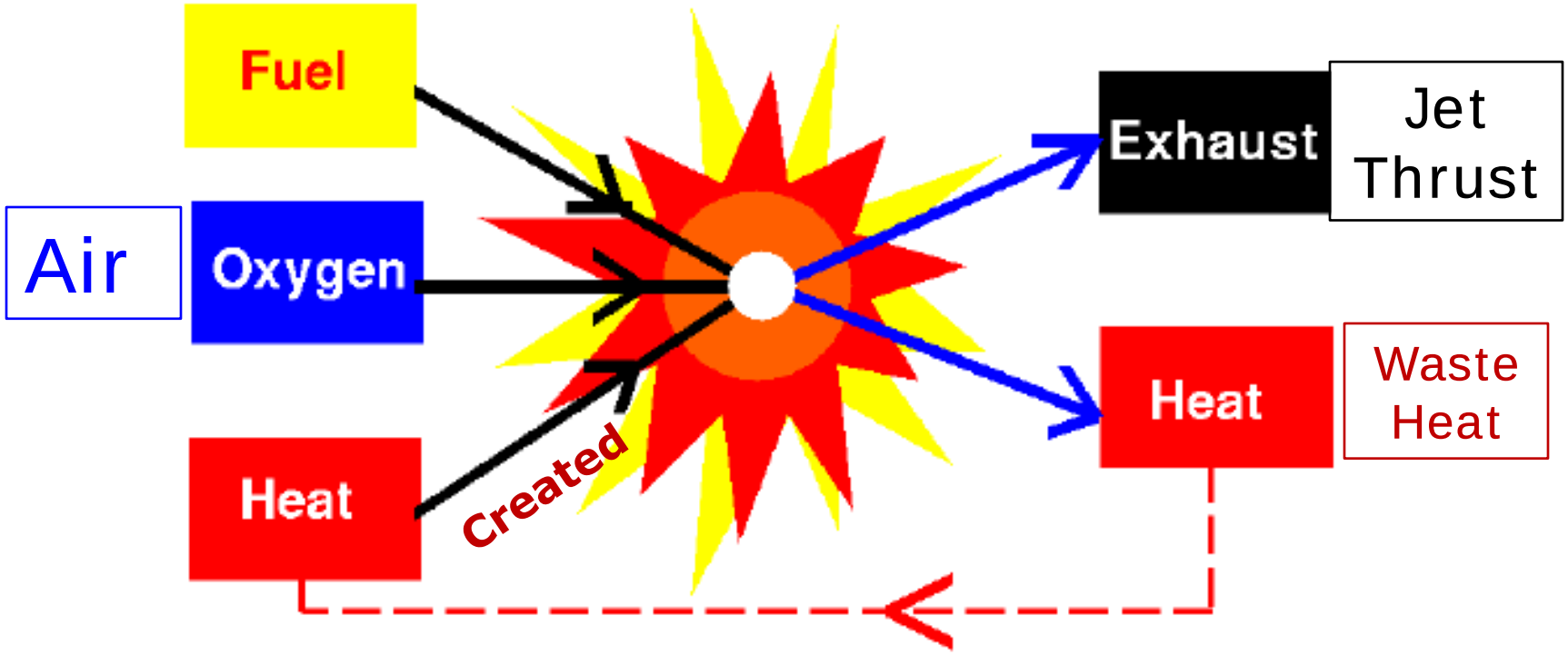
$$F = [(\dot{m}.V)_e - (\dot{m}.V)_a] + [(p_e - p_a).A_e]$$

Normally, the magnitude of the pressure-area term is small relative to the m-dot$_x$V terms.

A Jet Engine Schematic

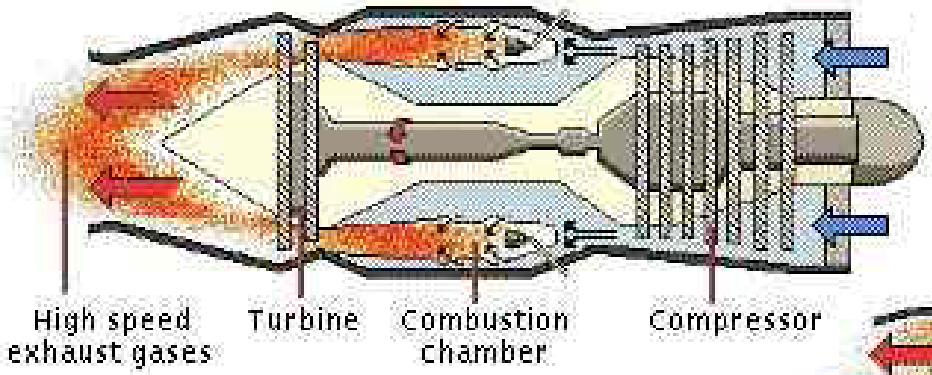


Jet Engine fundamentally is a Heat Engine



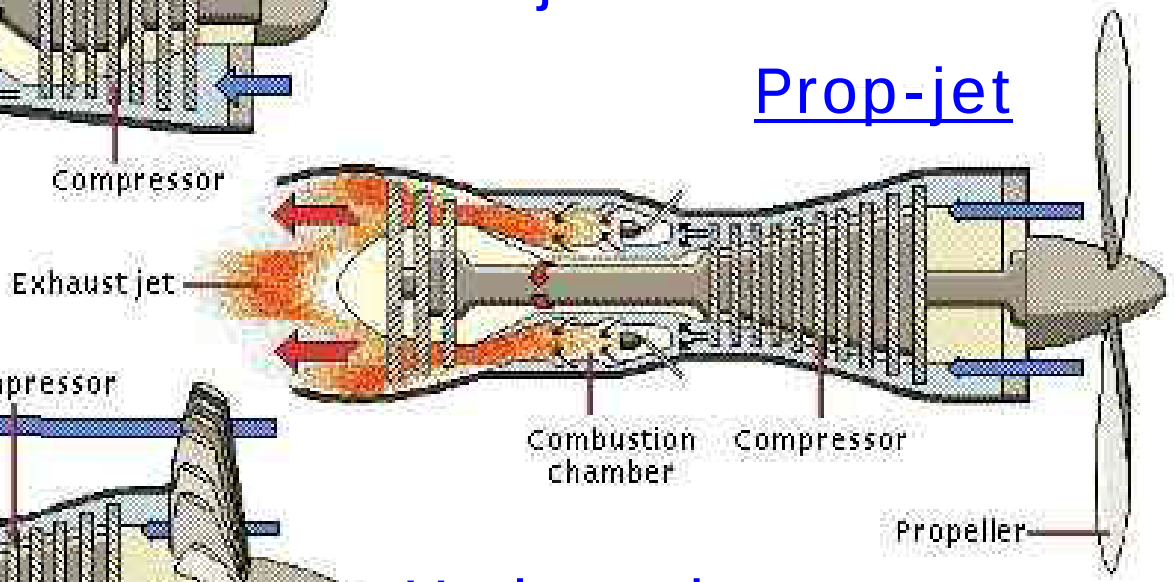
***Combustion** is the energy input in to the engine and is key to the operation of a jet engine*

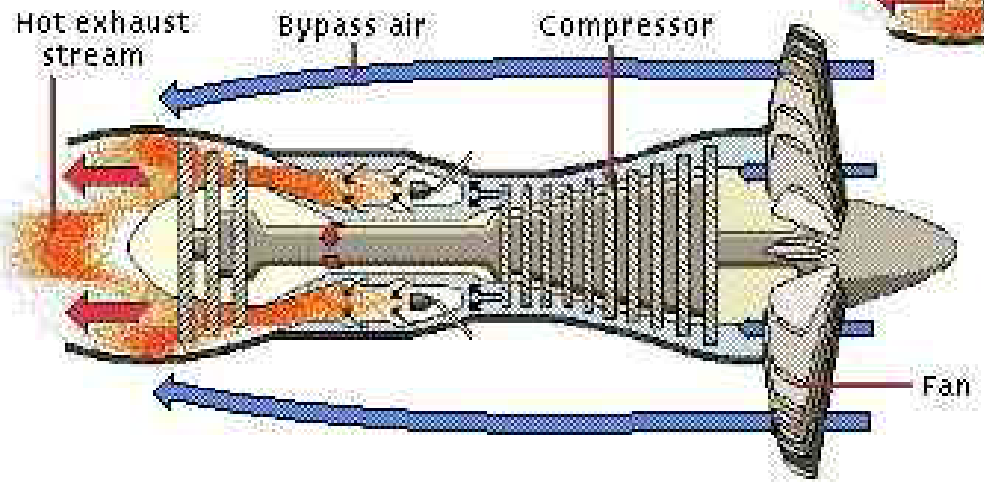
Fundamental varieties of jet engine



Pure Turbojet

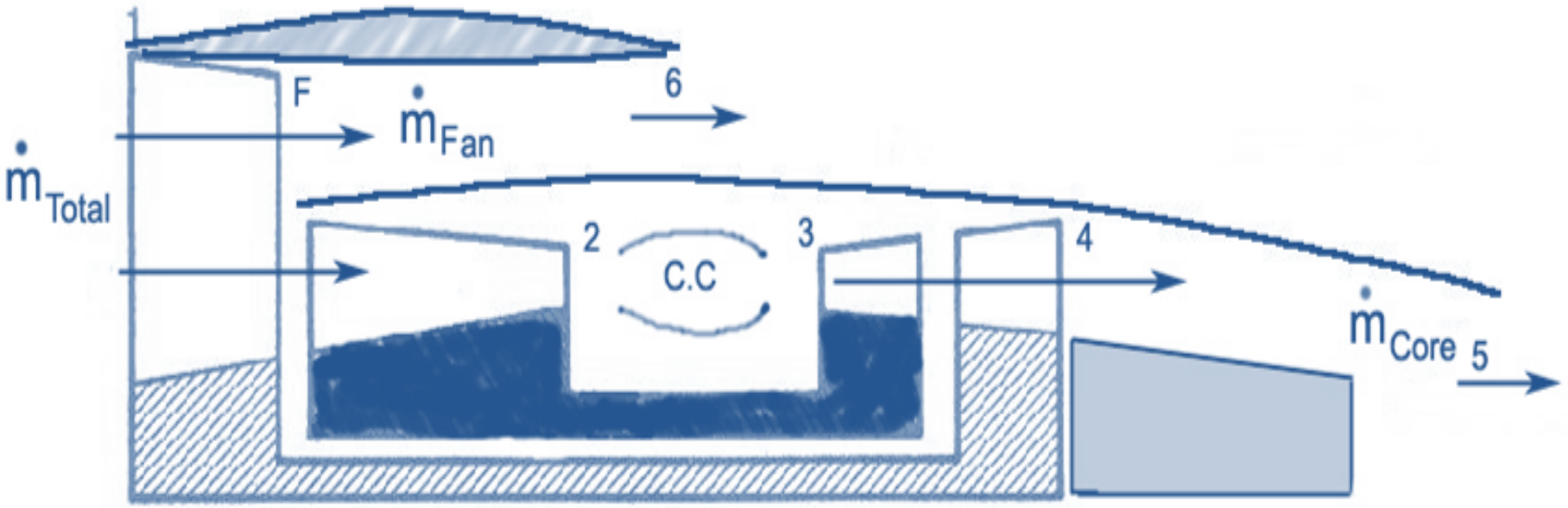
Prop-jet



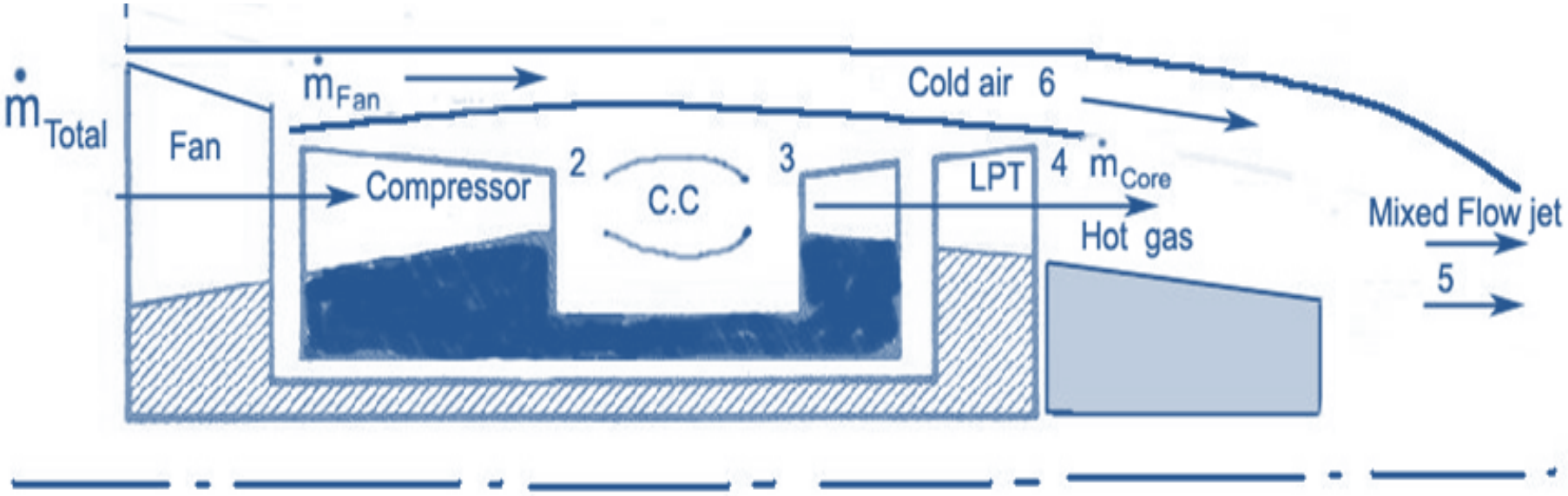


Unducted or Ducted fan

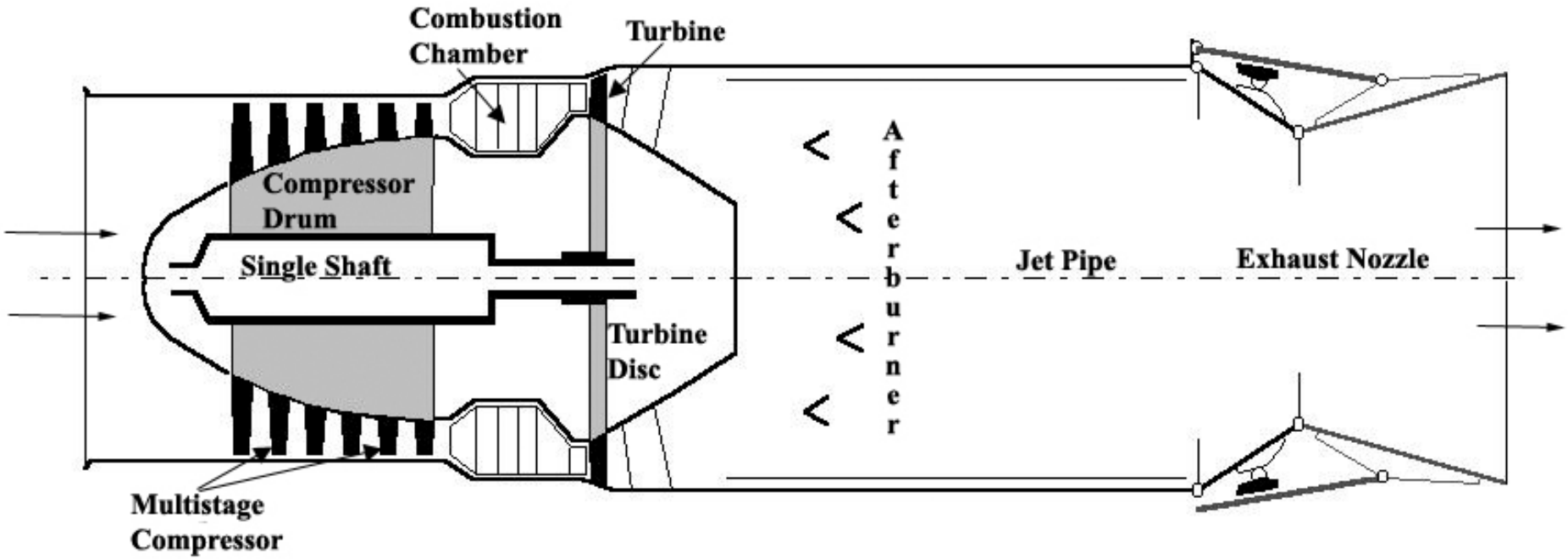
A Bypass Jet engine



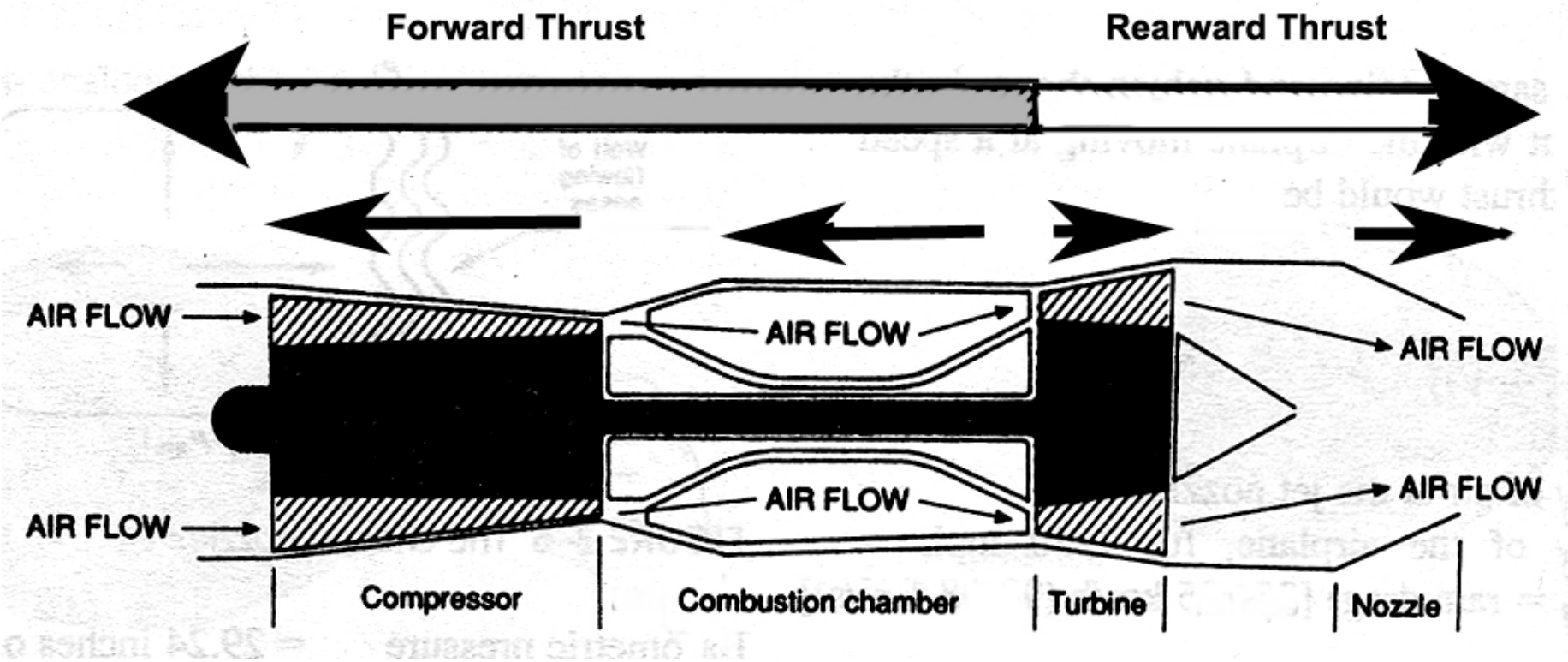
A mixed flow bypass jet engine



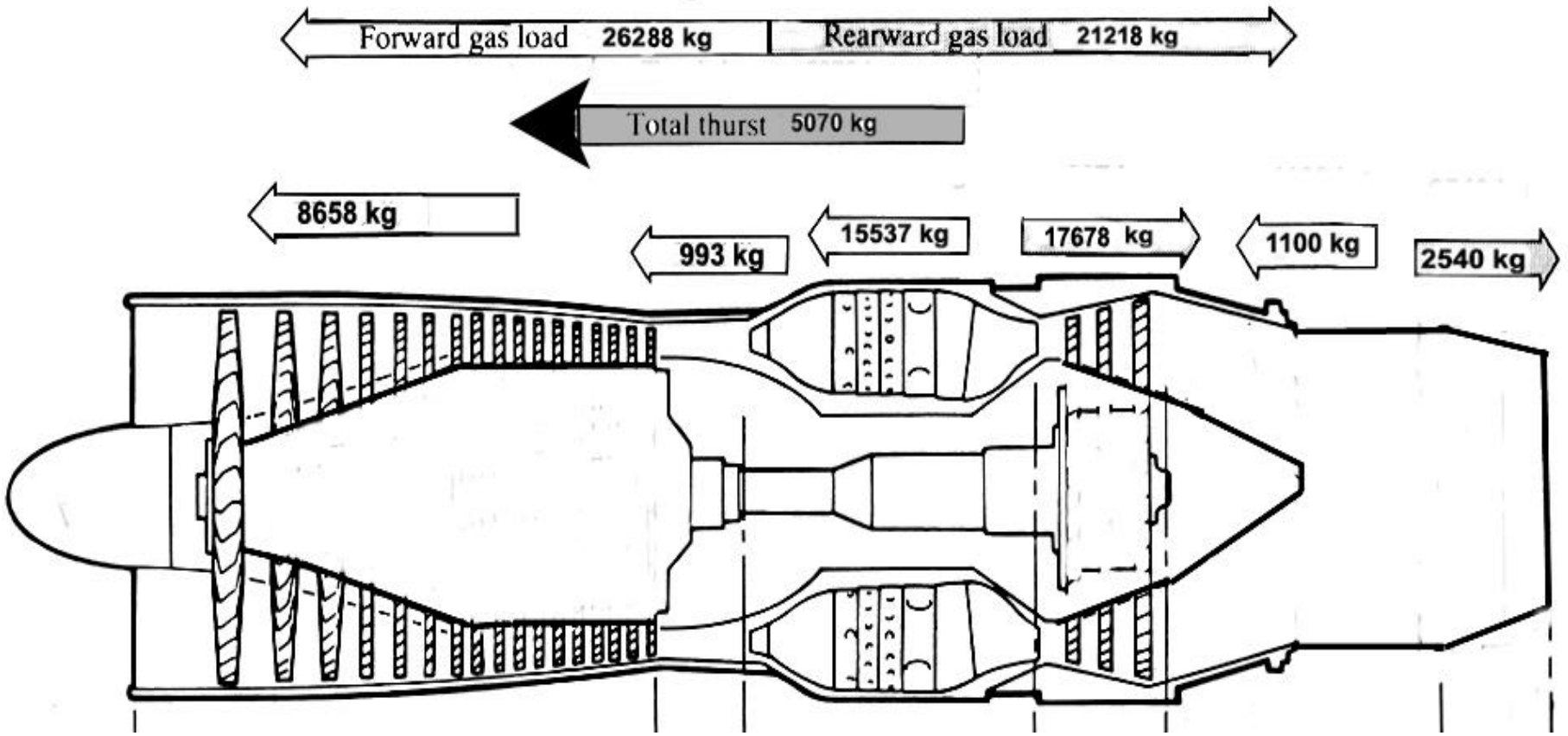
A pure turbojet engine with afterburner (mixed flow)



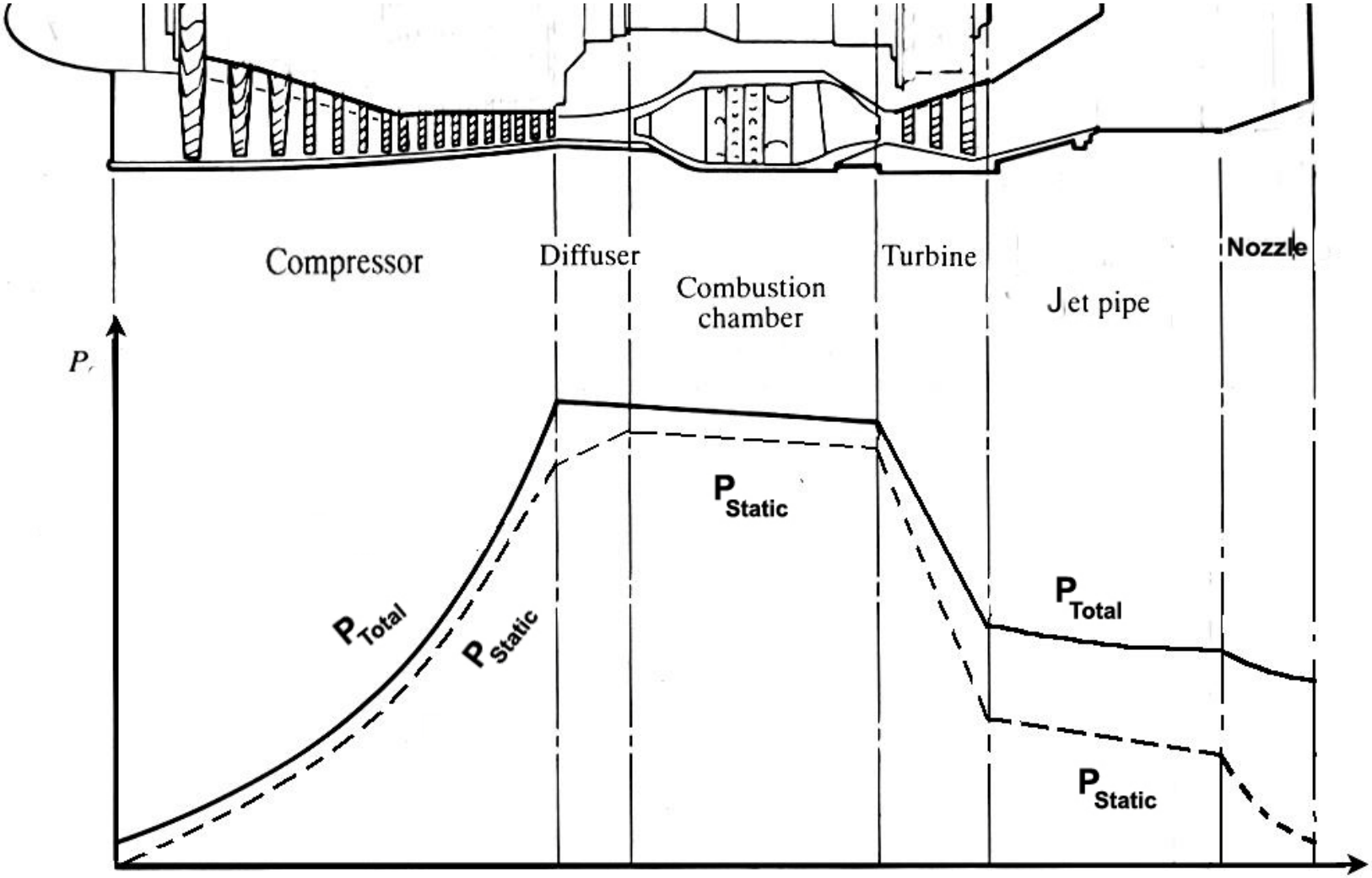
Mechanical Creation of Thrust by all components



Mechanical Forces created by various components of a Jet engine



Total and Static Pressures acting on various parts of a jet engine

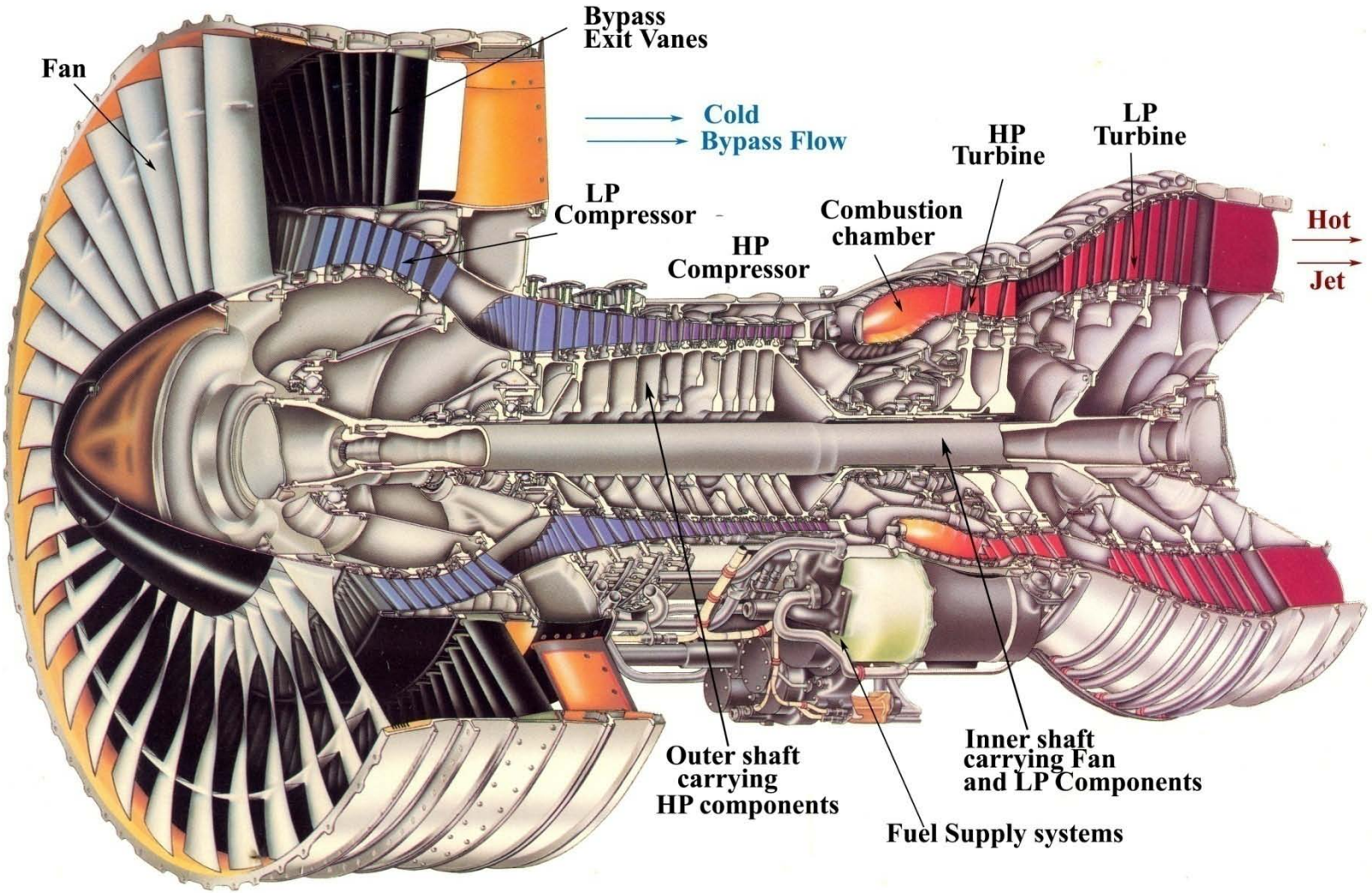


- All Mechanical loads (e.g. gas loads etc) are to be borne by various components of the engine. These are the components, that pass on the load to the overall structure of the engine. The engine, is rigidly attached to the aircraft, and provides pull (thrust) for motion.
- The load is variable and continuous during the entire operation of the engine.
- The load bearing components, e.g. bearings, struts etc need to be designed and installed to withstand these continuous forces. Otherwise the engine is liable to fail under huge mechanical loads, applied continuously.

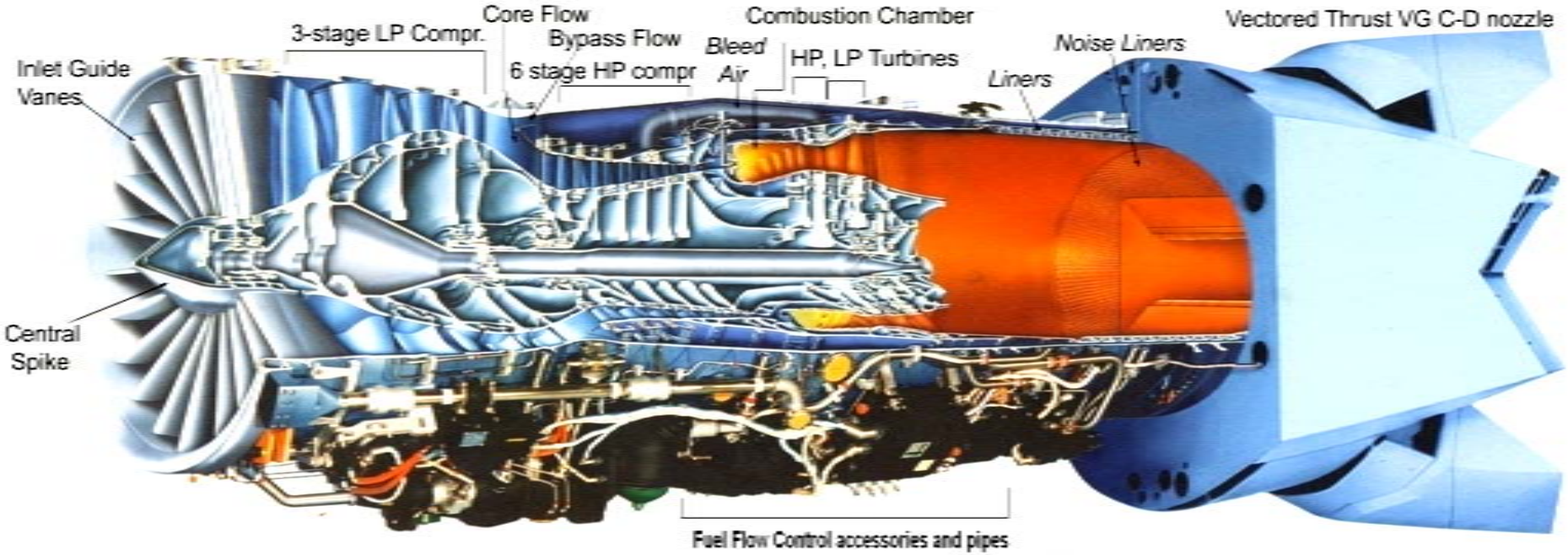
Thrust needs to be created for all flight regimes of the aircraft:

- **Take-off** – normally maximum thrust
- **Climb** – reducing from maximum thrust
- **Cruise** – normally minimum thrust
- **Manoevres** – variable thrust
- **Acceleration & Deceleration** - variable
- **Descend** – Low thrust
- **Landing** – Less than maximum thrust

A modern Large Turbofan Engine



A modern very-low bypass (almost pure turbojet) engine



Next class :

Jet Engine Performance Parameters

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