# Jet Aircraft Propulsion

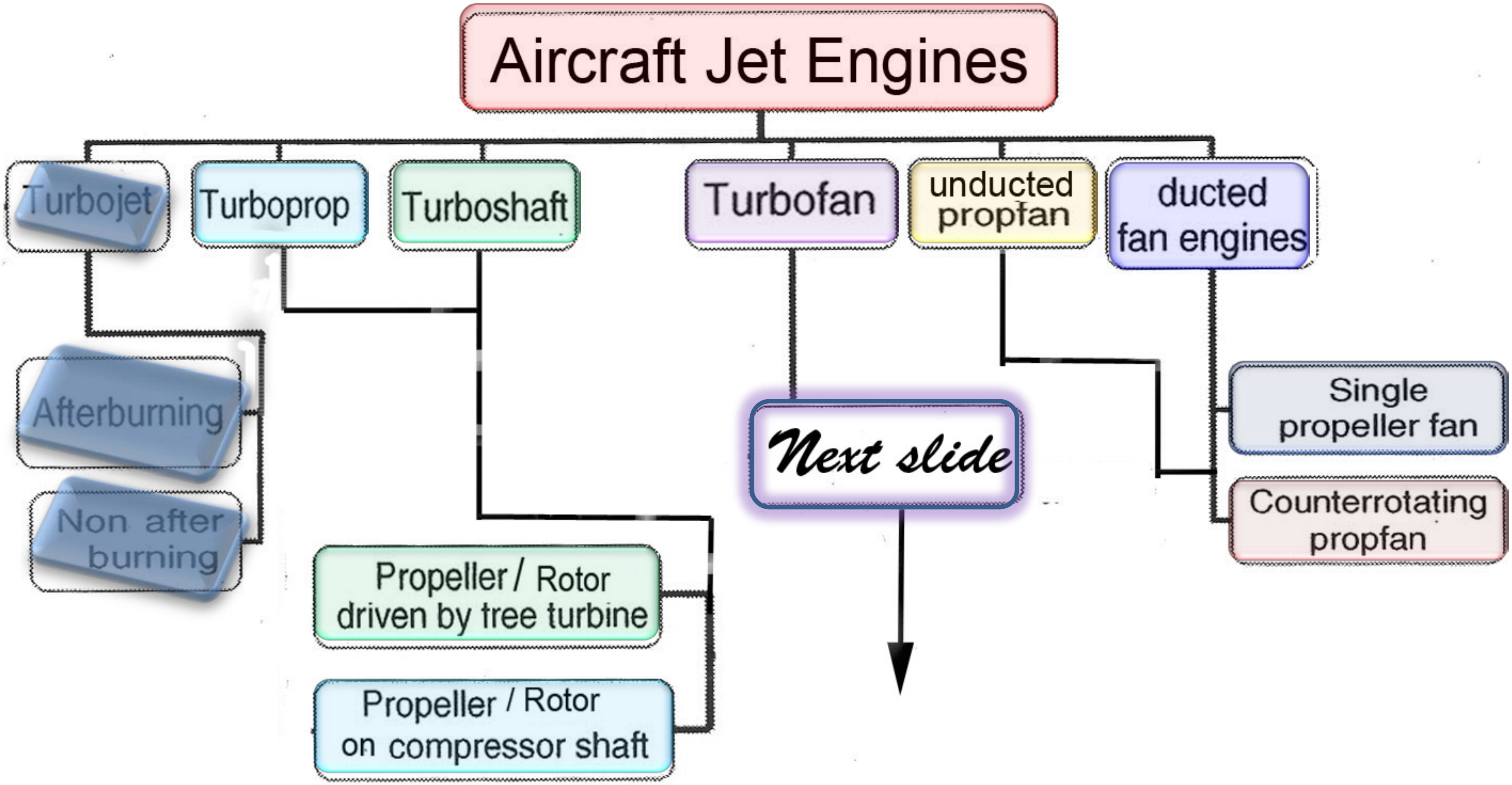
**Prof. Bhaskar Roy, Prof. A M Pradeep**
Department of Aerospace Engineering,
IIT Bombay

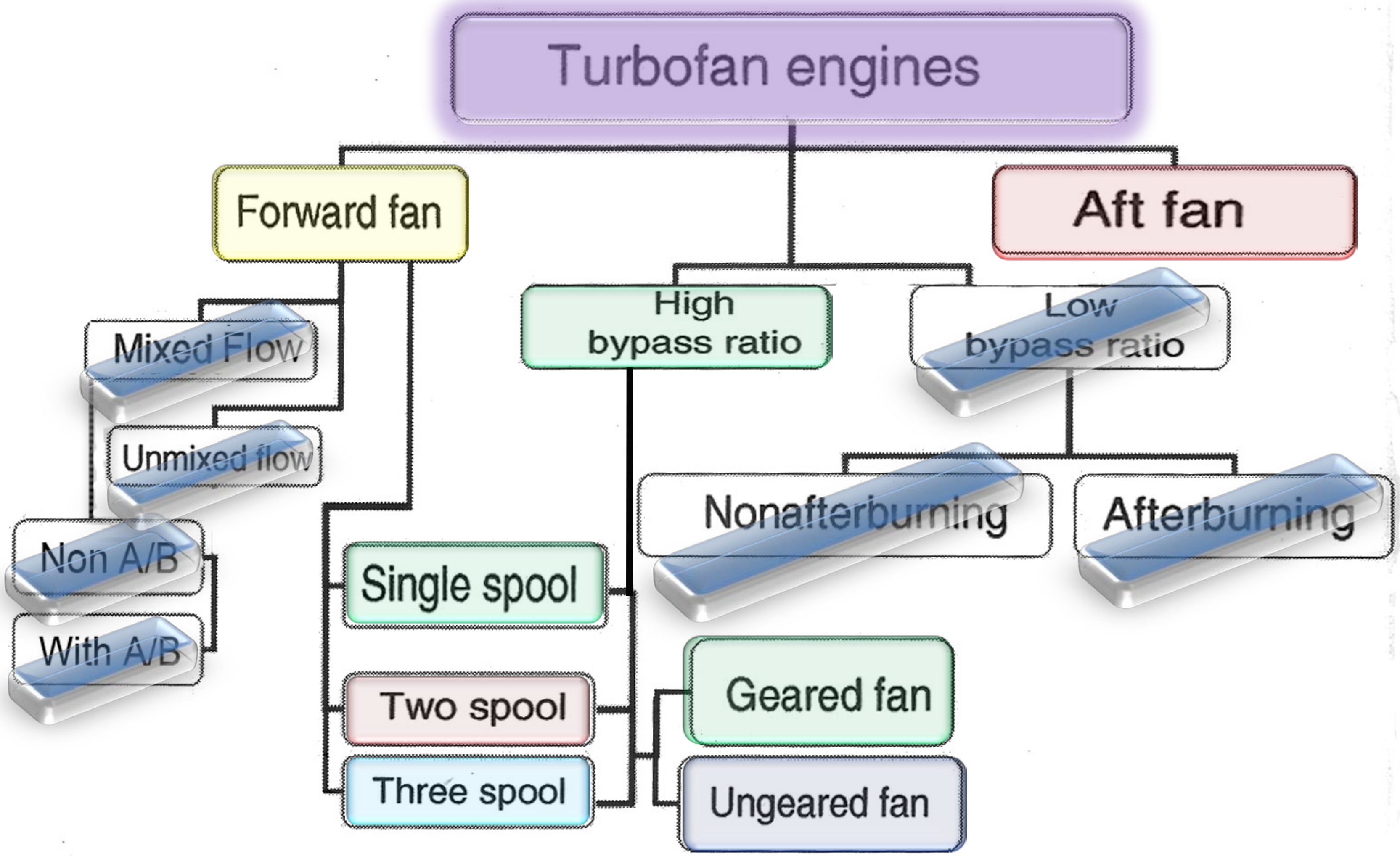
Lecture 5

**Today :**

# Variants of Aircraft Jet Engines


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

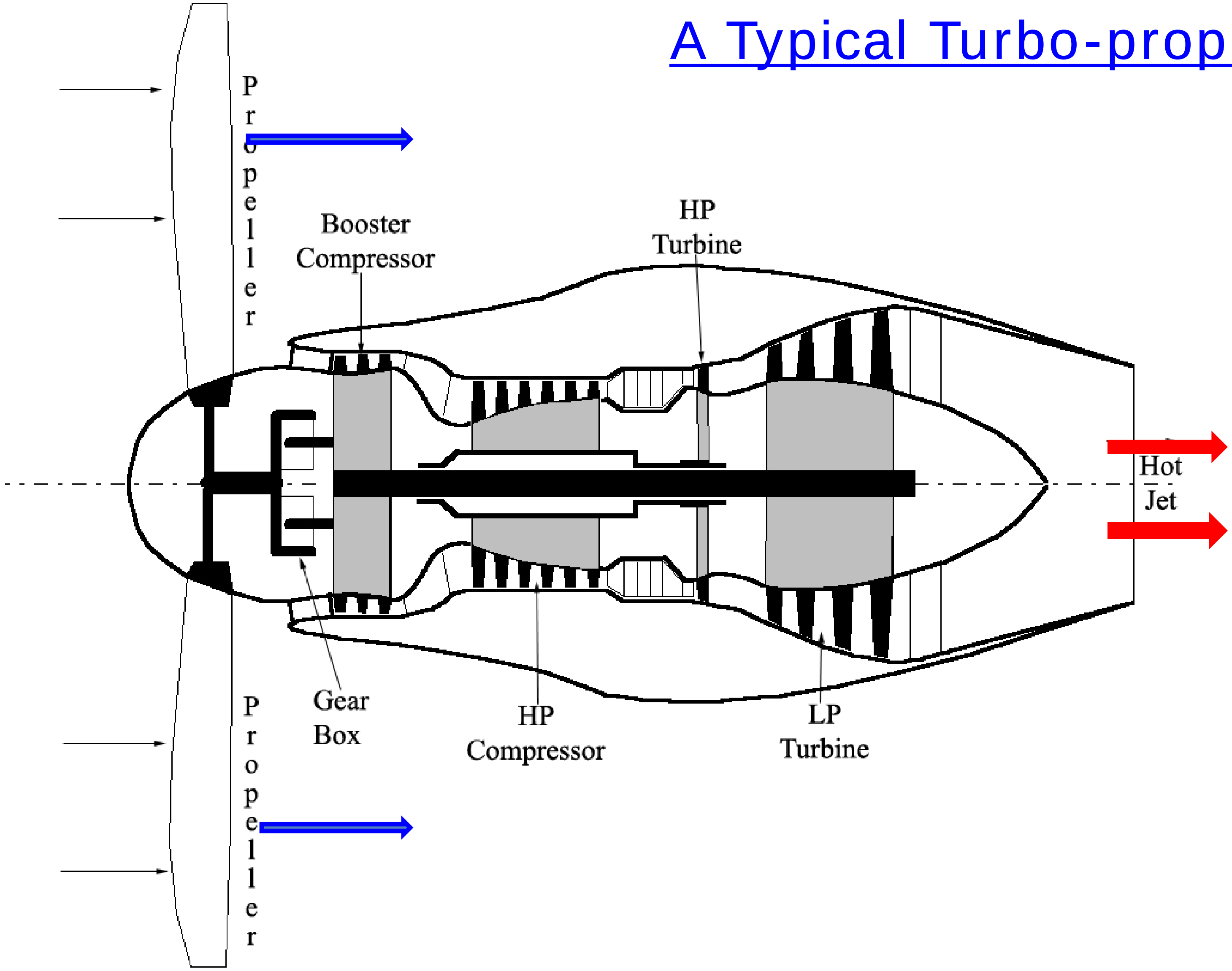

Aircraft Jet Engines
Turbojet
Turboprop
Turboshaft
Turbofan
unducted propfan
ducted fan engines
Afterburning
Non after burning
Propeller / Rotor driven by tree turbine
Propeller / Rotor on compressor shaft
Next slide
Single propeller fan
Counterrotating propfan





Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# A Typical Turbo-prop Engine



## Performance of Turboprop engines

Since most turboprop engines develop a small jet thrust of about 15-20% of the total thrust, it is necessary to account for this thrust in describing turboprop performance.

The total *thrust horsepower* of a turboprop engine is

$$\text{Total THP} = F_t V = \eta_p . \text{BHP} + F_j V$$

where $F_t$ = Total thrust of the engine

$\eta_p$ = Propeller efficiency

BHP = Shaft horsepower supplied to propeller

$F_j$ = Jet thrust

V = Aircraft velocity



Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

## Performance of Turboprop engines

Alternately

$$ESHP = BHP + \frac{F_j . V}{\eta_p}$$ , where, ESHP is *Equivalent shaft horsepower*,

or , $THP = \eta_p . ESHP$

$\eta_p$, is the propulsive efficiency of the jet thrust

$\eta_p$ is the propeller efficiency

Equivalent Total Thrust, $F_{t\text{-}eq} = THP / V$

**Sp Fuel Consumption, SFC = $\dot{m}_f$ / THP, kg / hr / kW**

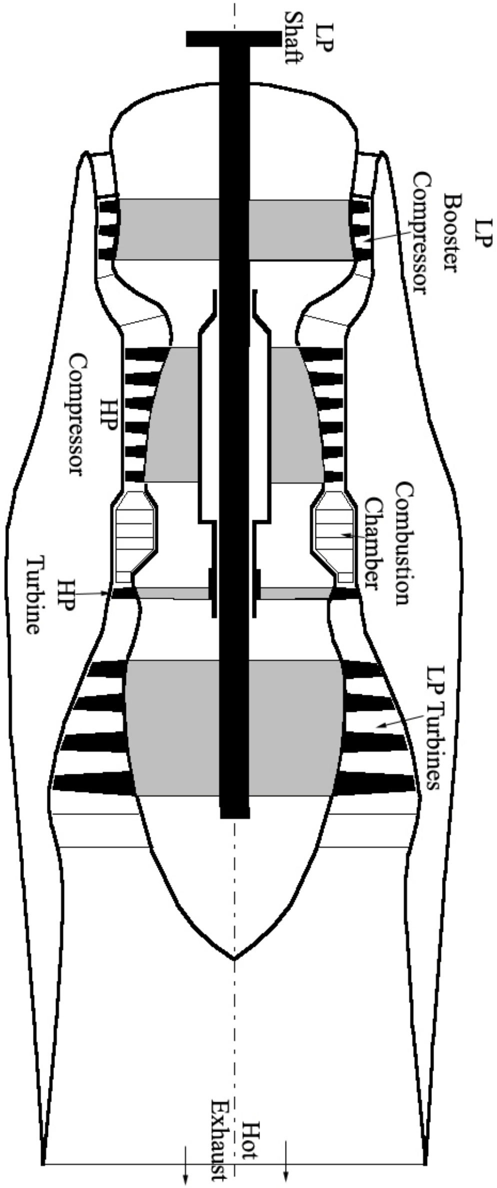
**or, SFC = $\dot{m}_f$ / ESHP, kg / hr / kW**

**or, SFC = $\dot{m}_f$ / $F_{t\text{-}eq}$, kg / hr / kN**



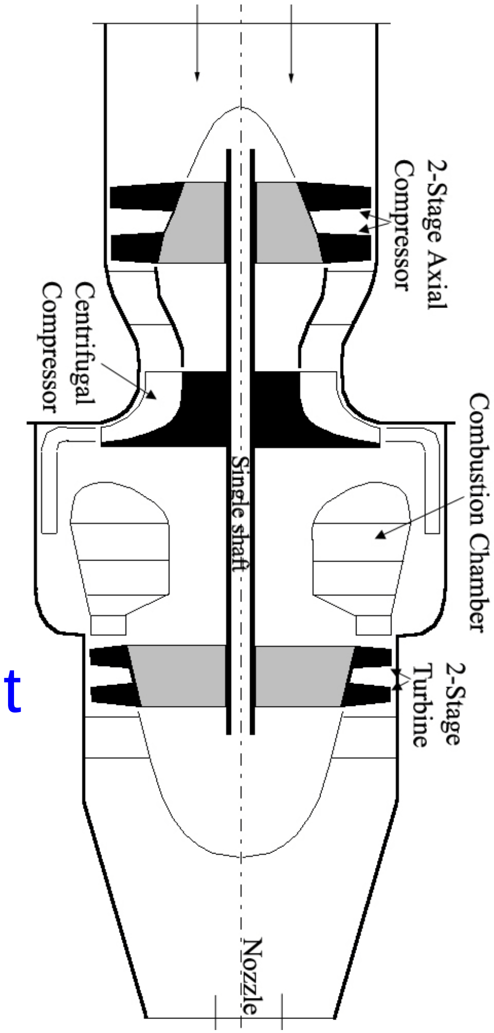
Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# Turboshaft Engines




Large Turboshaft Engine

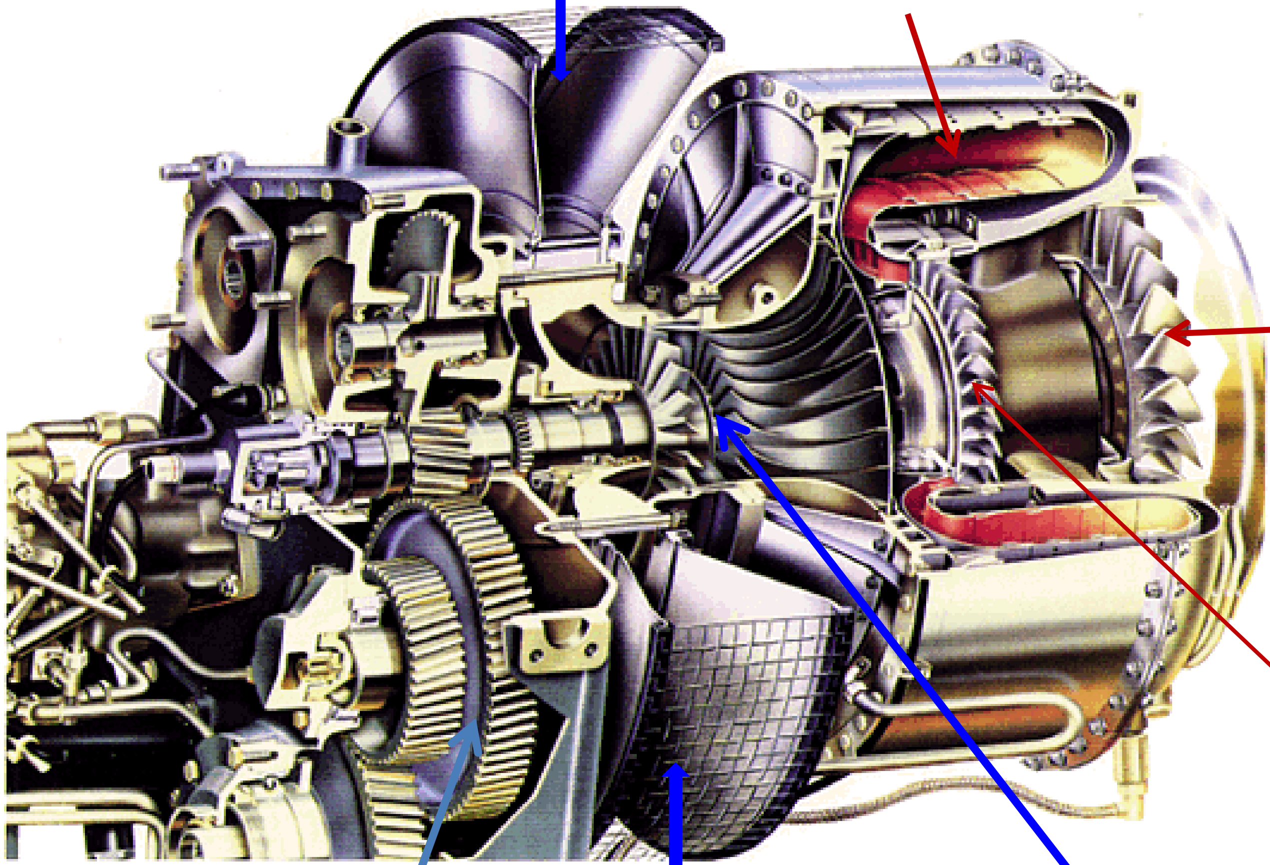
Medium sized Turboshaft Engine





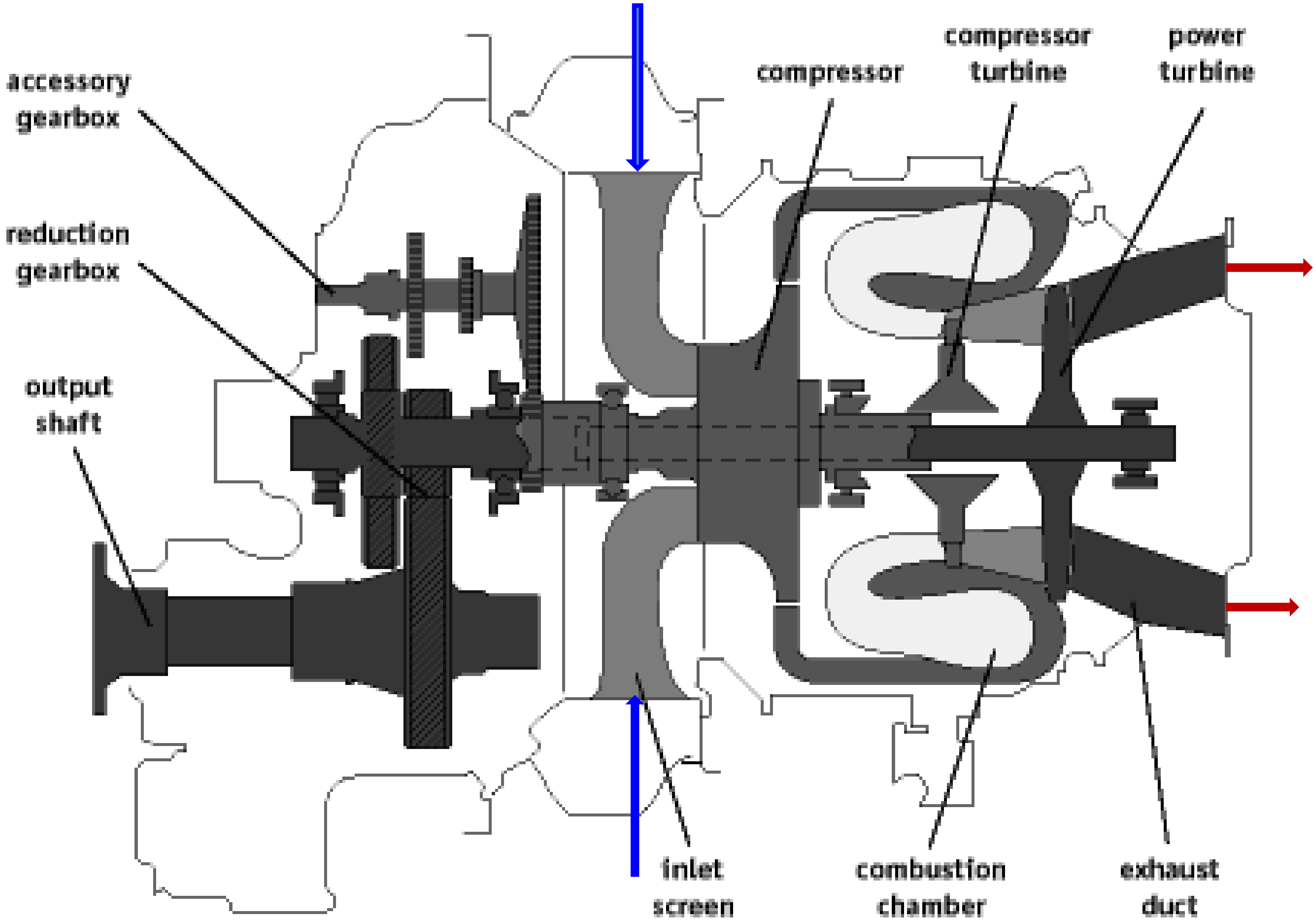

Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# Cut out of a turboshaft engine

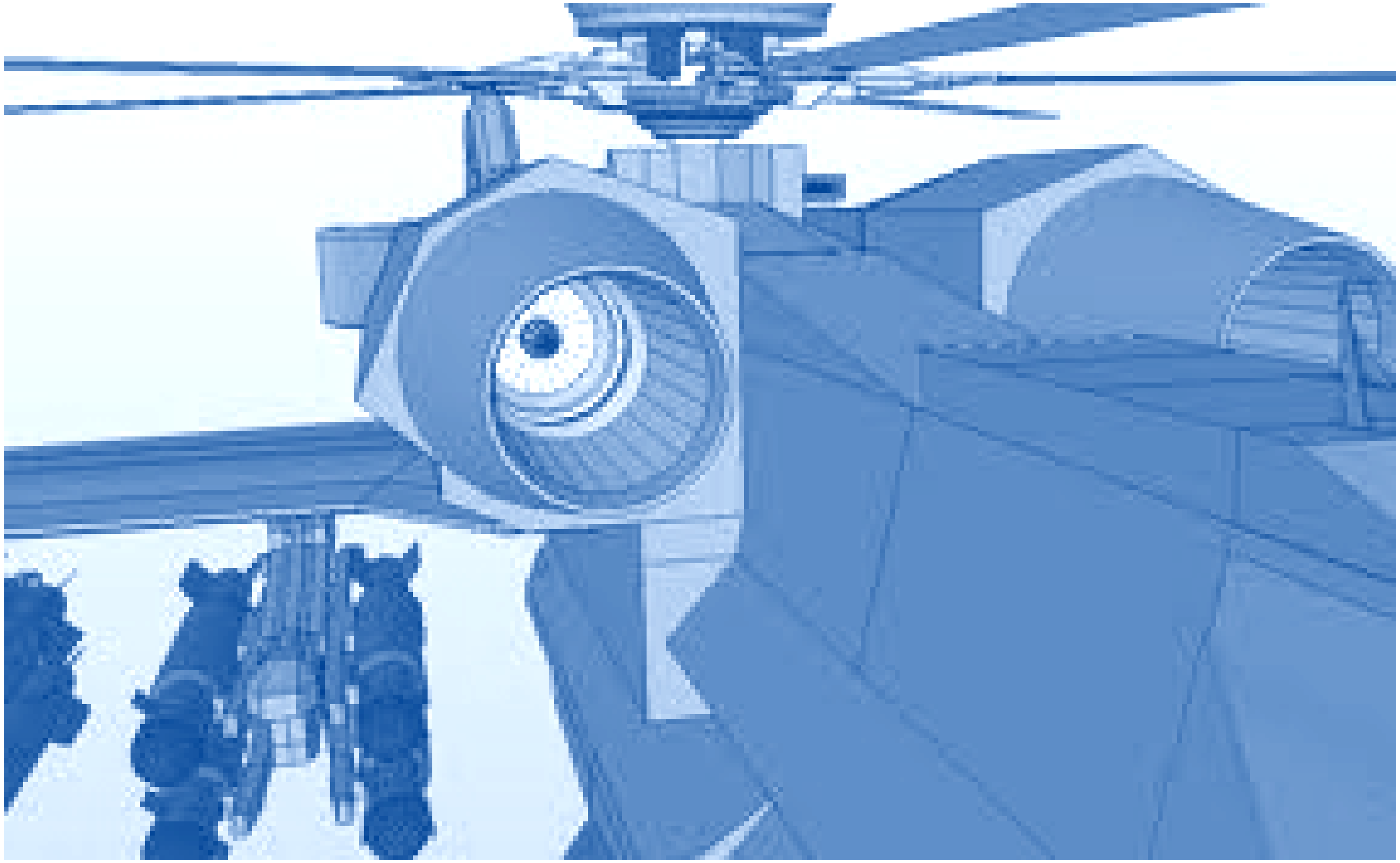




Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

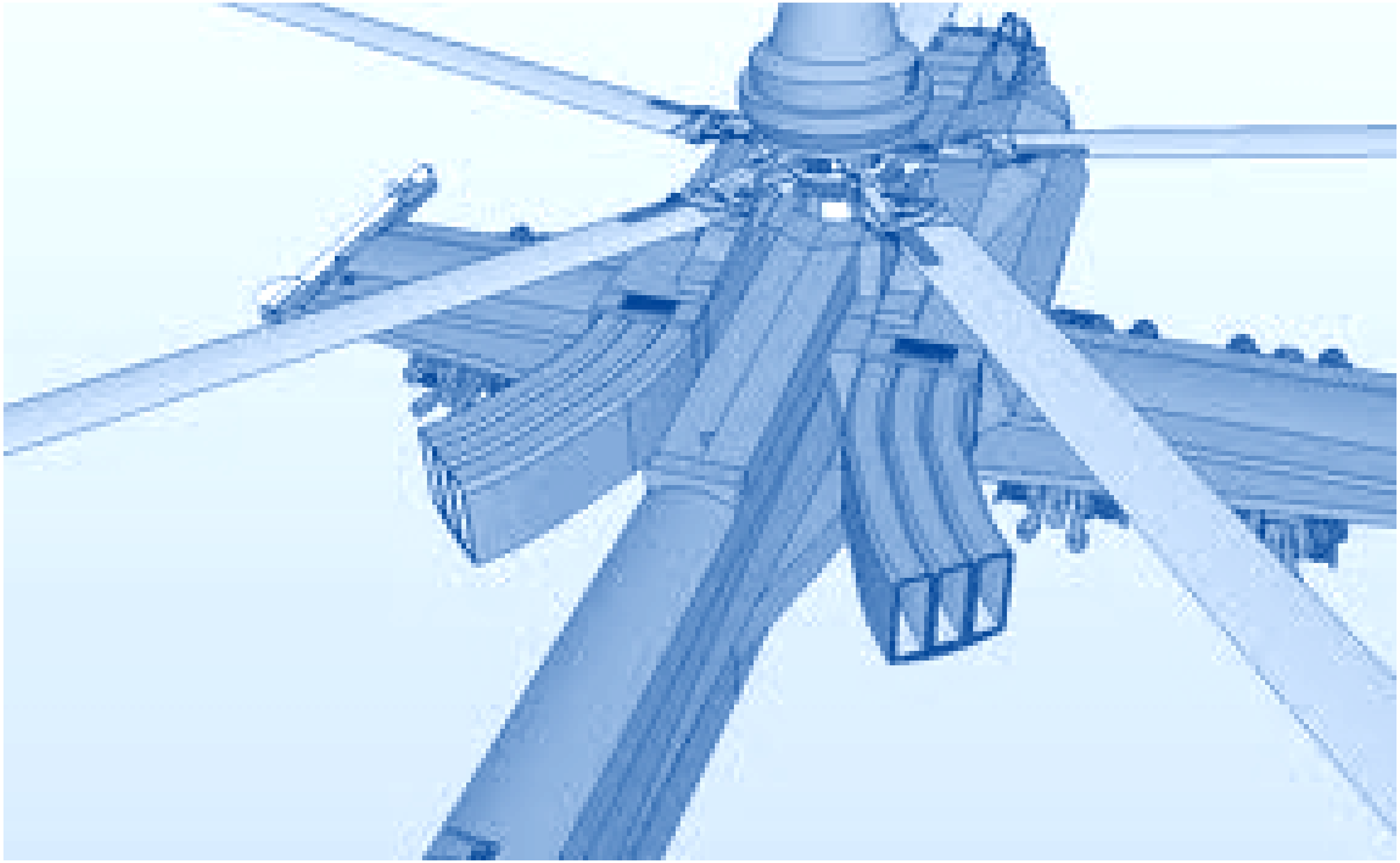

accessory
gearbox
reduction
gearbox
output
shaft
compressor
compressor
turbine
power
turbine
inlet
screen
combustion
chamber
exhaust
duct

# Helicopter engine Intake




Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

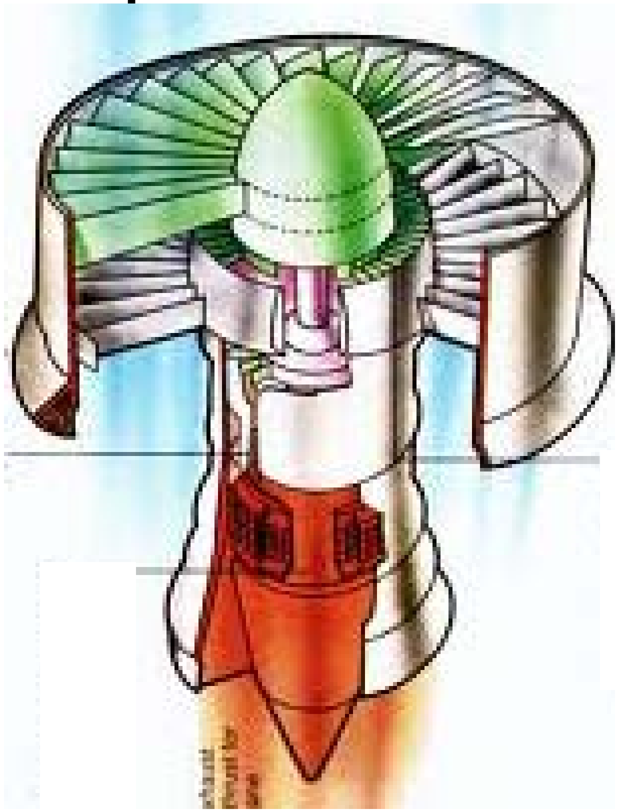
# Helicopter Engine Exhaust



# Turbo-shaft performances

$$THP = BHP \,.\, \eta_{P\text{-rotor}} \;,\; kW$$

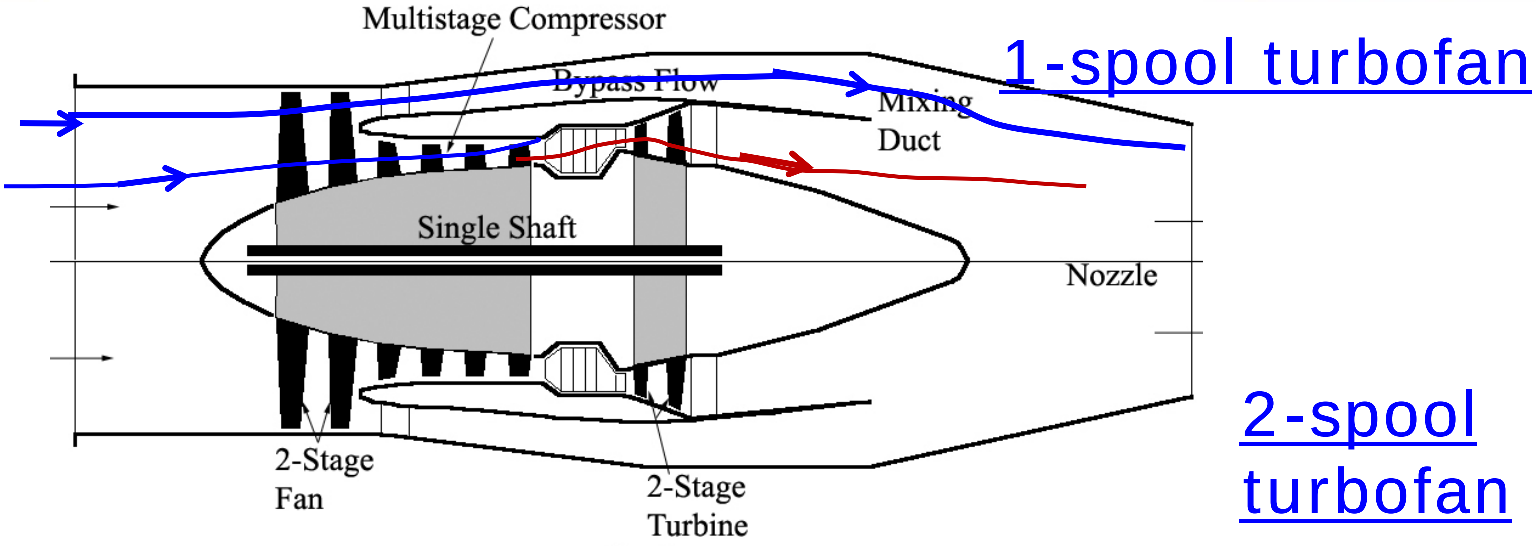
**Specific Fuel Consumption,** $SFC = \dot{m}_f / THP$, kg / hr / kW

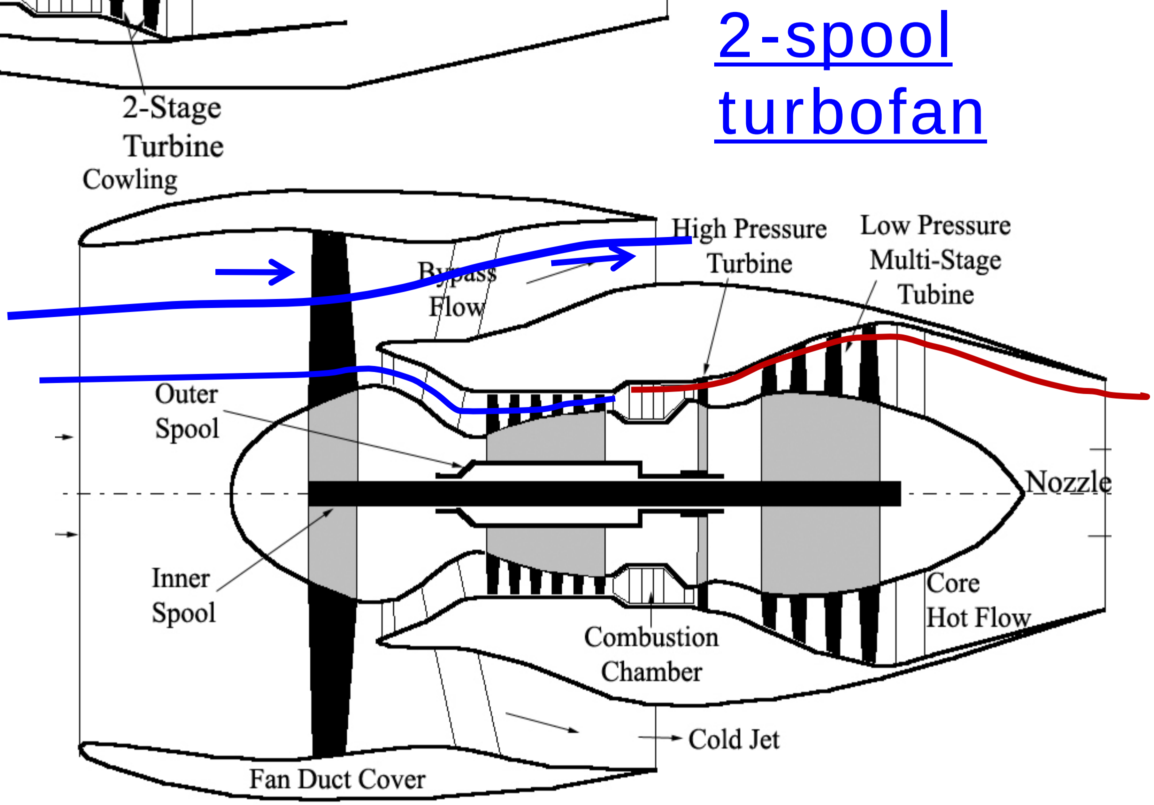


## Tilt rotor turbo-shaft cum turbo-fan engine

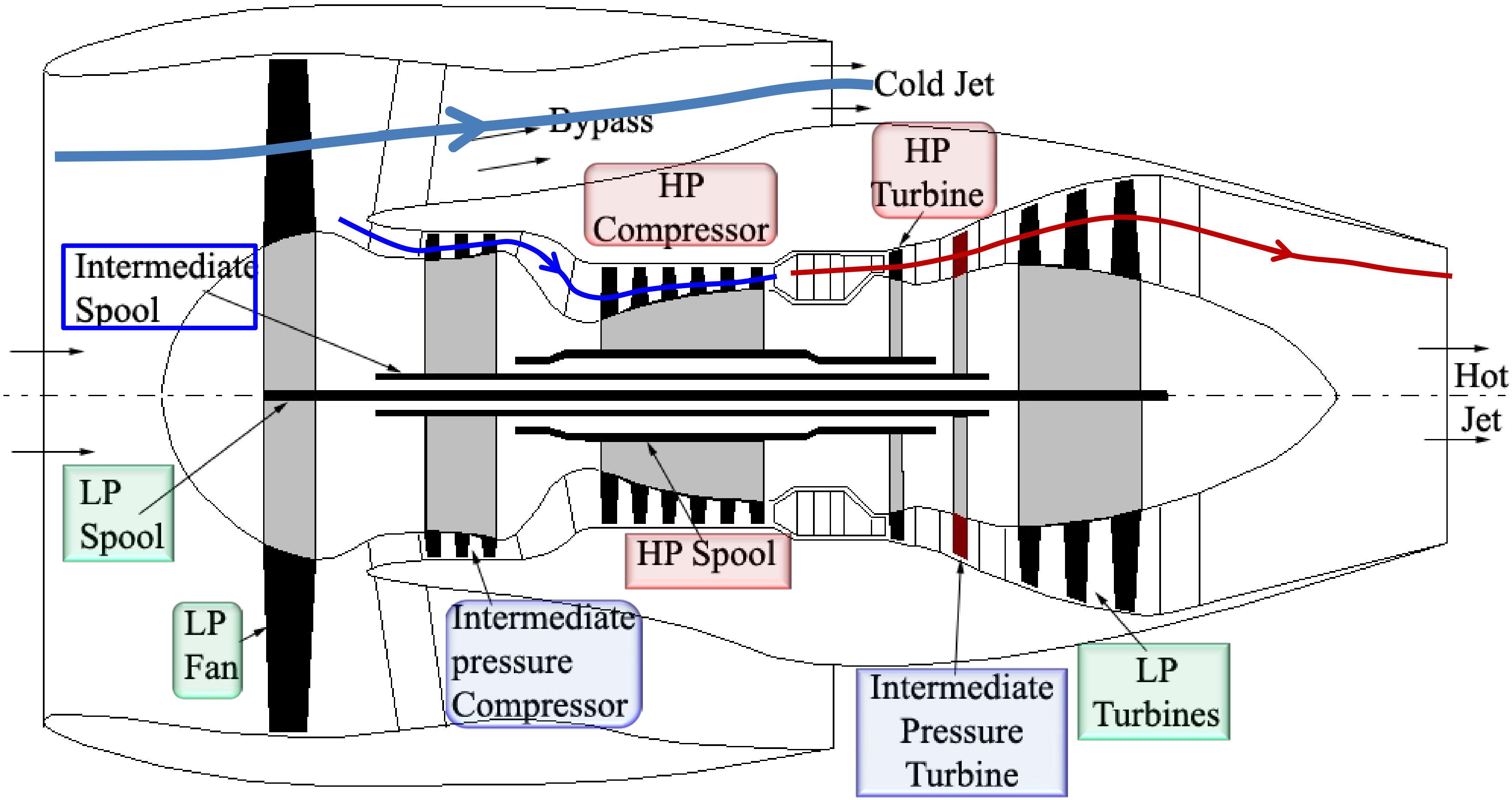


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay


Multistage Compressor
Bypass Flow
Mixing
Duct
Single Shaft
Nozzle
2-Stage
Fan
2-Stage
Turbine
1-spool turbofan


2-spool
turbofan
Cowling
High Pressure
Turbine
Low Pressure
Multi-Stage
Tubine
Bypass
Flow
Outer
Spool
Nozzle
Inner
Spool
Core
Hot Flow
Combustion
Chamber
Cold Jet
Fan Duct Cover

## 3-spool turbofan



## Thrust of a bypass engine

$$F_n = [(\dot{m}_a + \dot{m}_f)V_{e\text{-}hot} - \dot{m}_a . V_a]_{hot\text{-}jet}$$

$$+ \; \dot{m}_{a\text{-}bypass}[V_{e\text{-}bypass} - V_a]$$

## SFC of a bypass engine

$$SFC = \frac{\dot{m}_{f-cc}}{F_{n-hot} + F_{n-cold}}$$


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# Overall Efficiency of Bypass Jet engine

$$\eta_o = \frac{\dot{m}.V_a.(V_e - V_a)}{\dot{m}_f.\dot{Q}_{fuel}} = \eta_p . \eta_e$$

# Exhaust Jet waste

$$\frac{\dot{m}_{hot}.(V_{e\text{-}hot} - V_a)^2 + \dot{m}_{cold}.(V_{e\text{-}bypass} - V_a)^2}{2}$$


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# Propulsive Efficiency of Bypass Jet engines

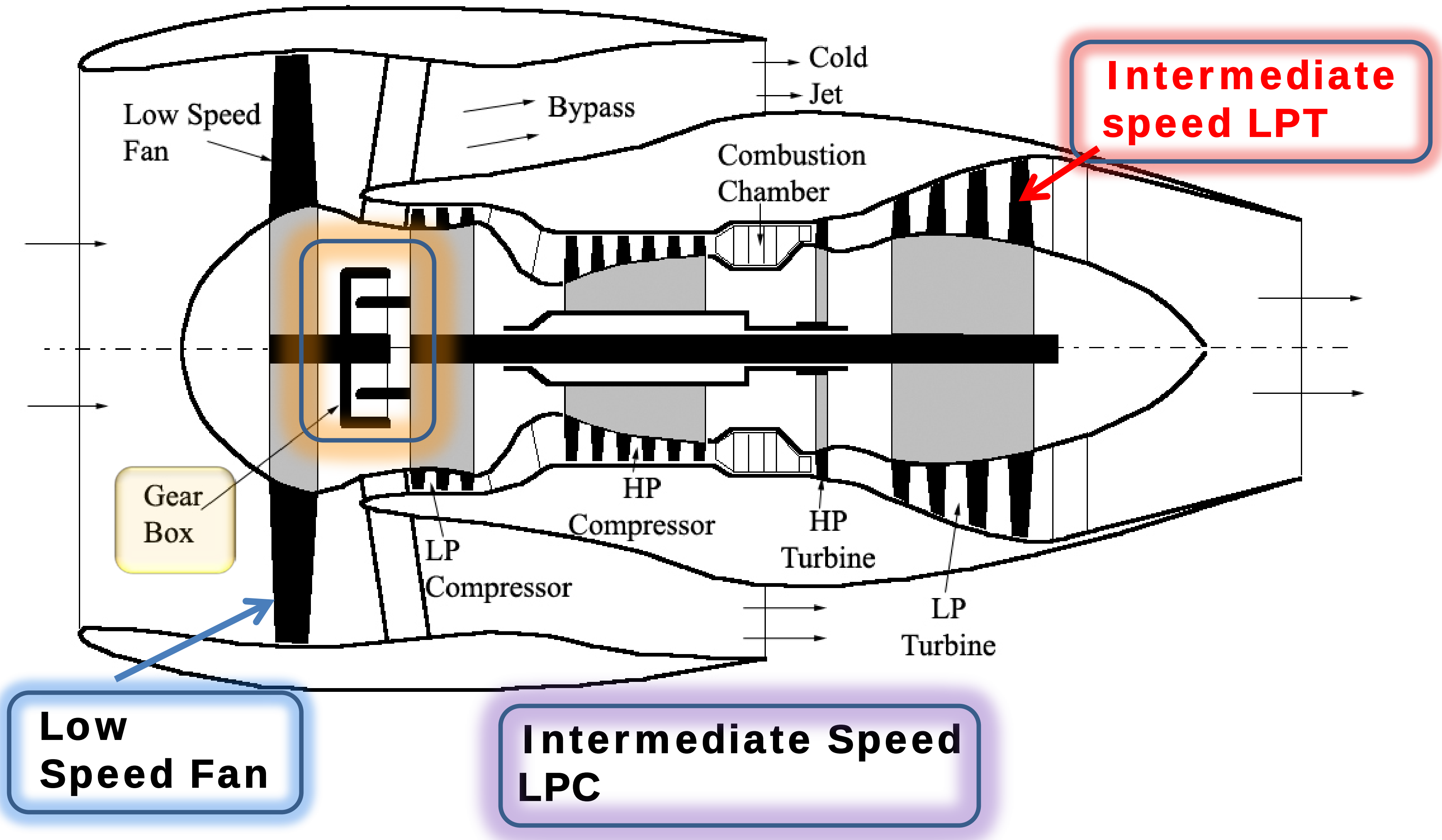
$$\eta_p = \frac{2}{1 + \frac{V_{e-average}}{V_a}}$$

where, $$V_{e\text{-}average} = \frac{\dot{m}_{a\text{-}hot} . V_{e\text{-}hot} + \dot{m}_{a\text{-}bypass} . V_{e\text{-}bypass}}{\dot{m}_{a\text{-}hot} + \dot{m}_{a\text{-}bypass}}$$

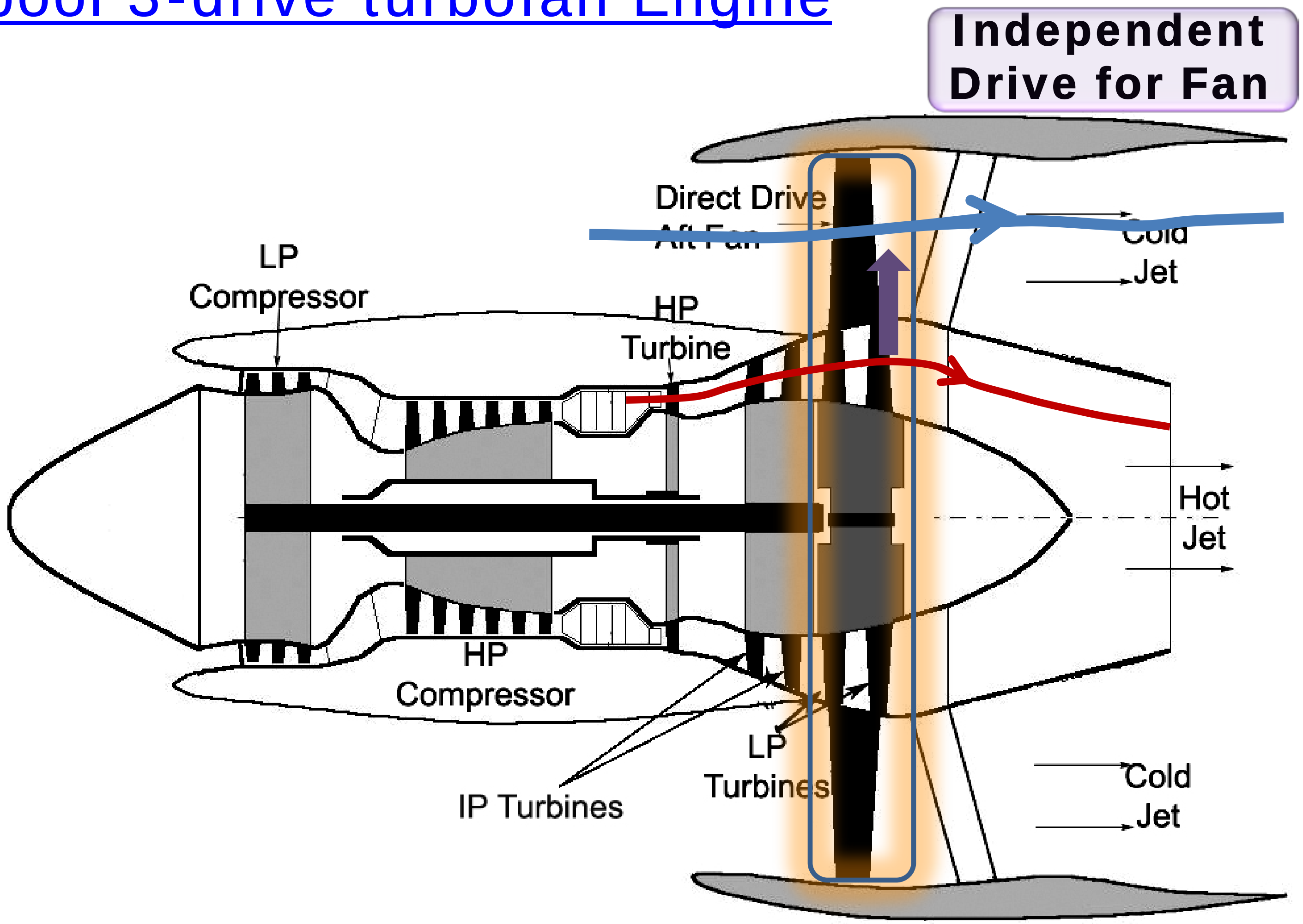
*and*, Bypass Ratio, $$\mathbf{B} = \frac{\dot{m}_{a\text{-}bypass}}{\dot{m}_{a\text{-}hot}}$$


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# A 2-spool geared turbofan jet engine



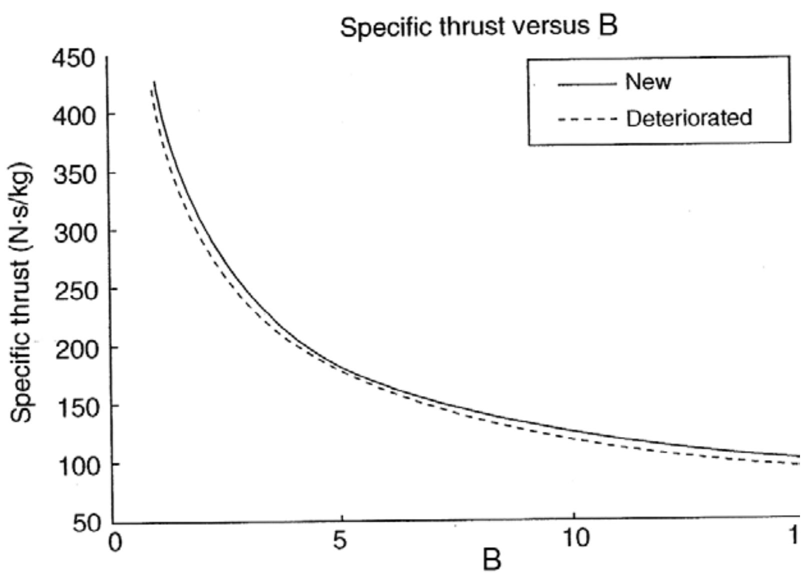
# A 2-spool 3-drive turbofan Engine



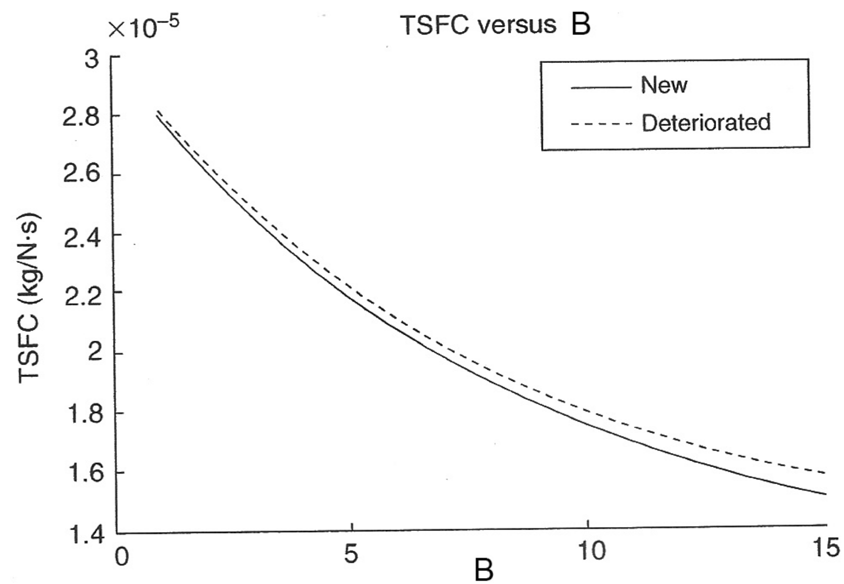


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# Effect of Bypass ratio on Engine Performance parameters




Variation of specific thrust with BPR.



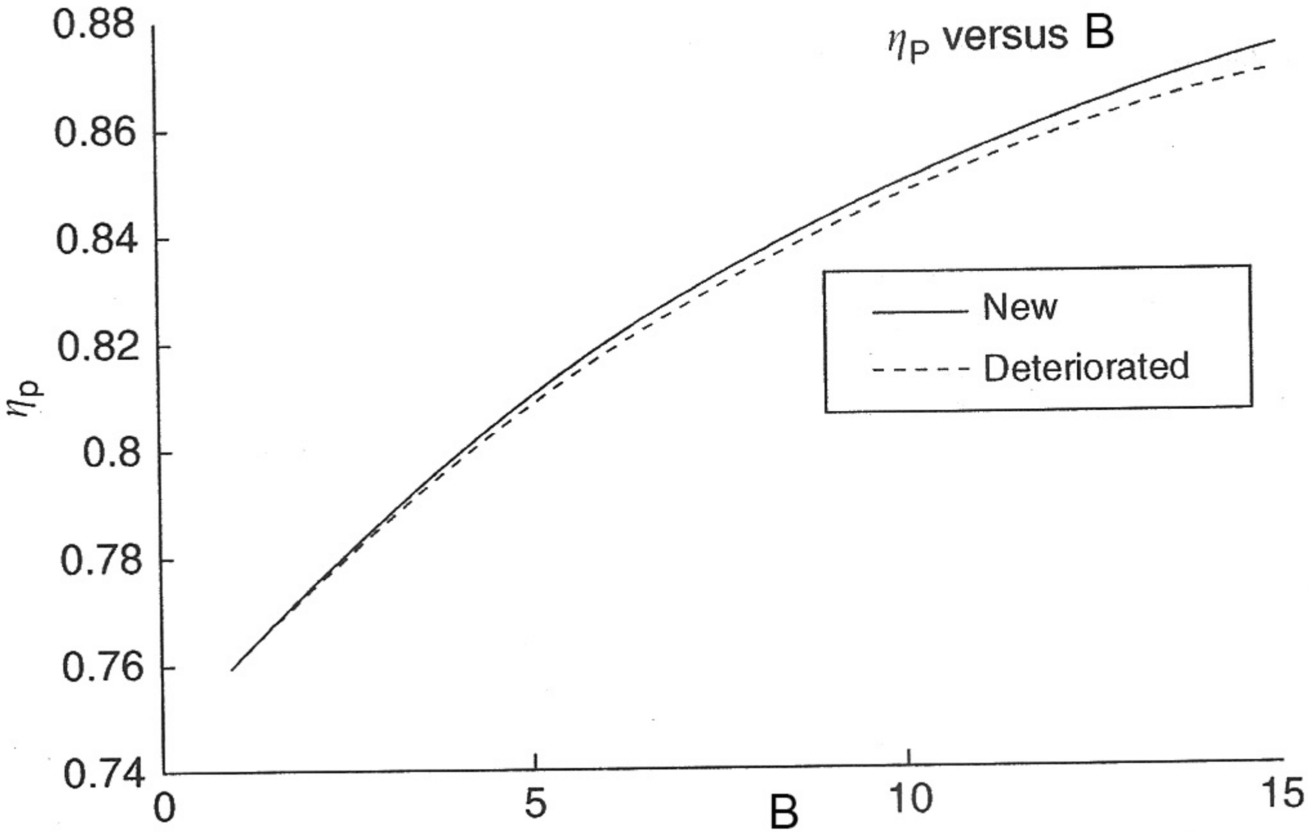

Variation of specific fuel consumption with BPR.

Sp Thrust vs BPR

TSFC vs BPR


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

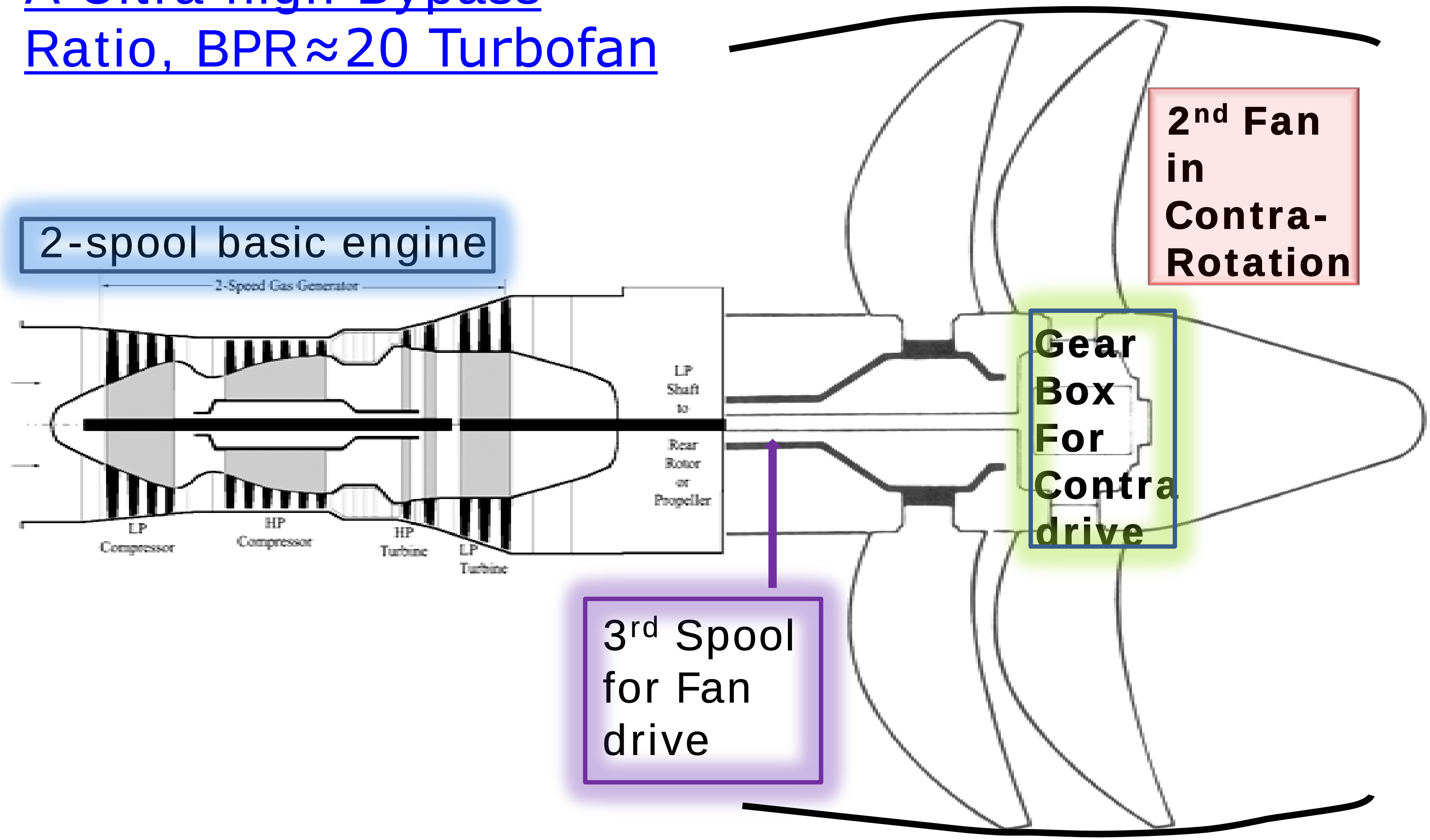
# Effect of Bypass ratio on Engine Performance parameters




Variation of propulsive efficiency with BPR.


Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

# A Ultra high Bypass Ratio, BPR≈20 Turbofan





Prof. Bhaskar Roy, Prof. A M Pradeep, Department of Aerospace, IIT Bombay

Next Lecture :

**Cycle Analysis**

by

Prof A M Pradeep