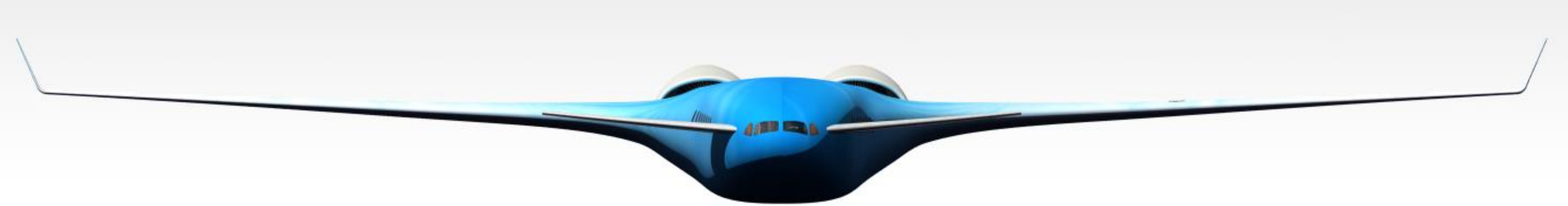


AE4238: Aero Engine Technology
Tutorial: cycle calculation

14 November 2025

TU Delft

Outline of the tutorial

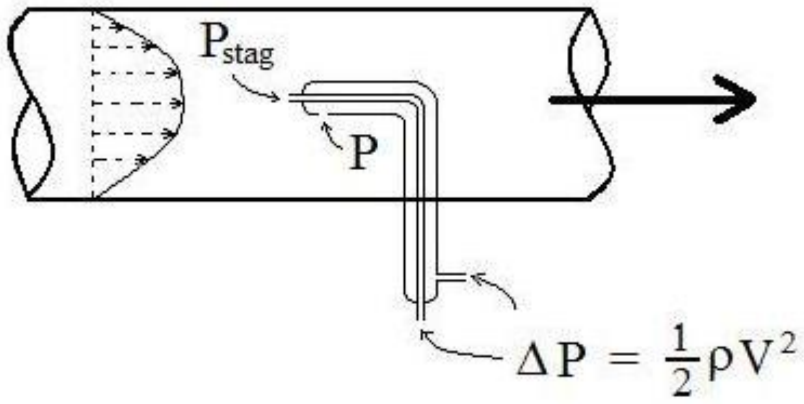
- Single-shaft turboprop
- Twin-spool turbofan

General Procedure

- Basic idea is to mathematically model all the processes of the engine's thermodynamic cycle using the known data for the engine considering real-Brayton case.
- Necessary simplification may be made as and when they are required
- The following are the main steps involved:
  - Calculate the parameters at the inlet of the engine
  - Model the compression process assuming adiabatic compression
  - The heat addition process can be analysed from the turbine inlet conditions
  - Like compression, expansion in a turbine can also be modelled as adiabatic expansion
  - Afterburner (if present) can be treated similarly to the main heat addition process
  - Lastly evaluating the expansion in the exit nozzles will yield the exhaust parameters
  - Thrust and other performance indicators can be evaluated once the exhaust parameters are known

Note

- Total properties (T_t, P_t) are used to account for the fluid's motion during the whole cycle calculation. Static properties are only used at stations inlet of the engine (station 1) and exit of the nozzle (station 8) to compute the thrust



- Nomenclature note: total properties can be noted with the sub-index *t* or *0*

Useful formula

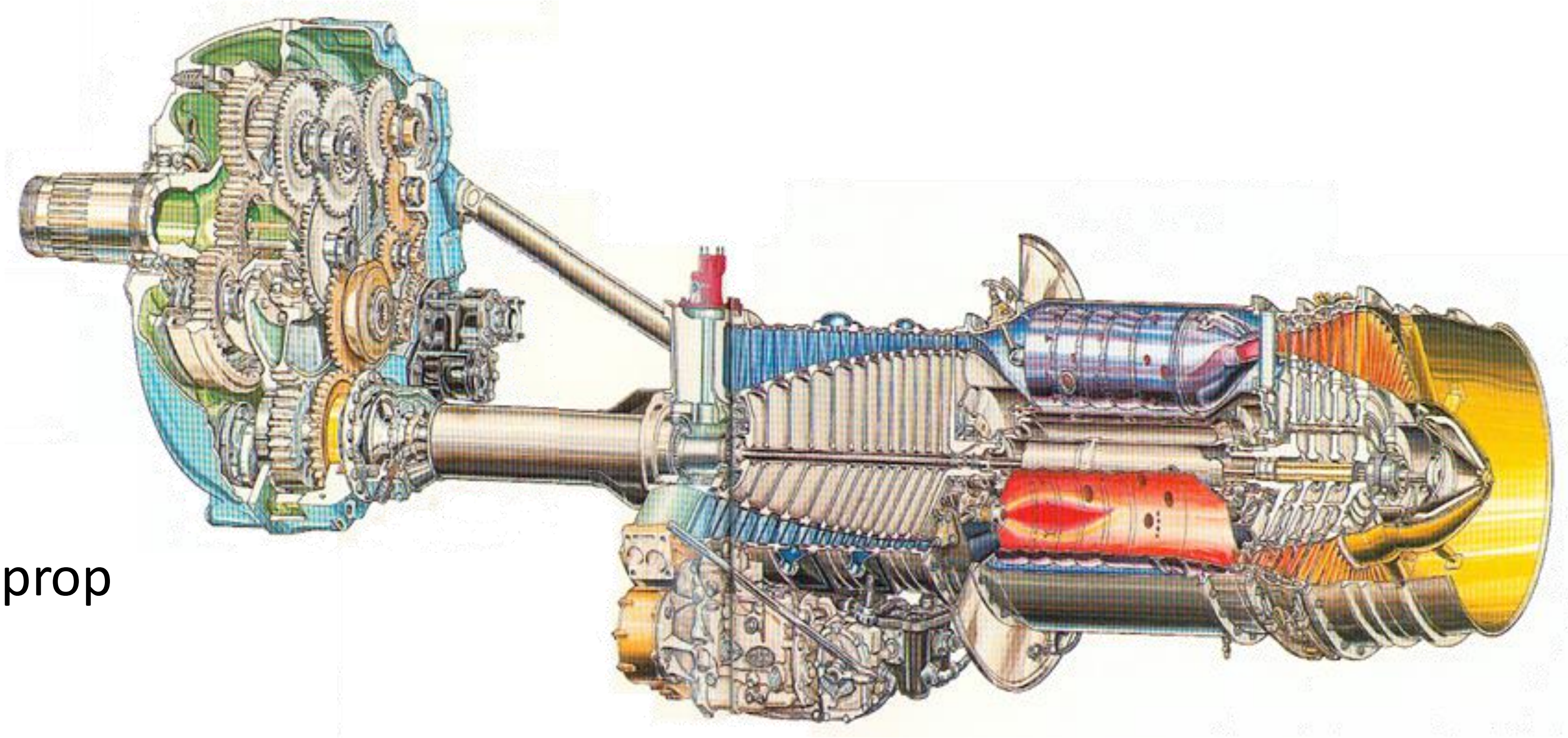
- Thrust: $F = \dot{m}(v_j - v_0)$
- Specific fuel consumption: $\mathrm{SFC} = \frac{\dot{m}_f}{F}$
- Nozzle critical pressure ratio

$$p_{t,7} / p_{critical} = \left[\frac{1}{\left(1 - \left(\frac{1}{\eta_j}\right) \cdot \left(\frac{\kappa_g - 1}{\kappa_g + 1}\right)\right)^{\frac{\kappa_g}{\kappa_g - 1}}} \right]$$

Example of a single shaft turboprop engine

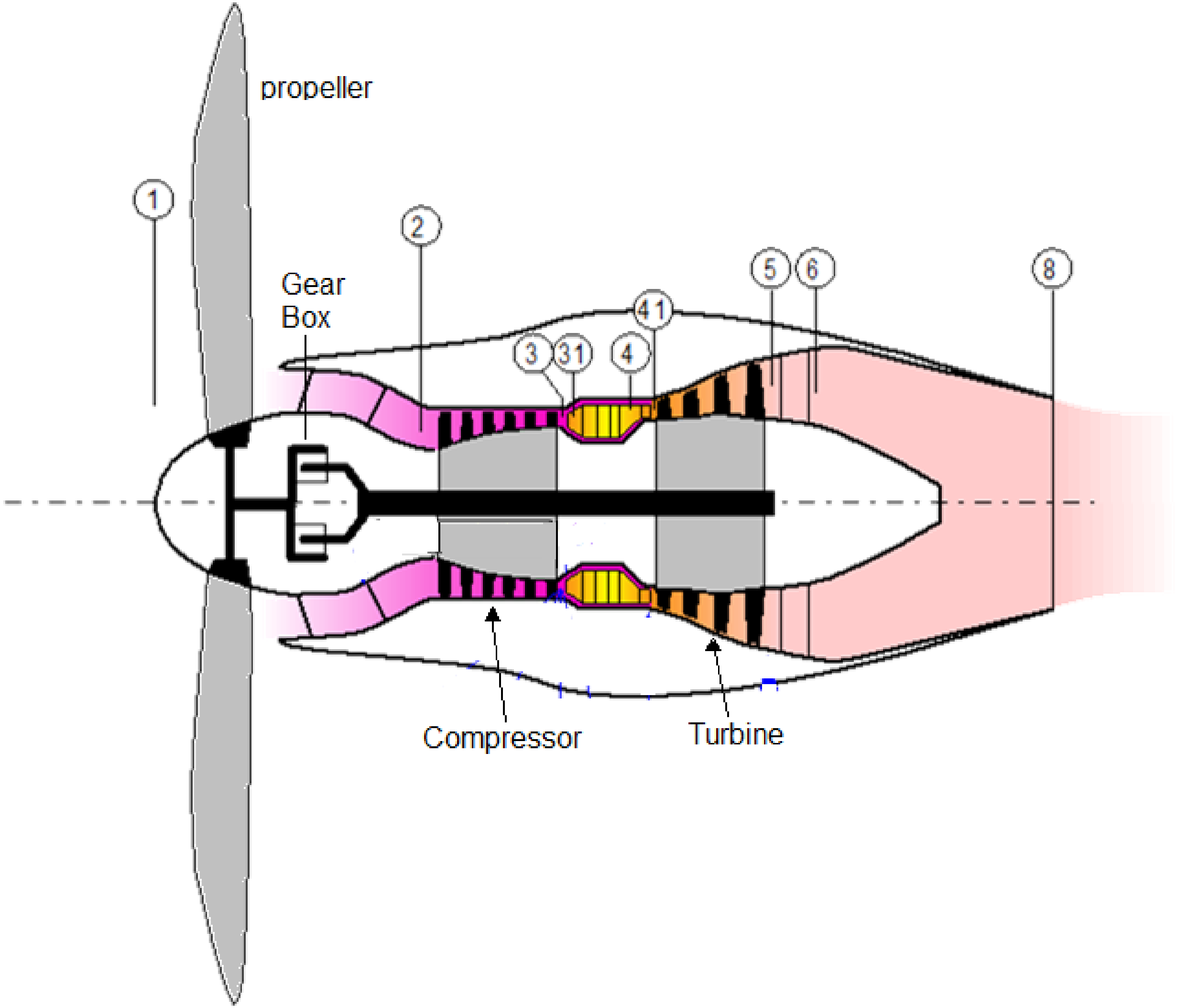
E-2C Hawkeye

Rolls Royce T56-A Series IV



Single shaft turboprop
Length: 3.71 m
Diameter: 0.69 m
Basic weight: 1940 lb
Power-to-weight ratio: 2.75:1

Engine Nomenclature



T56-A Series IV Specifications

General characteristics at SL, ISA take off conditions, Mach = 0.5

- Compressor= 14 stages axial flow
- Combustors= 6-cylindrical flow-through
- Turbine= 4 stages axial flow
- Nozzle= Convergent
- Shaft power = 5250 shp (3.91MW)
- Compressor Pressure Ratio = 11.5
- Combustor Exit Temperature (T4) = 1130K
- Engine mass flow rate= 35 kg/s
- Intake Pressure ratio= 1.0

Calculate pressure, temperature and mass flow at every station. Calculate the total thrust

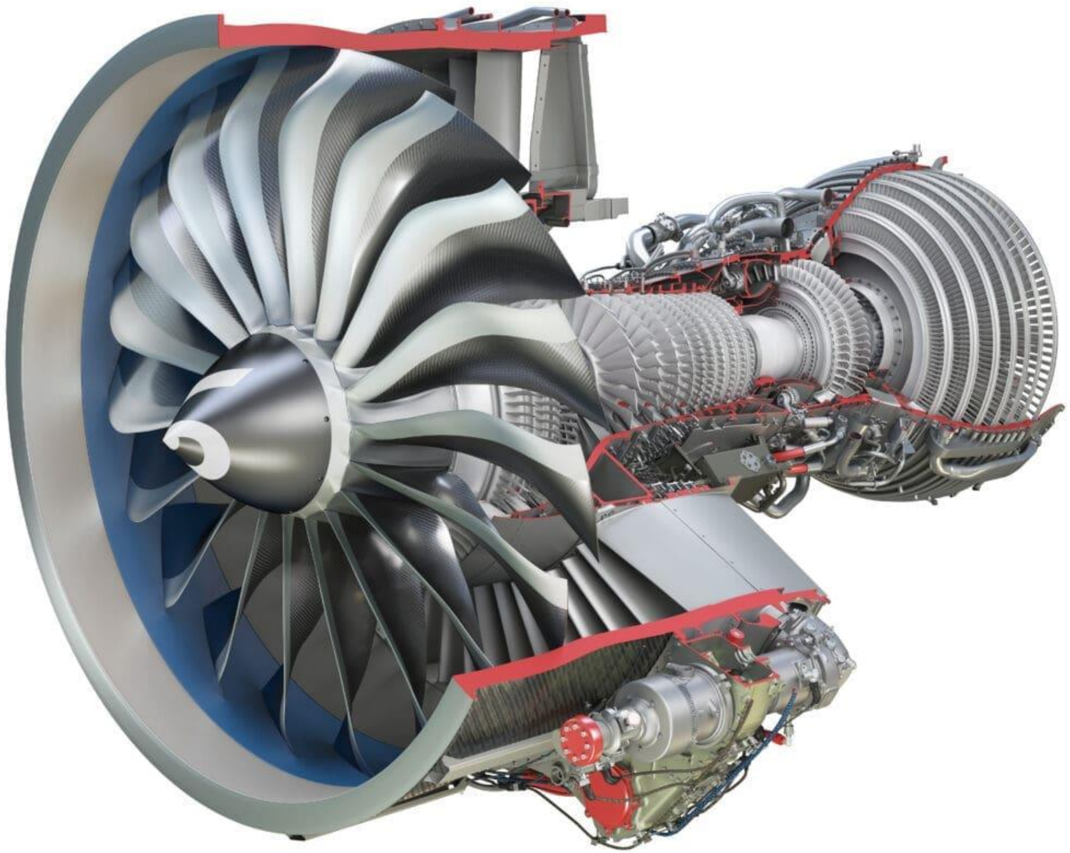
- Propeller efficiency = 0.9
- Compressor isentropic efficiency = 0.85
- Turbine isentropic efficiency = 0.89
- Mechanical efficiency = 0.99
- Combustion efficiency = 0.995
- Combustion chamber Pressure Ratio = 0.96
- Nozzle efficiency = 0.95
- C_{Pair} = 1000 J/kg-K; kappa air = 1.4
- C_{Pgas} = 1150 J/kg-K; kappa gas = 1.33
- Gas constant= 287 J/kg K
- Fuel calorific value = 42.8 MJ/kg
- Ambient Pressure = 101325 Pa
- Ambient Temperature = 288.15K

Example of a twin-spool unmixed turbofan engine

A320 neo

Figure source: Airbus

LEAP-1A turbofan engine

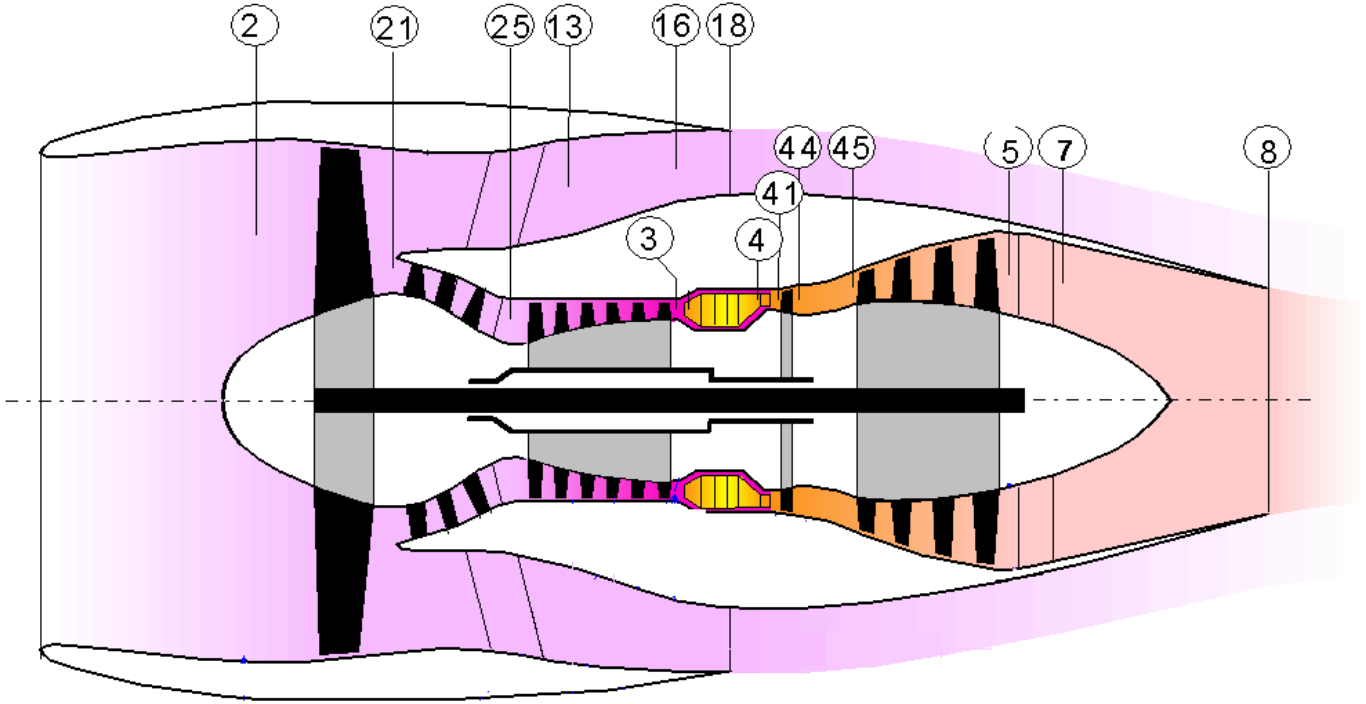


Twin spool turbofan:

- Compressor: 1 fan, 3-stage low pressure compressor, 10-stage high pressure compressor
- Turbine stages: 2-stage high pressure turbine , 7-stage Low pressure turbine
- Take off thrust: ~120 kN

Figure taken from: https://ses.aero/engines/

Turbofan Nomenclature



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LEAP-1A Turbofan

LEAP-1A at cruise condition(Mach = 0.78 Altitude = 10668 meter):

- Inlet pressure ratio = 0.98
- Engine air mass flow rate = 173 kg/s
- Bypass ratio = 12
- Fan Pressure Ratio = 1.4
- LPC Pressure Ratio = 1.7
- HPC Pressure Ratio = 12.5
- Combustor Exit Temperature (T4) = 1400 K
- Fan isentropic efficiency = 0.90
- LPC & HPC isentropic efficiency = 0.92
- LPT & HPT isentropic efficiency = 0.90
- Mechanical efficiency = 0.99
- combustor efficiency = 0.995
- combustor pressure ratio = 0.96
- Nozzle= Convergent
- Nozzle efficiency = 0.98
- Ambient Temp. = 218.8 K
- Ambient Press. = 23842 Pa
- Gas constant= 287 J/kg K
- Fuel calorific value (LHV) = 43MJ/kg
- $c_{P,air}$ = 1000 J/kg.K; k_{air} = 1.4
- $c_{P,gas}$ = 1150 J/kg.K; k_{gas} = 1.33

Calculate the thrust and specific fuel consumption!

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