Aircraft engines - overview

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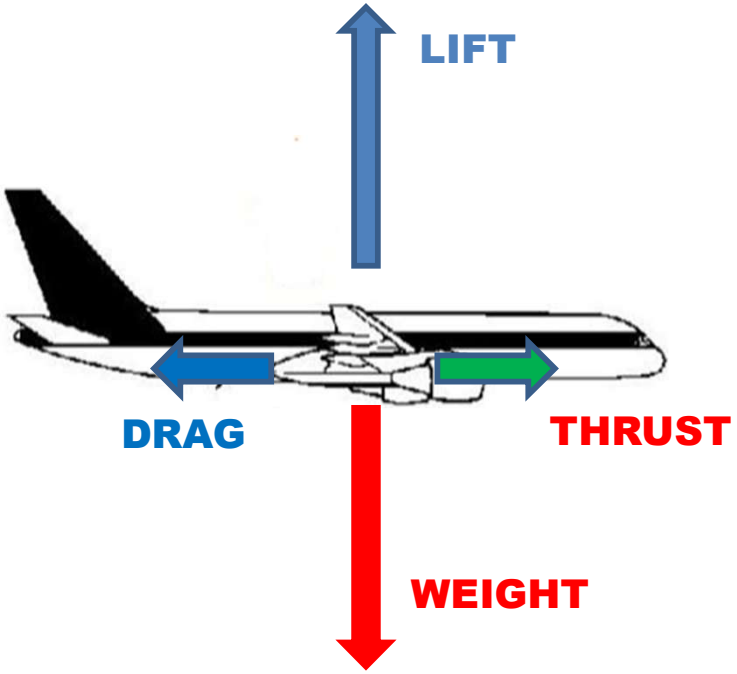
Literature

- Pasquale M. Sforza: Theory of Aerospace Propulsion
- Ahmed F. El-Sayed: **Aircraft Propulsion and Gas Turbine Engines**

Engine role in the plane

- How do Airplanes fly? - YouTube
- https://www.youtube.com/watch?v=YyeX6ArxCYI&t

Horizontal flight - speed and altitude increase



Energy consideration performance equation:

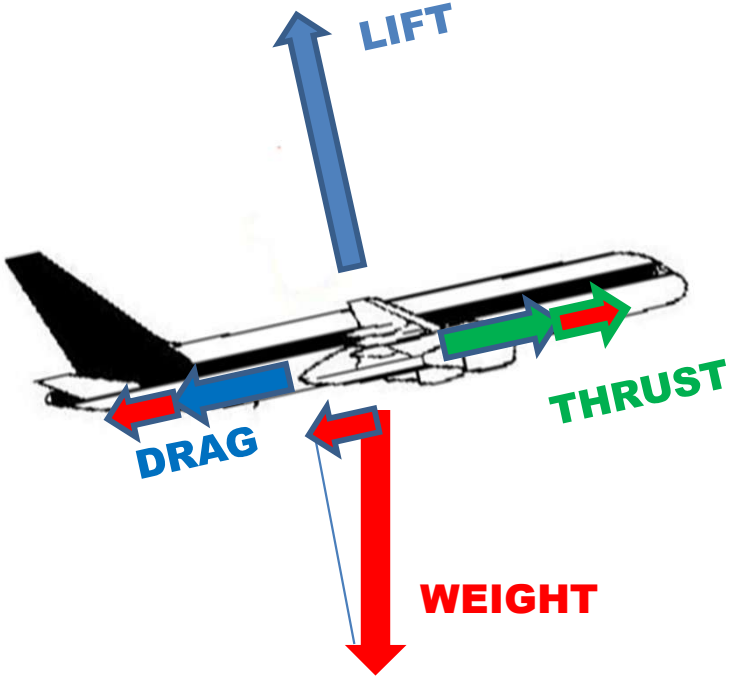
$$(T - DR) * V = W\frac{dh}{dt} + W\frac{d}{dt}\left(\frac{V^2}{2}\right)$$

$$\frac{(T - DR)}{W} = \frac{1}{V}\frac{d}{dt}\left(h + \frac{V^2}{2}\right)$$

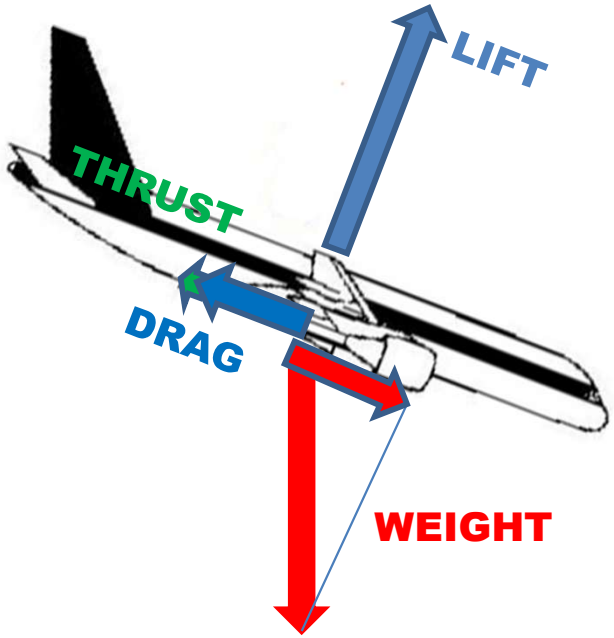
For horizontal flight with constant speed: Thrust = Drag and Lift = Weight

Weight specific excess power $\frac{(TR-D\ )}{W}$ is proportional to rate of climb $\frac{dh}{dt}$, and acceleration $\frac{dV}{dt}$

Ascent and descent



Engines thrust should be increased of additional weight component in ascent phase



Engine negative thrust could occur during descent due to an additional forward weight component.

Engine thrust vs. Plane weight

Plane	MTOW	Takeoff thrust	Thrust/MTOW
A330	251 t	2x324 kN (64,8 t)	0,258
737 MAX9	88,3 t	2x130 kN (26 t)	0,294
A320	79 t	2x120 kN (24t)	0,304

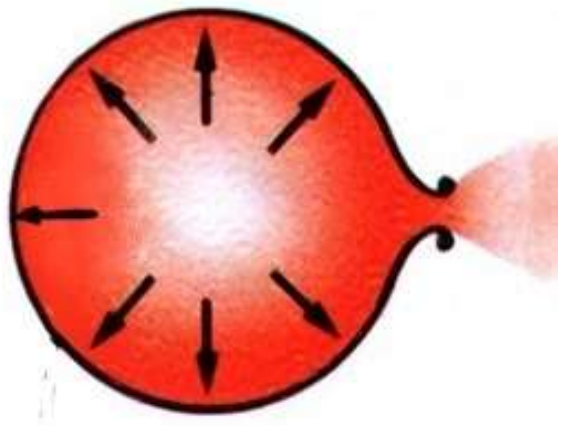
Engine should produce thrust wich:

- should compensate drag force in horizontal flight
- should compensate drag force and add additional component to lift force to balance plane weight in ascent flight phase
- is nearly 0 or negative in descent flight phase

How the turbojet engine Work

- https://www.youtube.com/watch?v=L24Wf0VlTE0

Thrust



Pressure difference cause, gas outflow the balloon. The action of gas flow cause reaction of balloon. Process could be described by **II** & **III Newton Laws**

$$T = F = \dot{m} \cdot c$$

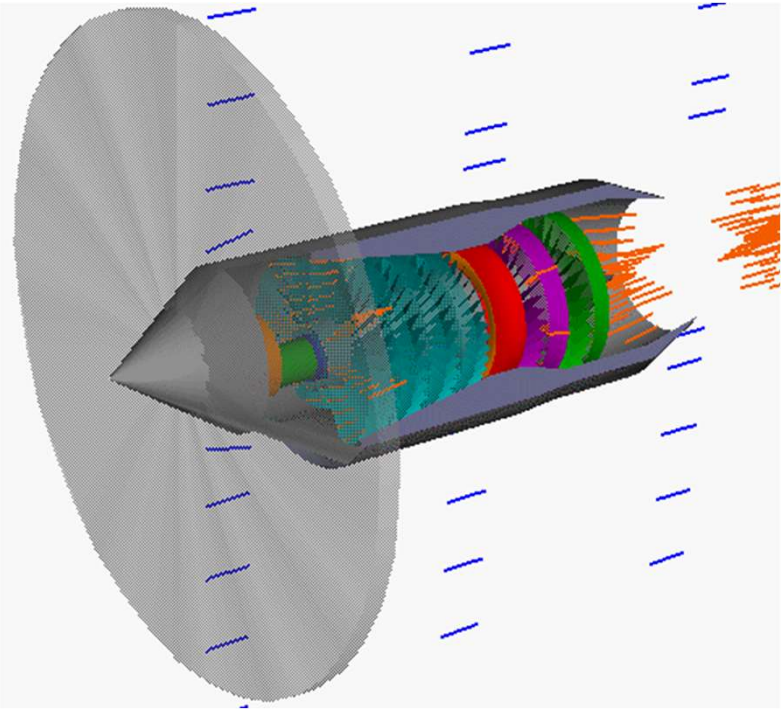
$\dot{m}$ – mas flow of gas

c – gas speed

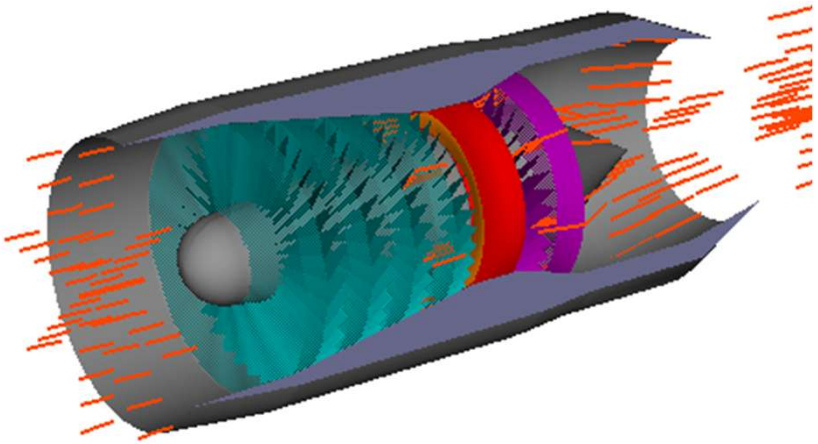
Jet streem forse



How we can produce the thrust?



Low gas speed after the propeller
Large mass of gas



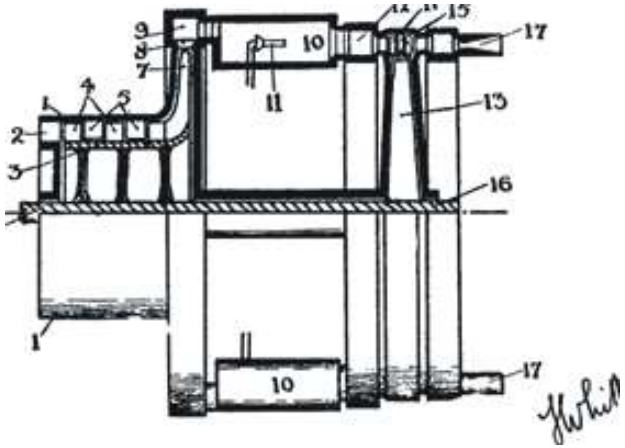
High speed of outlet gas
Small mass of gas

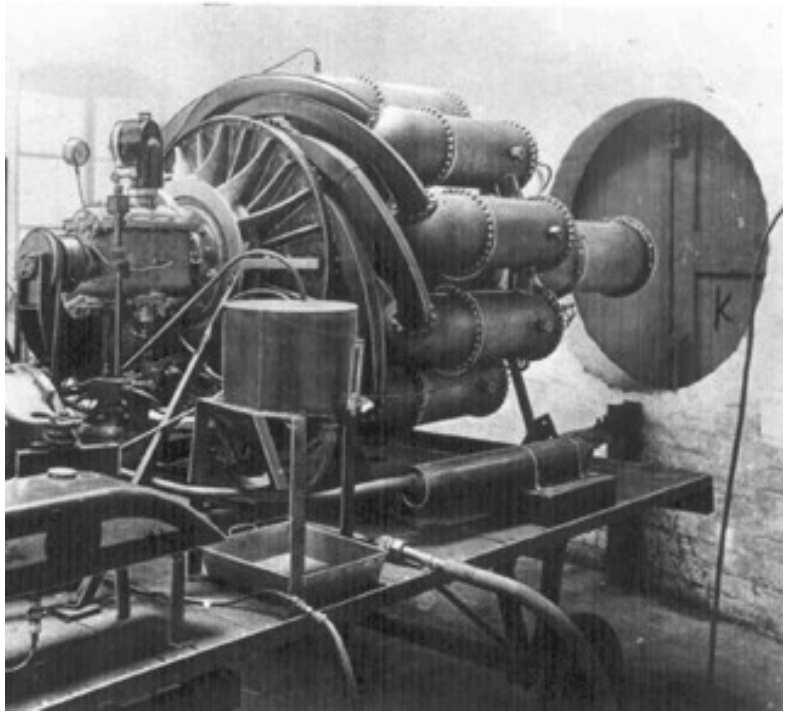
Begining of turbojet propulsion



Sir Frank WHITTLE
1907 - 1996

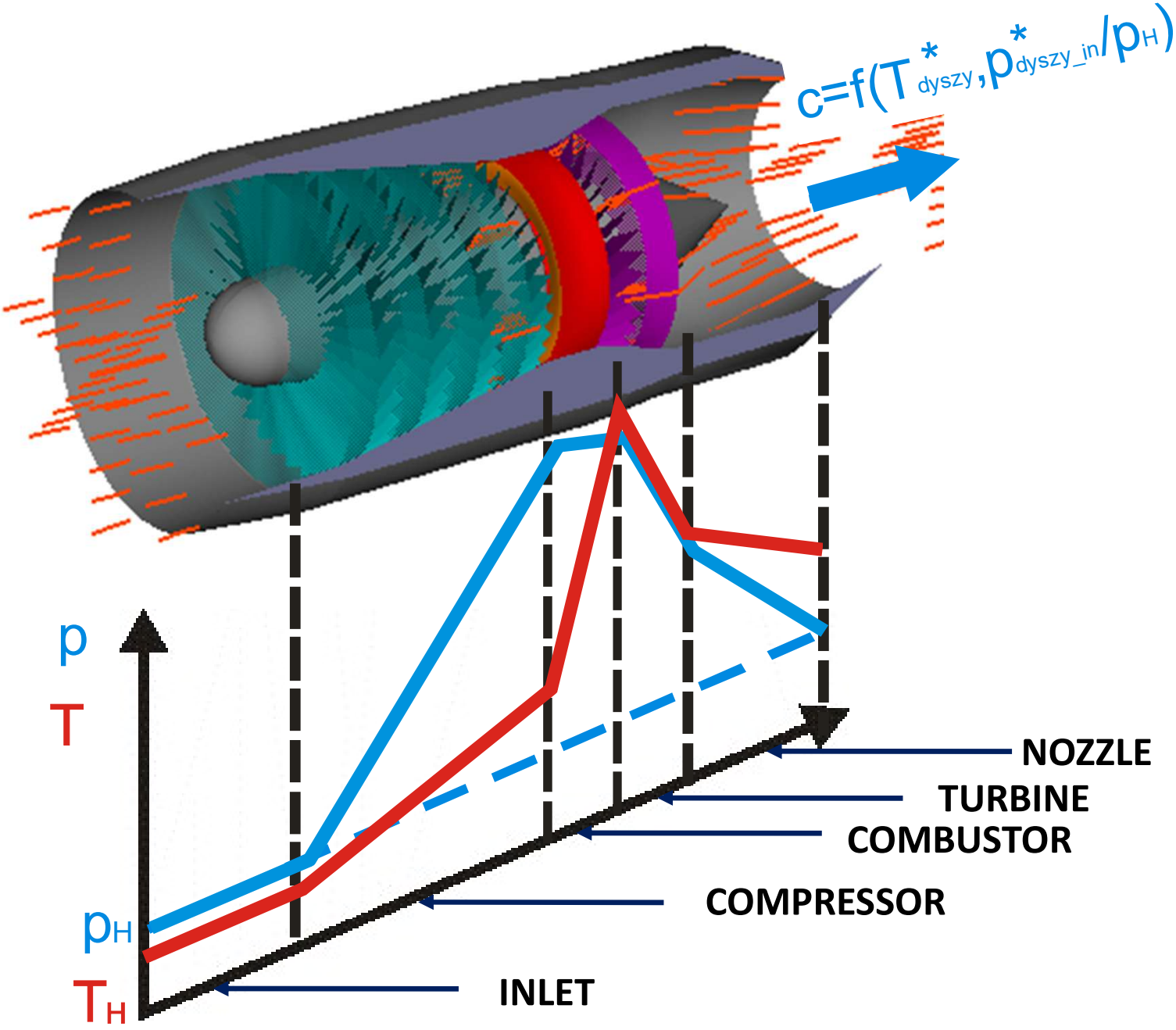
1. Axial compressor casing
2. Intake
3. Compressor body
4. Compressor blades
5. Stator blades
7. Centrifugal compressor
8. Compressor outlet
9. Elbow
10. Combustion chambers
11. Fuel injector
13. Turbine disk
14. Turbine blades
15. Stator blades
16. Shaft
17. Divergent nozzle ring.



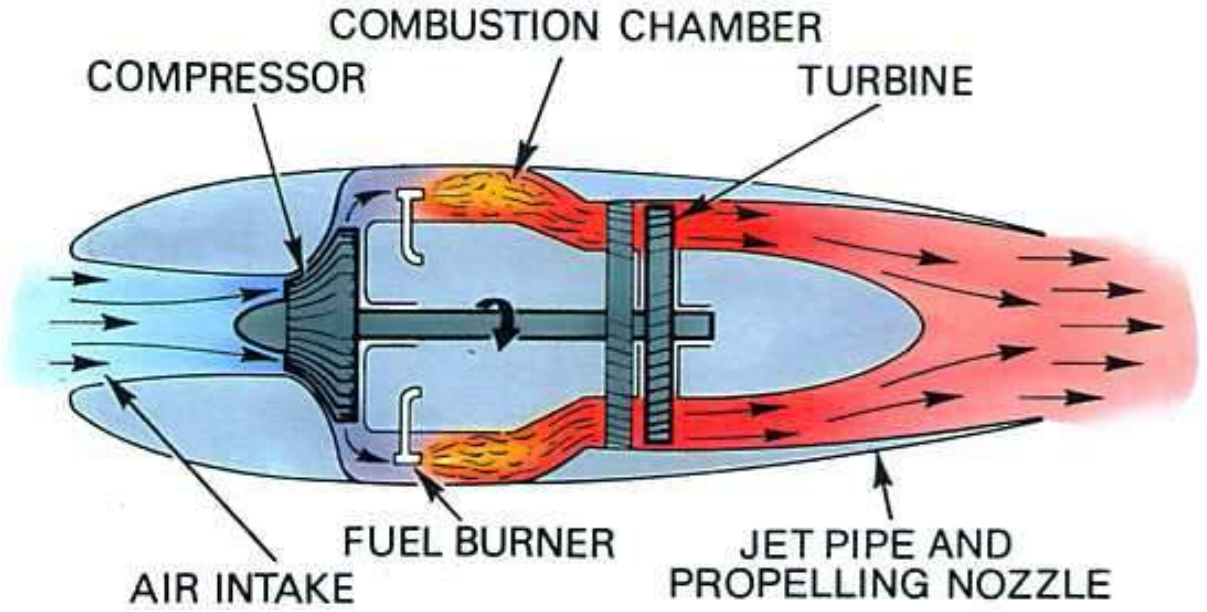


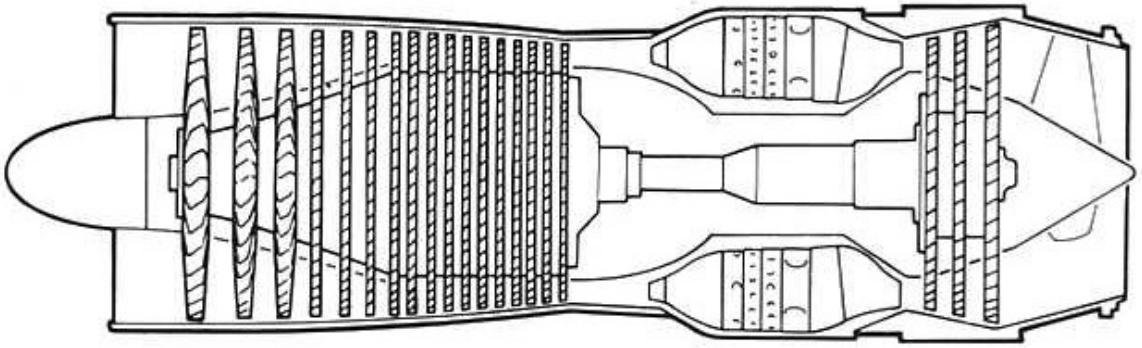
Dr Hans Joachim
PABST von OHAIN
1911 - 1998

TURBOJET ENGINE



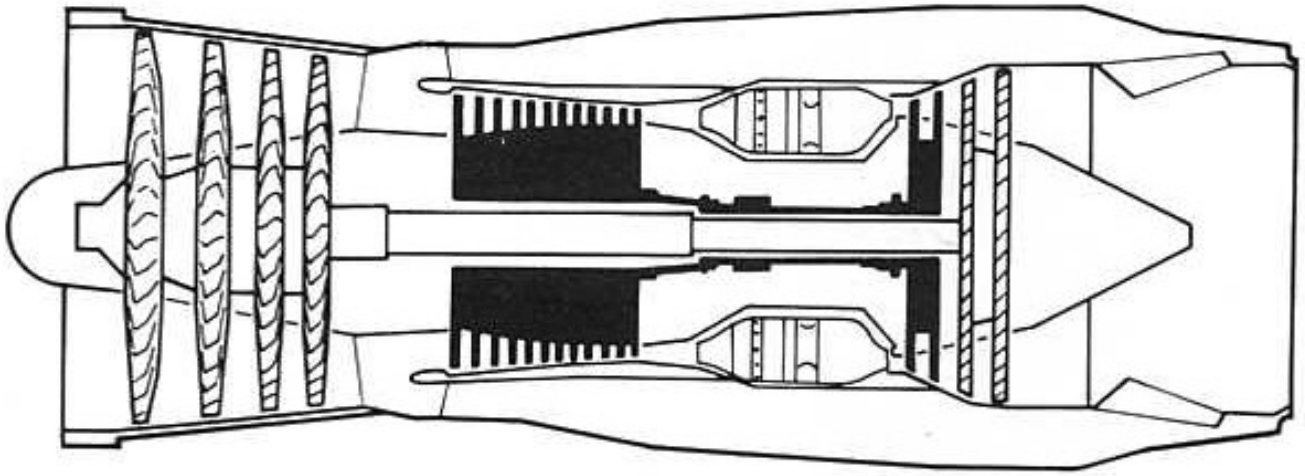
SINGLE SPOOL TURBOJET ENGINE



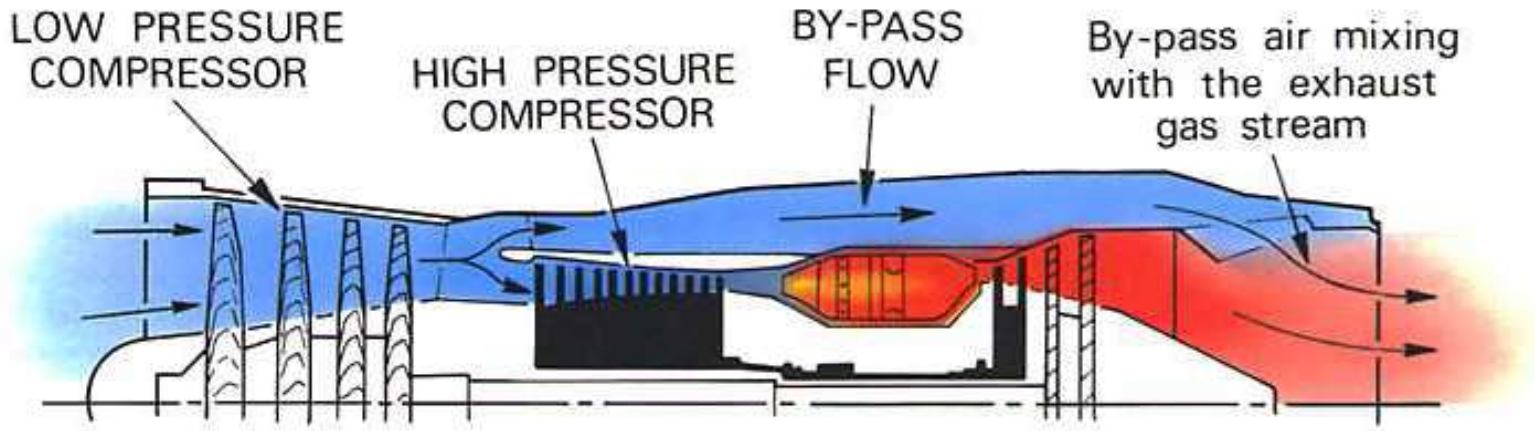


SINGLE-SPOOL AXIAL FLOW TURBO-JET

TWIN SPOOL BYPASS ENGINE

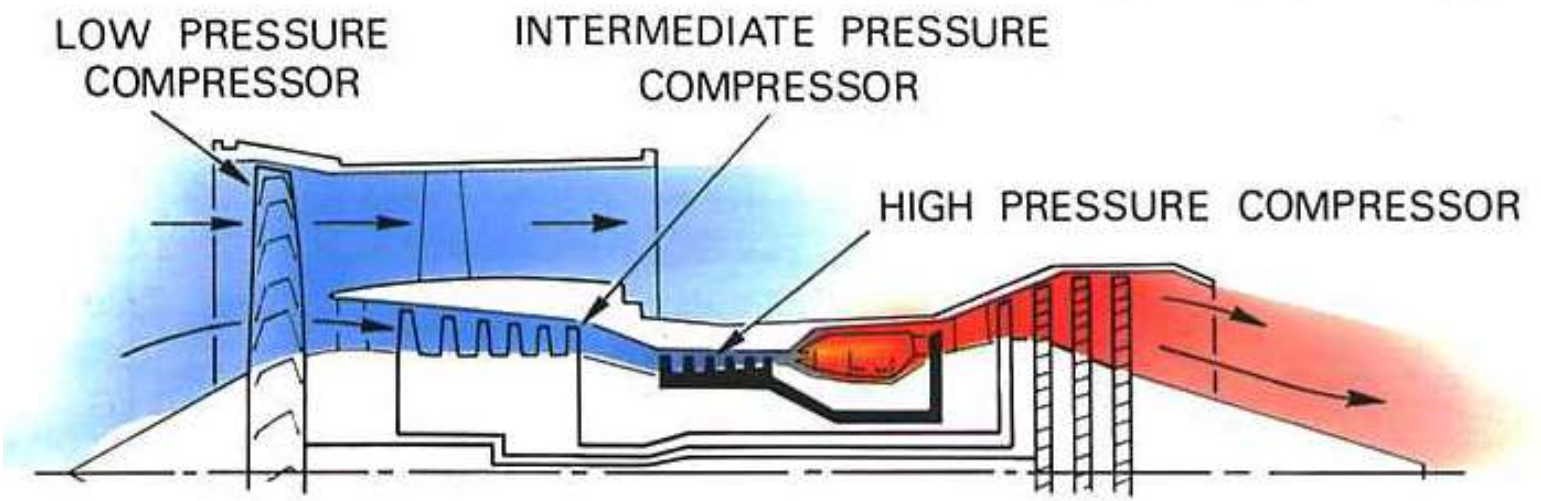


TWIN-SPOOL BY-PASS TURBO-JET



TWIN-SPOOL AXIAL FLOW BY-PASS TURBO JET ENGINE(low by-pass ratio)

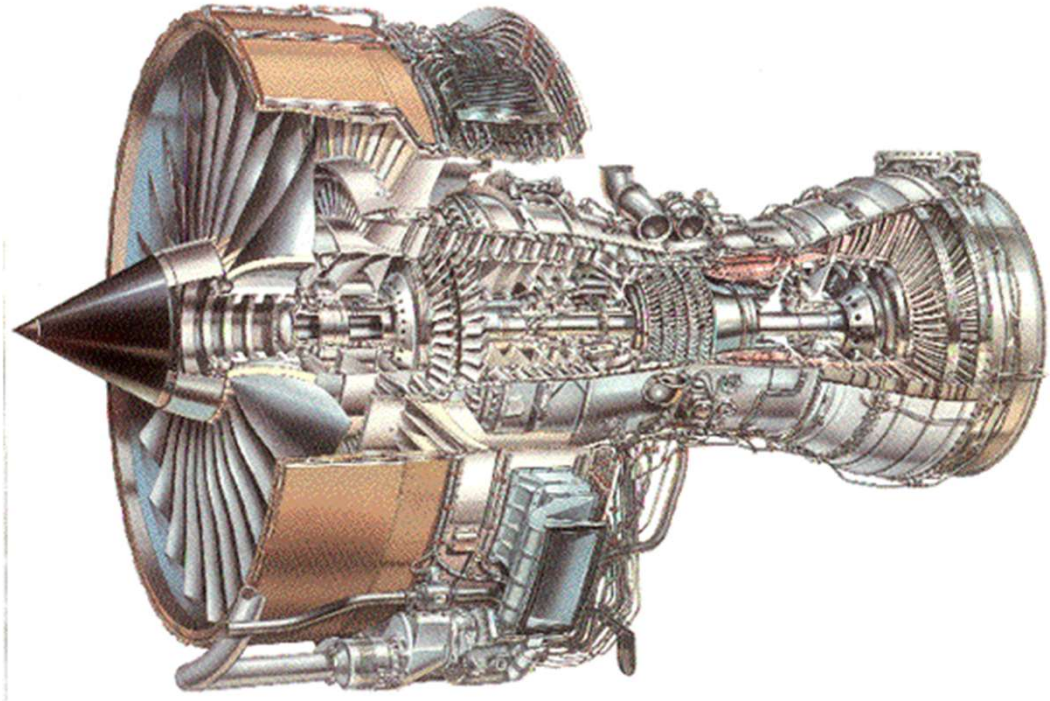
TURBOFAN ENGINE



TRIPLE-SPOOL AXIAL FLOW FRONT FAN TURBO JET ENGINE (high by-pass ratio)

Engine aplication

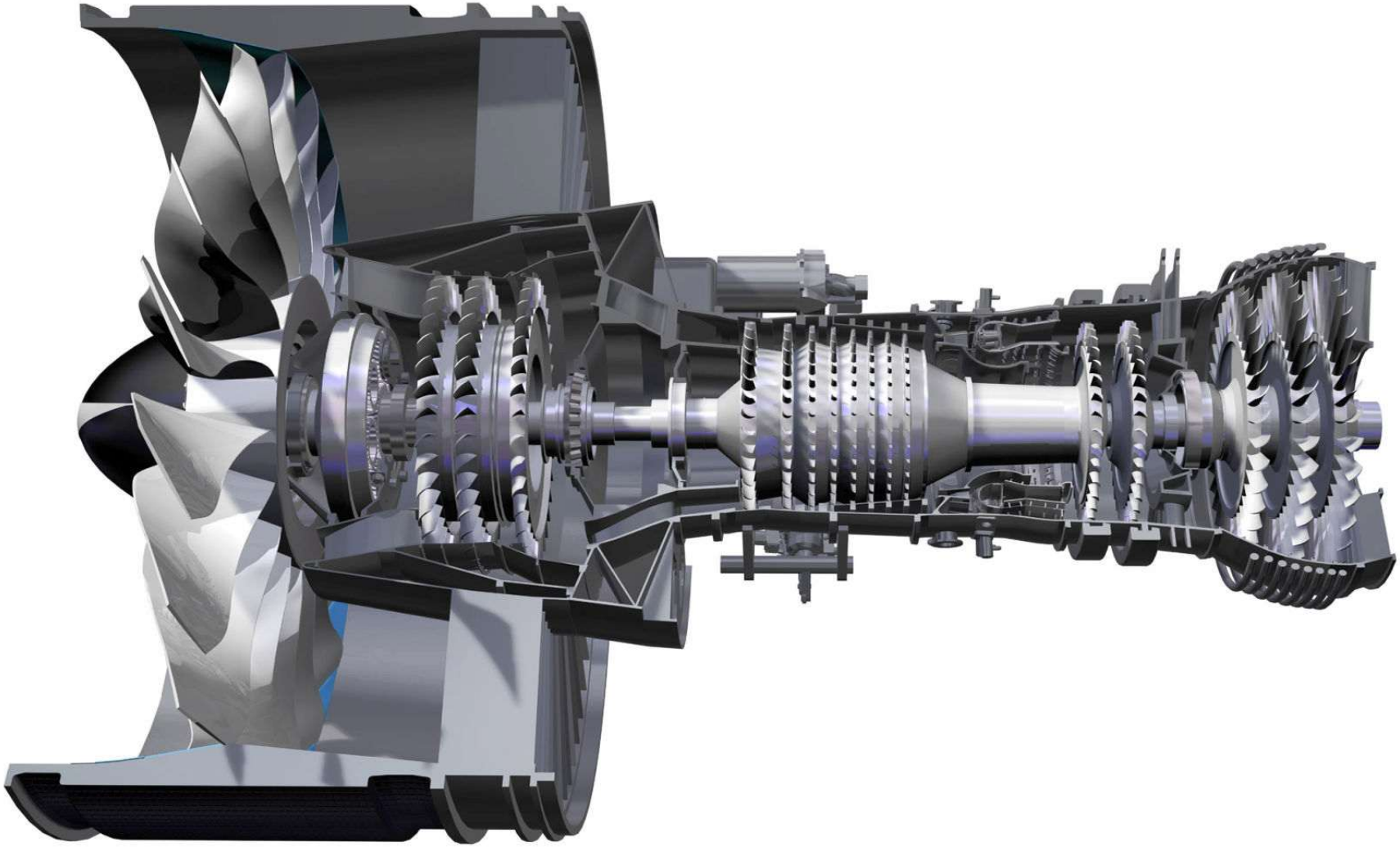




B-747-400 (MTOW 390 Ton)
Cruise speed: 0,855 Mach
Range: 13 490 km
Power – 4 engines RB 211
Takeoff field length: 2 955 m

RB-211-524G
Triple-spool high bypass turbofan
Thrust=250 kN, SFC 0,396 kg/daN/h
OPR=32
BPR=4.3
1 Fan, 7 IP stages, 6 HP stages
Turbine: 1 HP stage, 1 IP stage, 3 LP stage
Engine weight: 5,79 t

GTF (Geared turbofan)



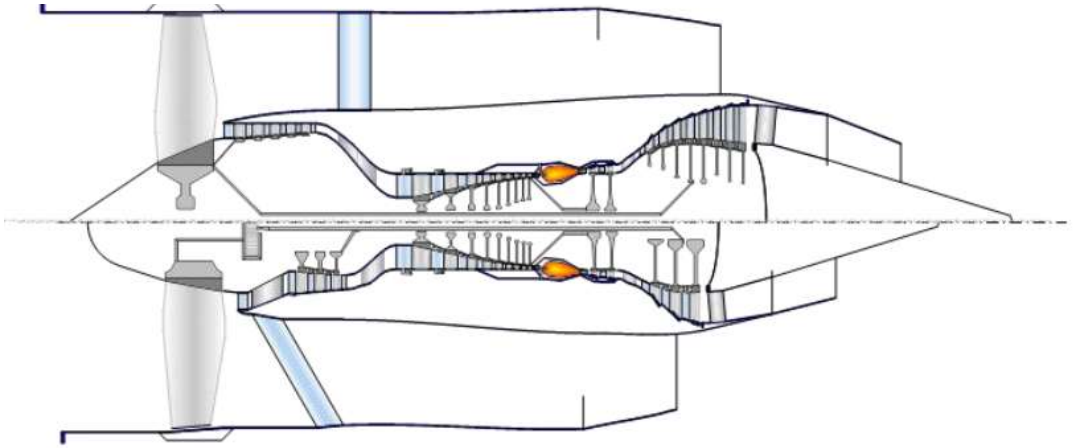
GTF vs TF

Parameter	IAE V2527-A5	CFM56-5B4	PW1127G
Aircraft	Airbus A320-232	Airbus A320-214	Airbus A320NEO
Thrust	26,600 lbs (118.3kN)	27,000 lbs (120.1kN)	27,000lbs (120.1kN)
Bypass Ratio	4.8 : 1	5.7 : 1	12 : 1
Architecture (Stage Count)	1-4-10-2-5	1-4-9-1-4	1-G-3-8-2-3
Fan Diameter	63.5 inches (1613 mm)	68.3 inches (1735 mm)	81 inches (2057 mm)
Overall Length	3201 mm	2600 mm	3800mm (estimated)*
High Pressure Spool RPM (N2)	14,950	15,183	18,000 – 20,000 (estimated)*
Low Pressure Spool RPM (N1)	5,650	5200	10,500 (estimated)*
Fan RPM	5,650	5200	3,500 (estimated)*
Overall Pressure Ratio	27.2	32.6	Unknown**
Engine Weight	2400 kg	2500 kg	Unknown**

Estimated by The Flying Engineer, for informative purposes only. Do not rely or quote estimated data. *,This field shall be updated when official data is available.*

TF

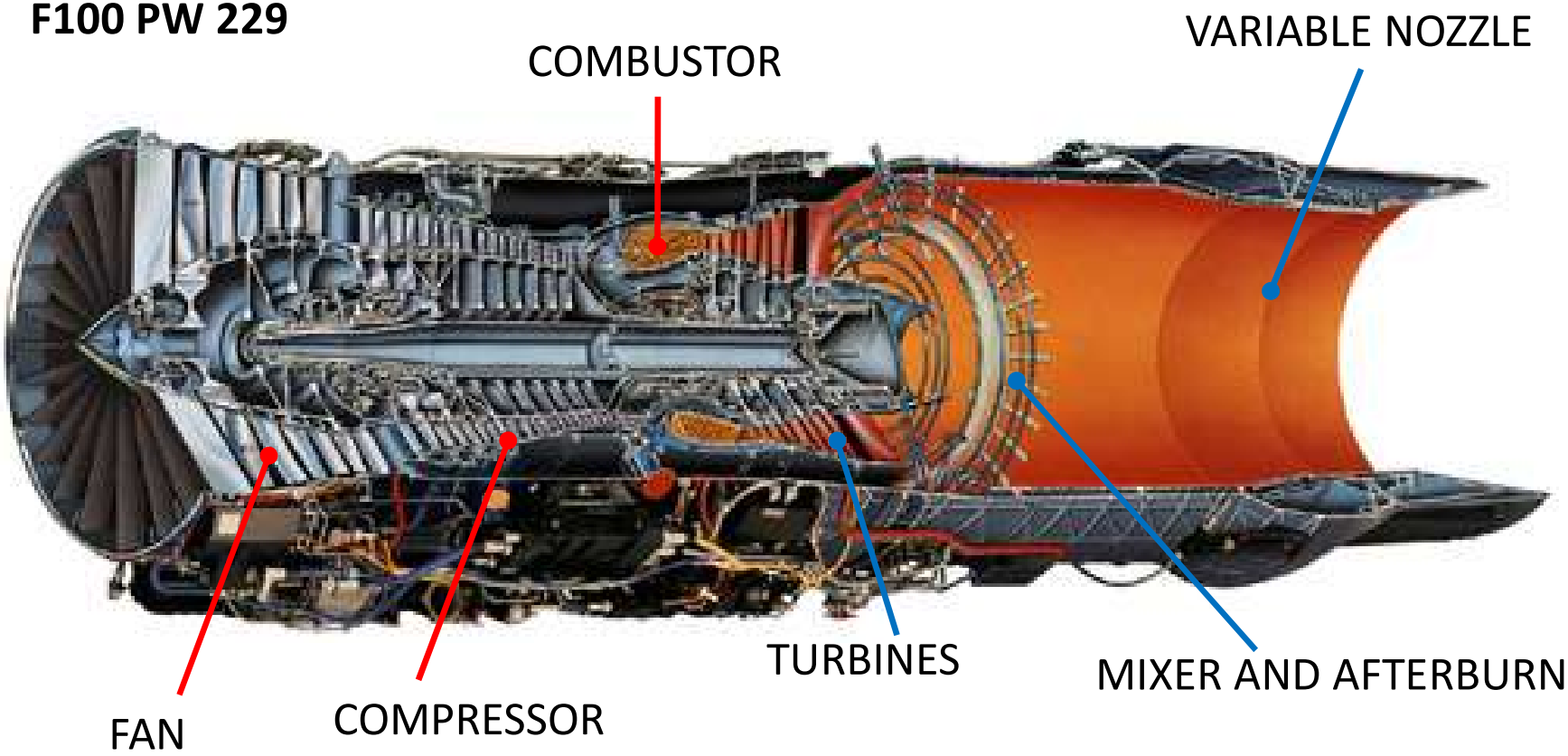
GTF



https://theflyingengineer.com/flightdeck/pw1100g-gtf/

BY-PASS ENGINE WITH MIXER (Military Application)

F100 PW 229



Thrust=130/80 kN,
SFC=2.05/0.74 kg/daNh,
Engine weight =1400 kg,
CPR=23,
TIT=1775 [K]

Military airplane propulsion aplication
F-16



top speed 2,178 km/h,
range 4,217 km,
service ceiling 15,240 m,
max takeoff weight 19,200 kg,

F-100-PW229



High-maneuvering aircraft (thrust vectoring)



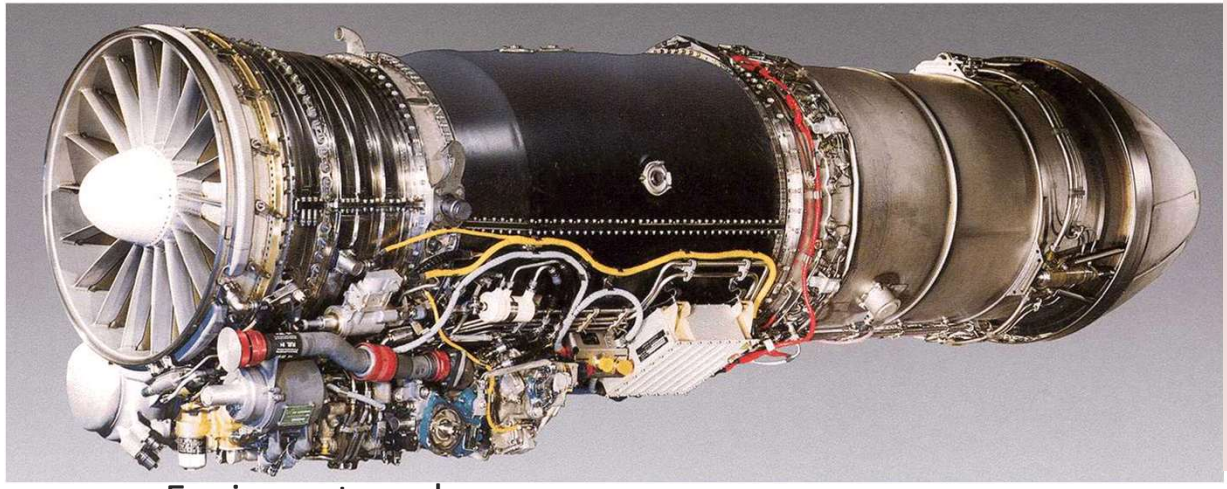
- Thrust vectoring allows for tight, low-speed maneuvers for a tactical advantage in combat missions.
- The F-22A Raptor Su-35 are fighters jet with advanced thrust vectoring capabilities.



Contemporary aero-engine

ENGINE HARDWARE





Engine externals

A turbojet engine is a very complex facility.
Its design and production requires knowledge from various filds of science.

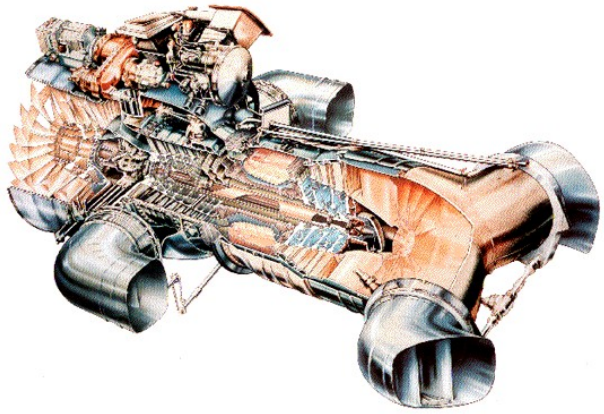
The turbojet engine is designed for specific purpose. It is a part of an aircraft and the reaqirments caming from this are crucial for determination engine feature (dimentions and performance)

ENGINES FOR AIRCRAFT OF VERTICAL TAKE OFF AND LENDING



Joint Strike Fighter
F-35 B Lightning II





Pegasus 11 Mk.103

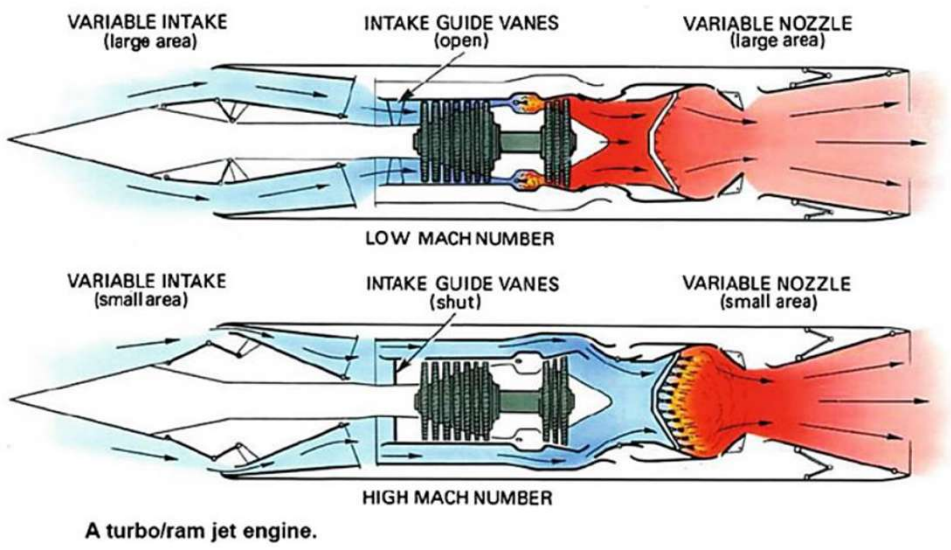
The Rolls-Royce LiftSystem comprises four major components:

- LiftFan (thrust 80 kN)
- Engine to fan driveshaft
- Three-bearing swivel module (3BSM) (thrust 89 kN)
- Roll posts (two) (thrust 17 kN) (total thrust (186 kN)

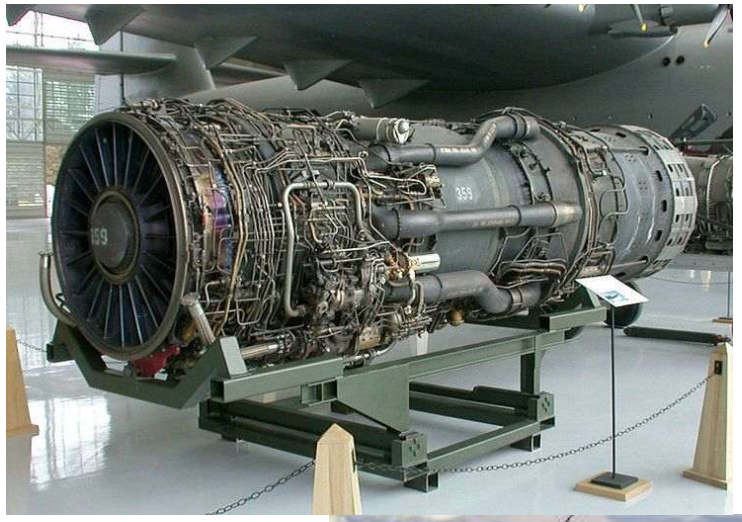


Harrier

VCE (variable cycle engine) J-85 For SR 71 Black Bird operation range Ma=0-3.2



A turbo/ram jet engine.

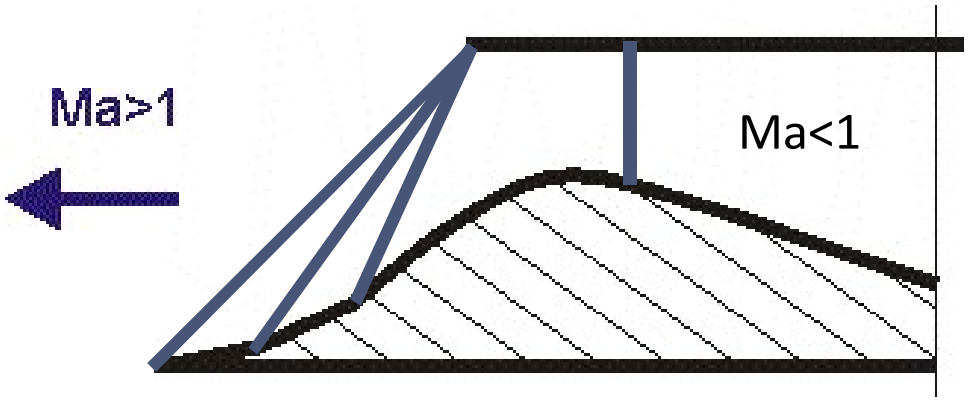




(520) The Mighty J58 - The SR-71's Secret Powerhouse - YouTube: https://www.youtube.com/watch?v=F3ao5SCedIk

Engine for supersonic flight Ramjet

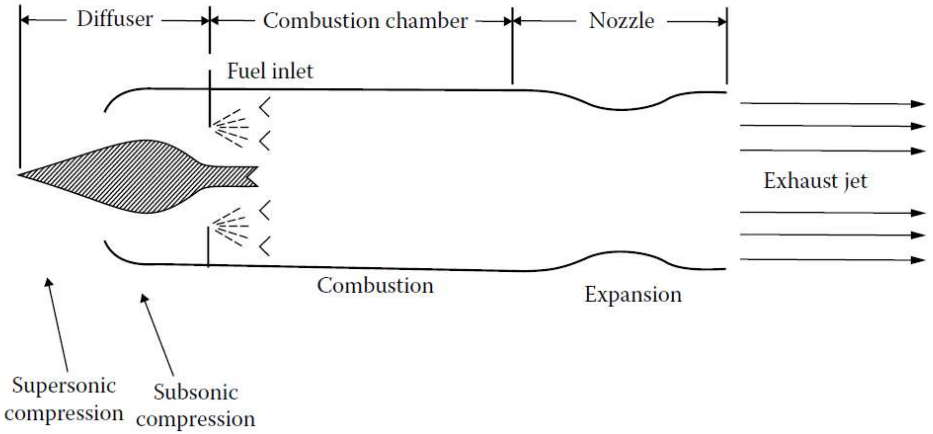
Inlet of supersonic engine



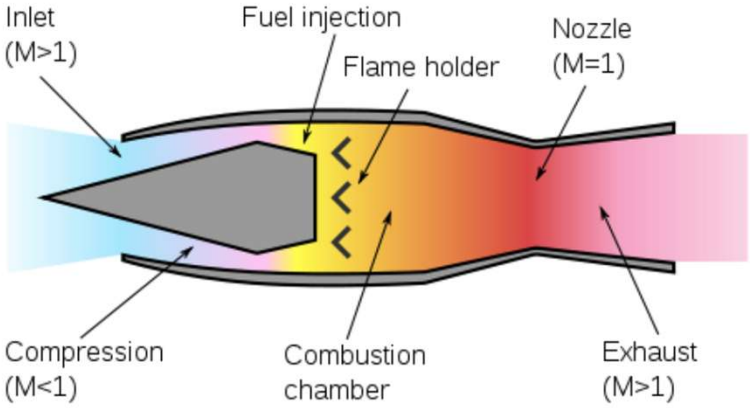
Flight speed Ma	Ram compression (ideal)
1	1,89
1,5	3,67
2	7,82
2,5	17,09
3	36,73

X-43A – M=6.83 (27.03.2004)

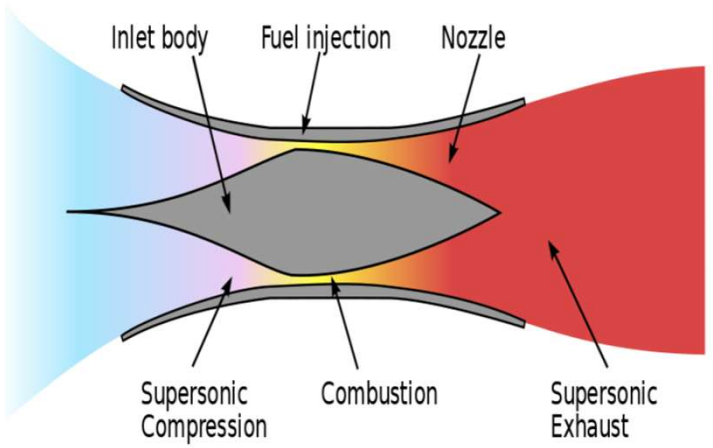




Ramjet and scramjet



Ramjet - gas flow in combustor is subsonic



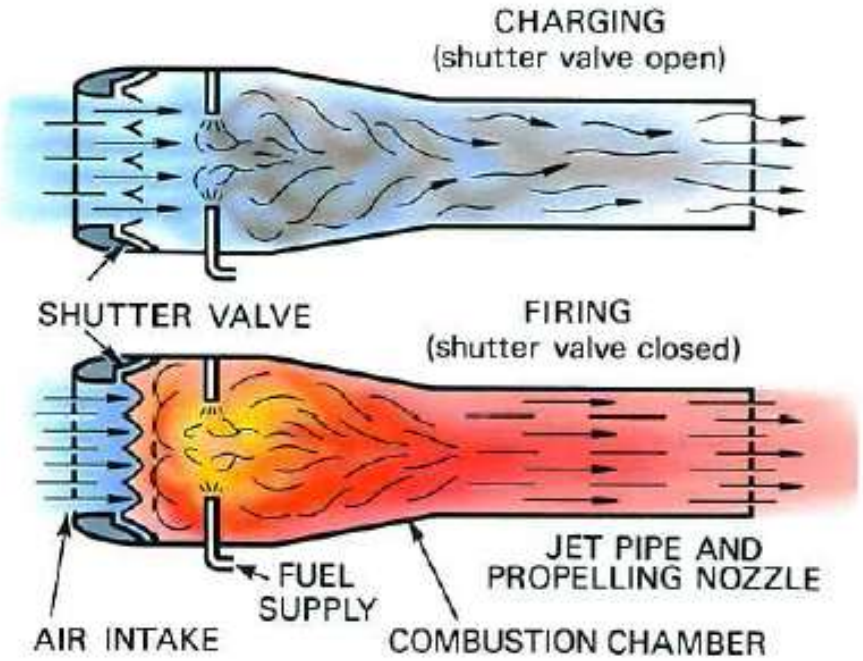
Scramjet – gas flow in combustor is supersonic



HYPOSED III 7,6 Ma
X-43A achieved speed 9,6 Ma

https://www.youtube.com/supported_browsers?next_url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DxpOa3B03gYg

Pulse jet engine



The most widely known pulsejet was the German V-1 missile, or buzz bomb, used near the end of World War II, which fired at a rate of about 40 cycles/s.

The pulsing effect can also be achieved in a **valveless engine**, or wave engine, in which the cycling depends on pressure waves traveling back and forth through a properly scaled engine.

A pulsejet engine delivers thrust at zero speed and can be started from rest, but the maximum possible flight speeds are below 960 km/h (600 mph). Poor efficiency, severe vibration, and high noise limited its use to low-cost, pilotless vehicles.

Propfan engines



30% decreasing of SFC

AIRCTAFT WITH TURBOPROP ENGINES



Helicopters

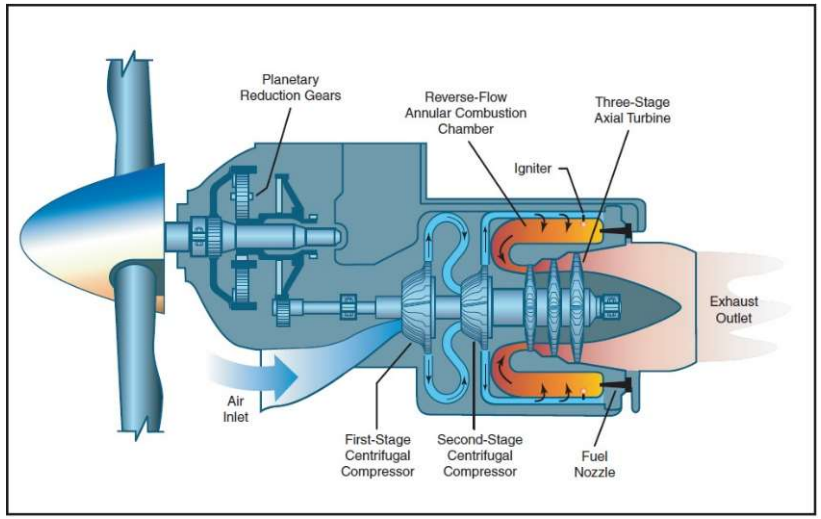


Two engines PZL – 10W , take off power 900 kW,



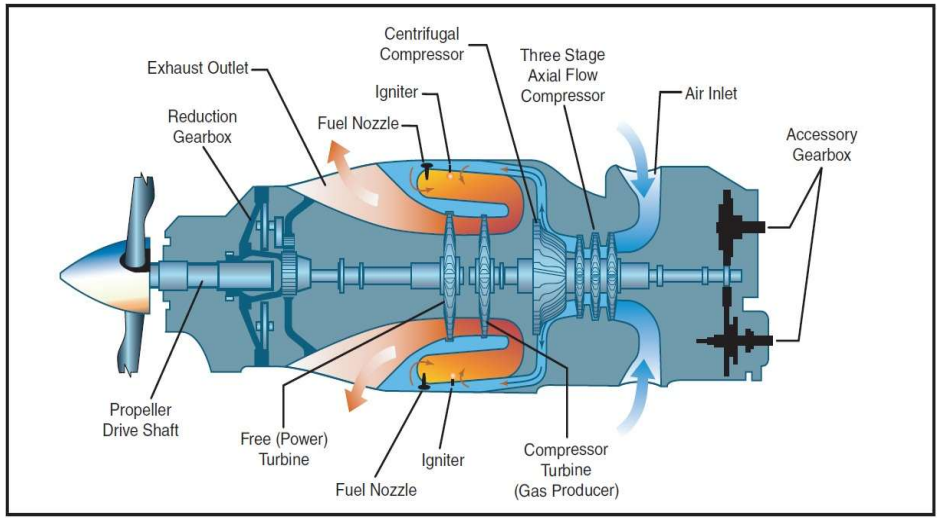
Helicopter **PZL W-3A Sokół** – max speed 260 km/h, flight altitude 6000 m

Turboprop propulsion systems



Single spool turboprop

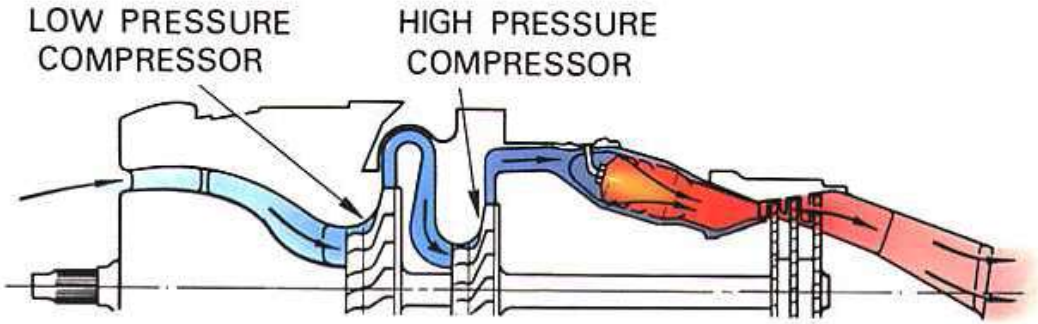
- Simple construction – only one spool.
- The propeller is driven via a reduction gearbox by the same shaft that powers the compressor.



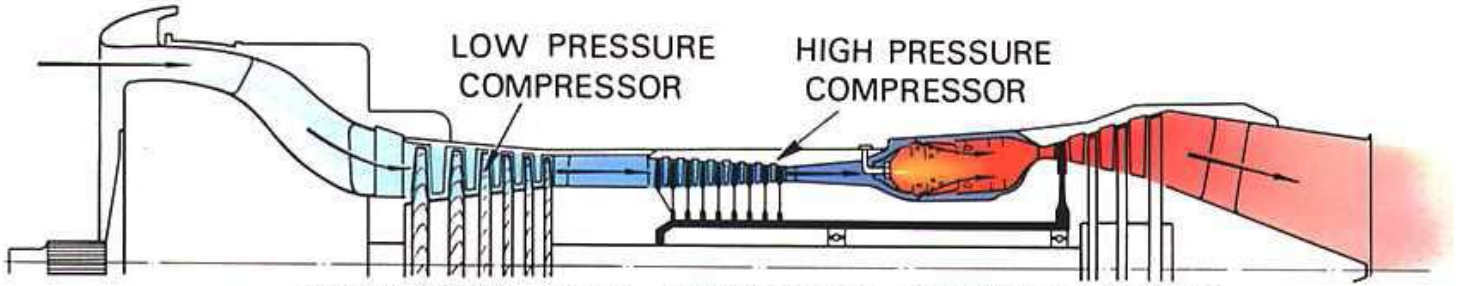
Free power turbine turboprop

- Offers better flexibility and performance during rapid power changes, such as during takeoff and landing,
- The propeller is driven by the free turbine through a separate shaft, allowing optimized, slower propeller speeds regardless of the gas generator speed.

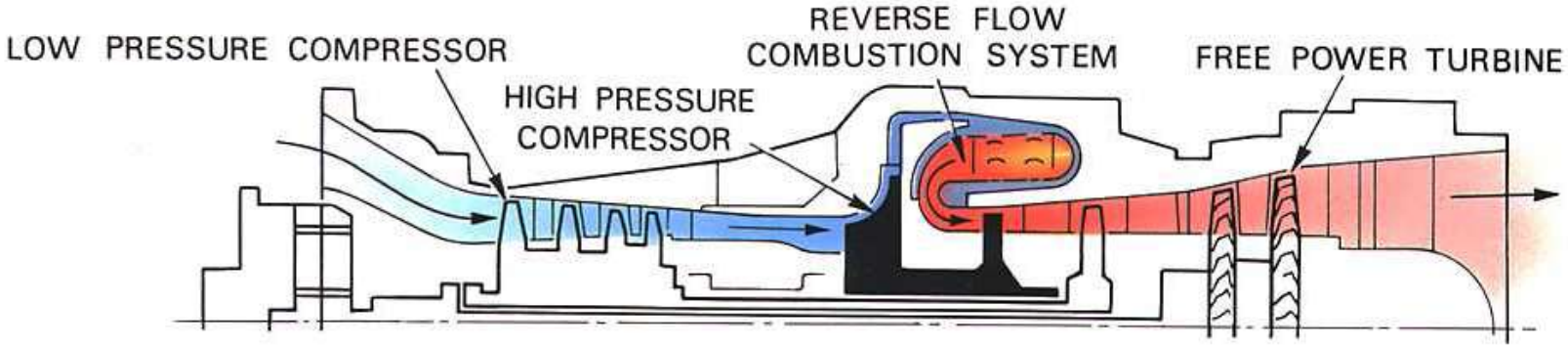
Examles of turboprop and turboshaft engines



TWO-STAGE CENTRIFUGAL FLOW TURBO-PROPELLER ENGINE

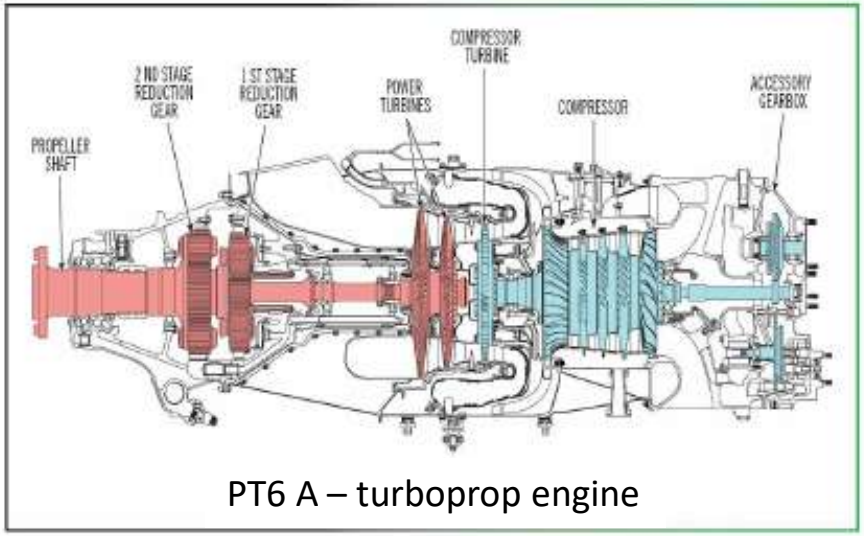


TWIN-SPOOL AXIAL FLOW TURBO-PROPELLER ENGINE

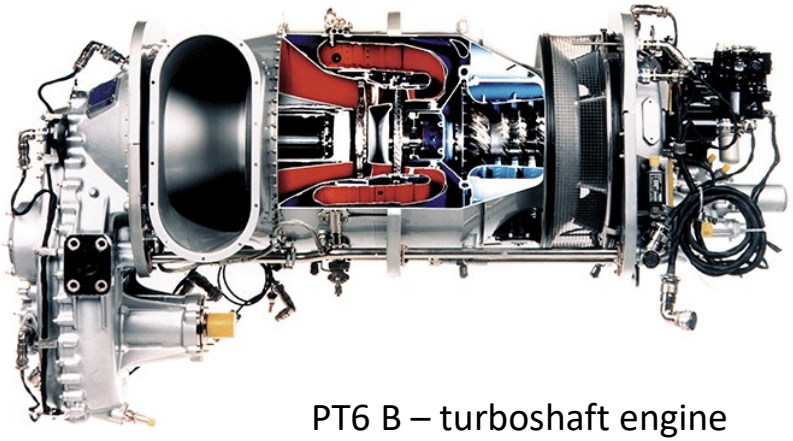


TWIN-SPOOL TURBO-SHAFT ENGINE (with free power turbine)

Turboprop and turboshaft engine



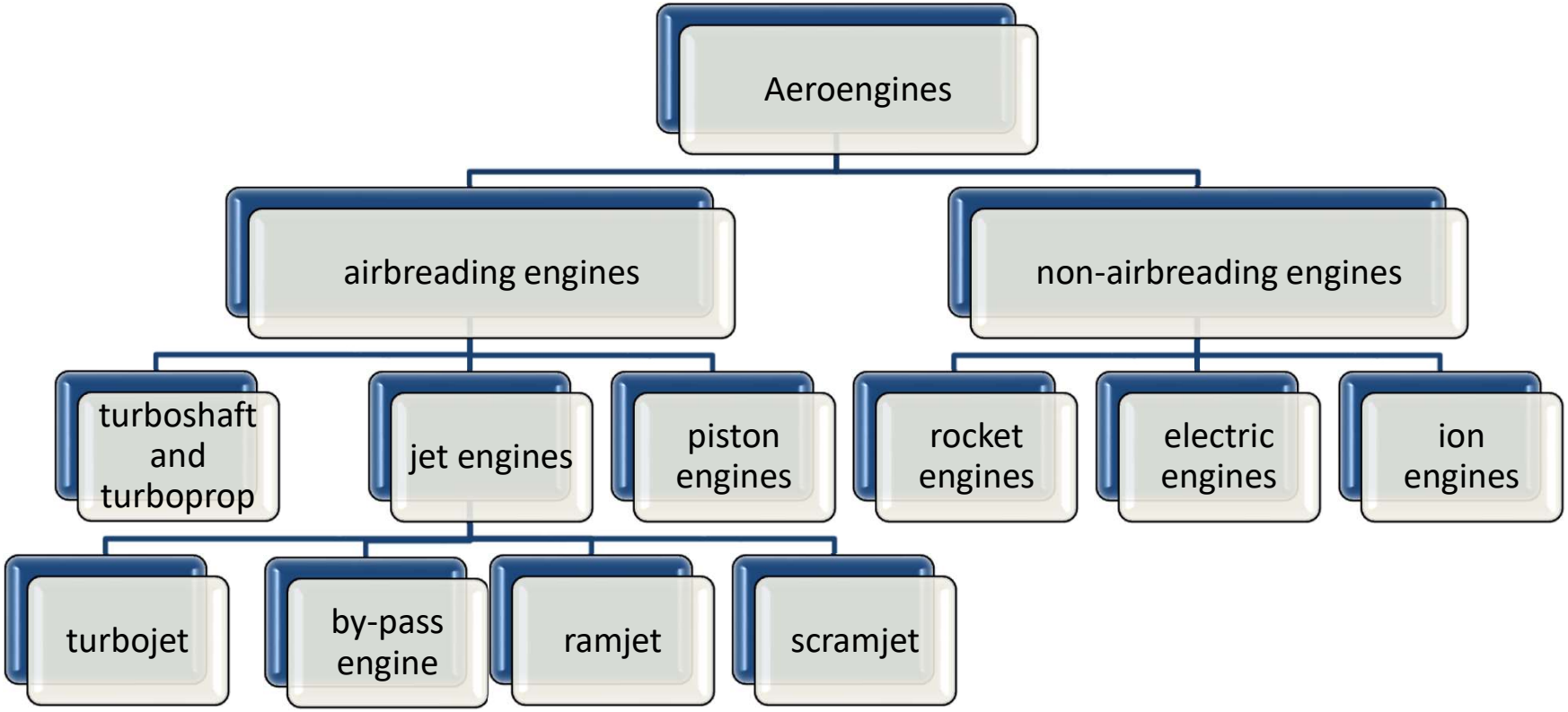
PT6 A – turboprop engine



PT6 B – turboshaft engine

PT 6 engine family of the shaft power from 500 shp to 19500 shp

Aeroengine clasyfication



Literature

“The Aircraft Gas Turbine Engine and its Operation”, United Technologies - Pratt & Whitney.

“The Jet Engine”, Rolls Royce Publications

Ahmed F. El-Sayed: **Aircraft Propulsion and Gas Turbine Engines,**