Blast Off!

Lecture 6

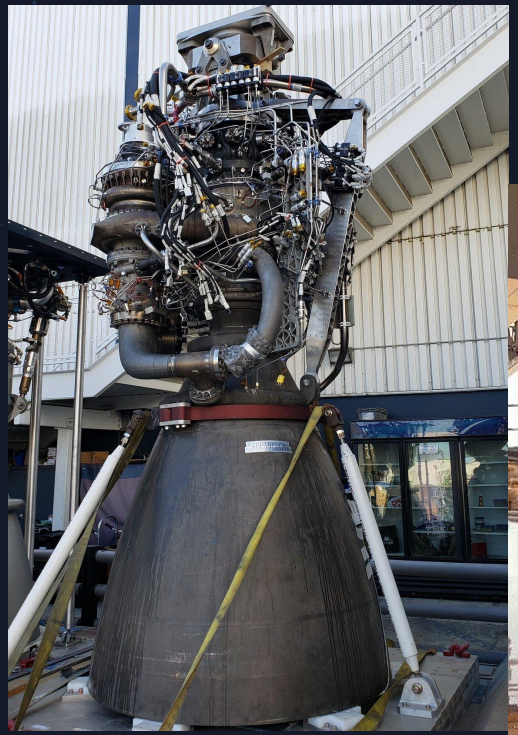
Engines

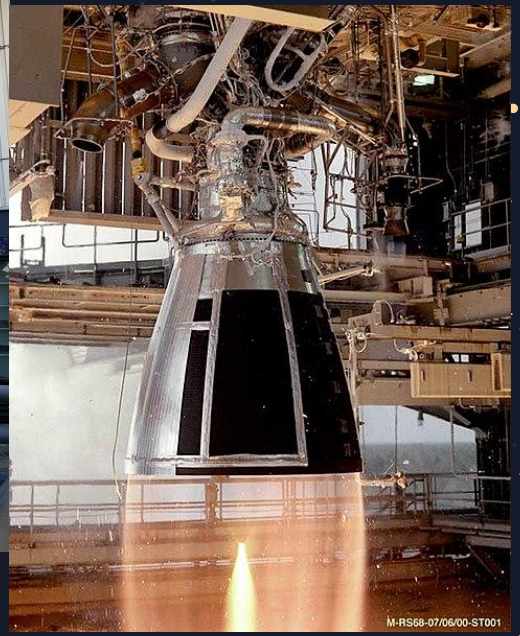
Engine Hardware:

- Nozzle
- Turbopumps
- Combustion Chamber
- Plumbing

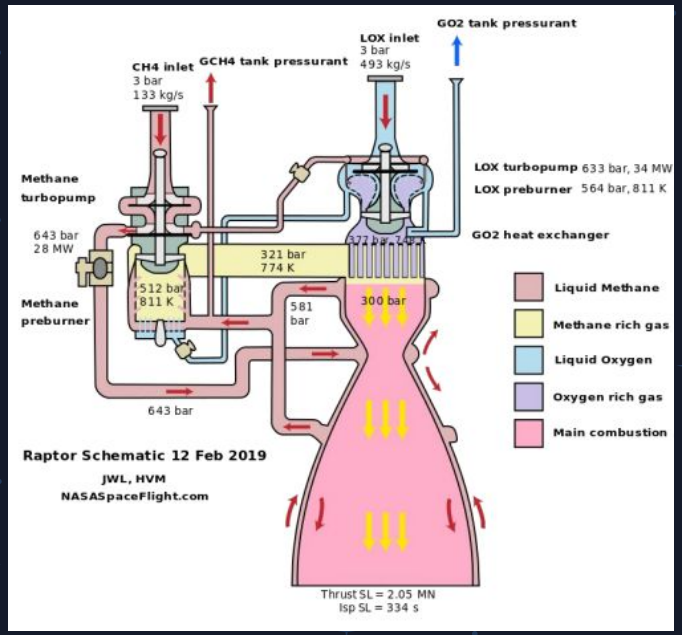
Engine Considerations:

- Gas expansion
- Combustion Instabilities
- Cooling

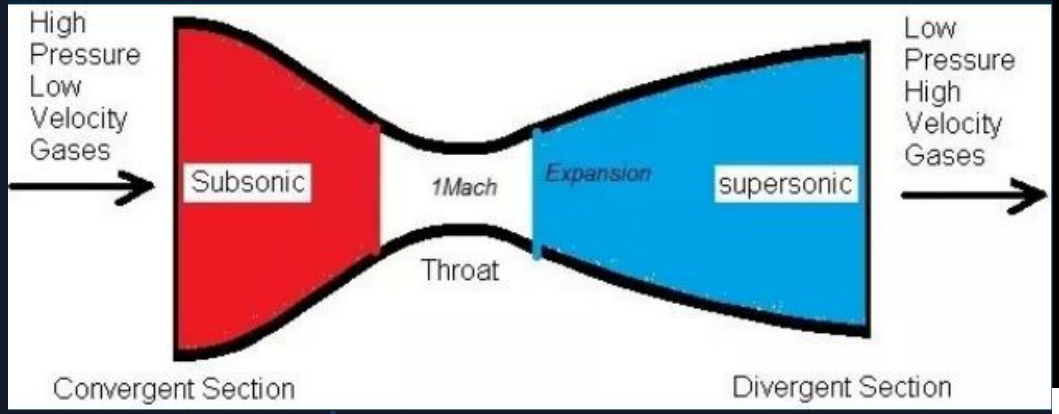


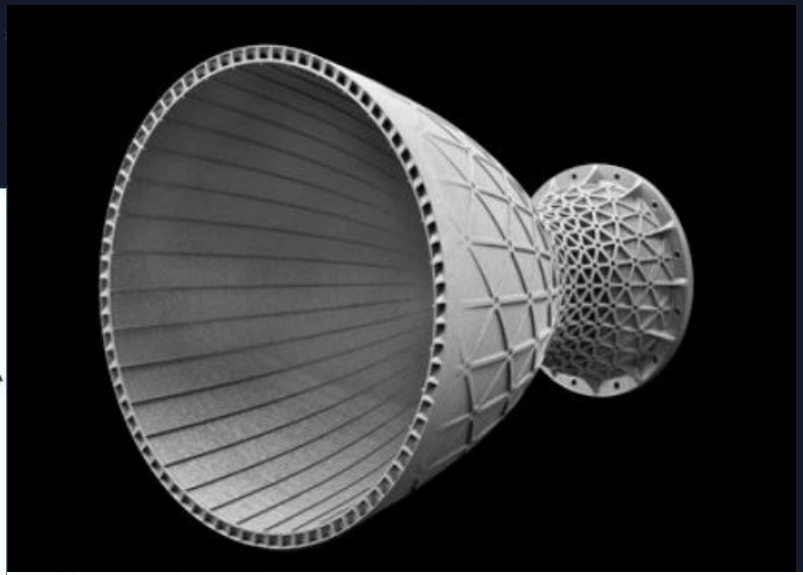


- Complicated beasts
- Gravity methods are not reliable enough for pressurizing the fuel
- Needs:
  - Plumbing
  - Cooling
  - Strength
  - Gimbaling
  - Sensing

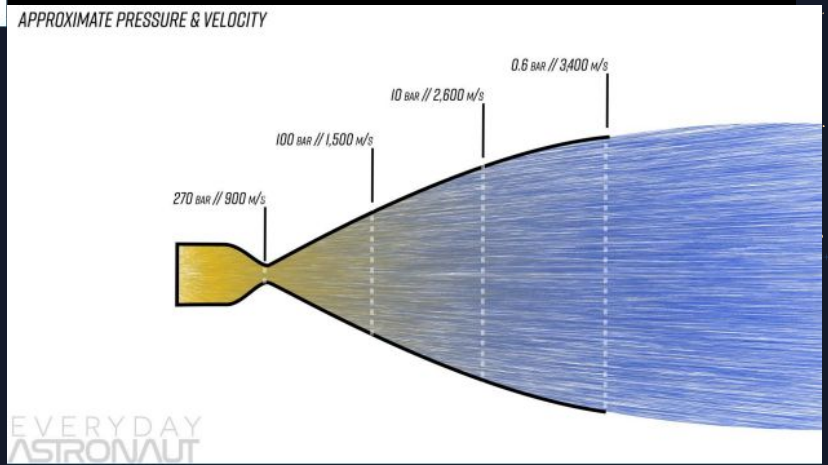


Nozzle





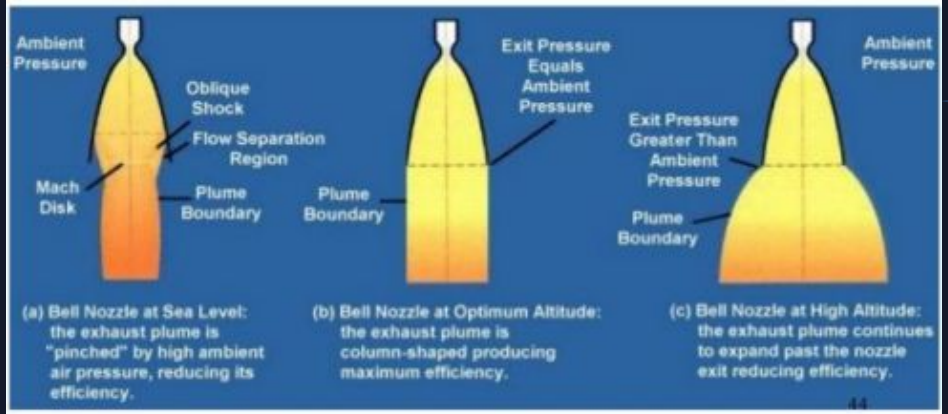
Why does the velocity not decrease after the throat?

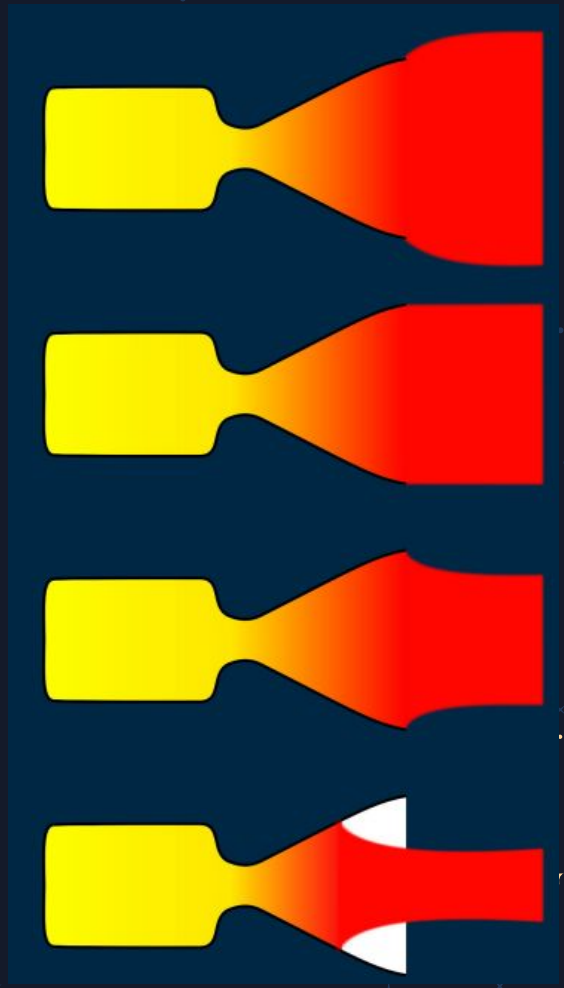


Gas Expansion

ALTITUDE BEHAVIOR: BELL

- Low Altitude
- OVER-Expanded
  - Pe < Pa
  - Do not expand beyond Pe=0.4 Pa
- Intermediate Altitude
- Ideally-Expanded
  - Pe = Pa
- High Altitude
- Under-Expanded
  - Pe > Pa

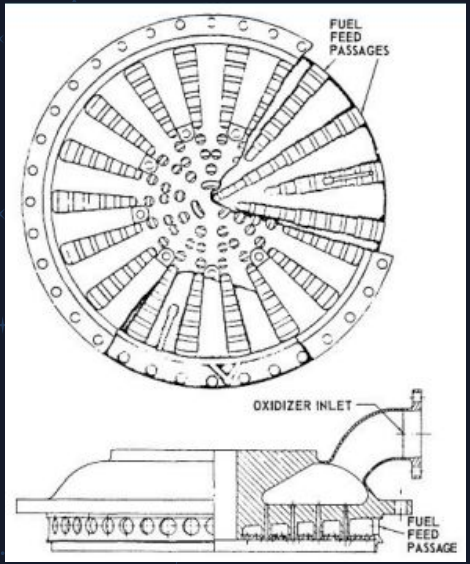


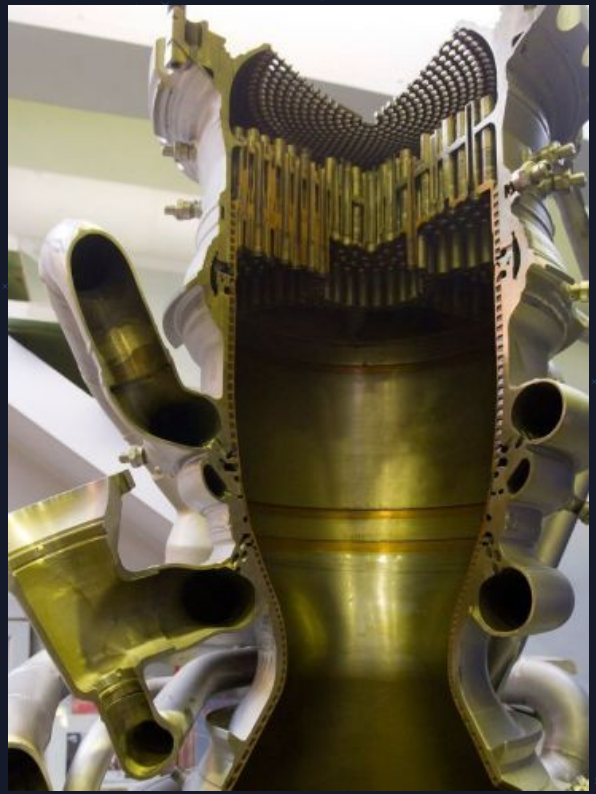


Combustion Chamber

Parts:

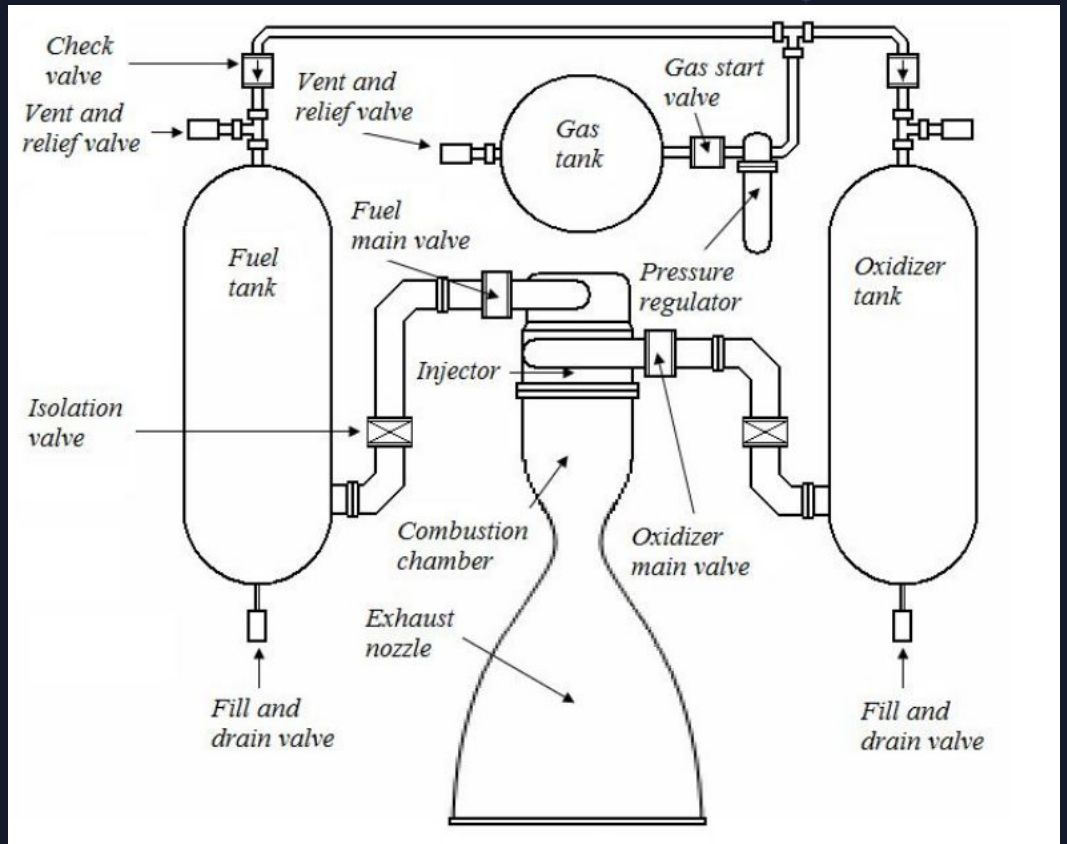
- Pintle Injector
- Casing





Plumbing
Power Cycles

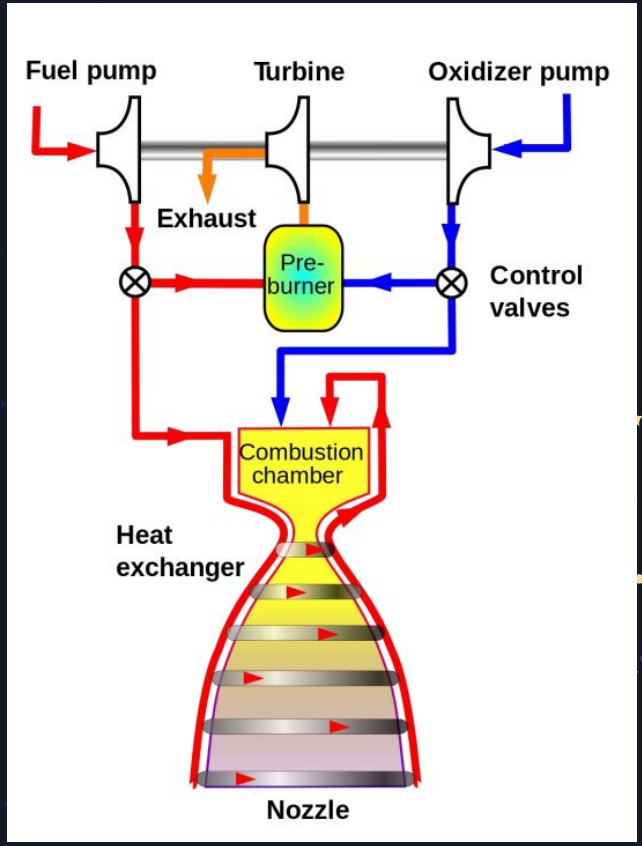
Simple Design(Pressure fed)



Gas Generator Cycles

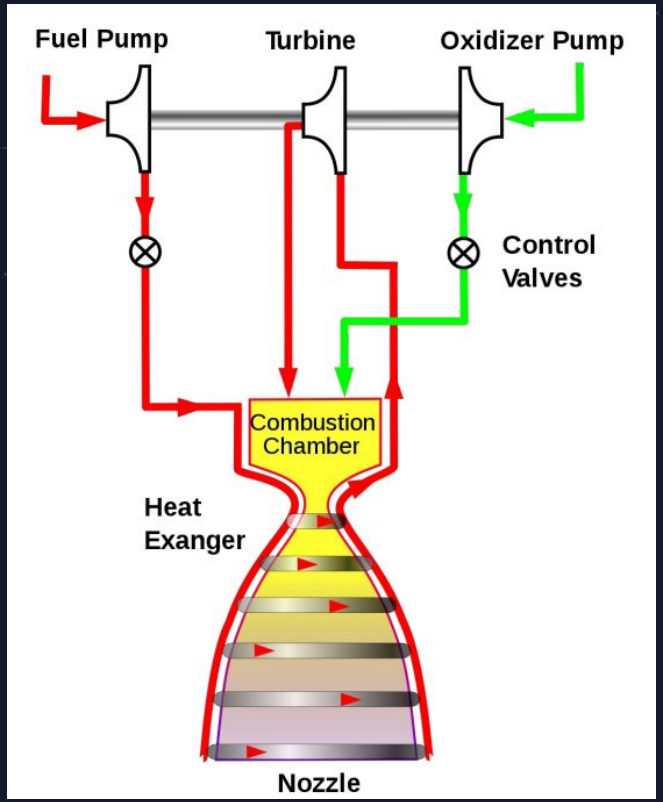
- **Examples:**
  - F1
  - J2
  - Vulcan

- Open Cycle engine
- Loss of efficiency due to discarded propellent
- Simple to build and operate



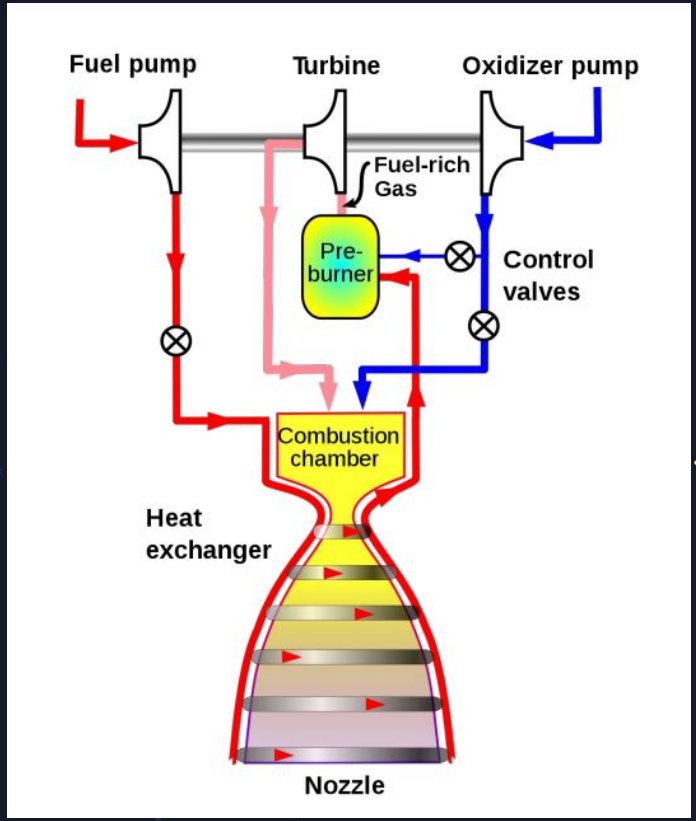
Expander Cycle

- **Examples:**
  - Rocketdyne RL10
  - Vinci(Airane 6)
- No wastage of fuel energy
- Some modifications also available



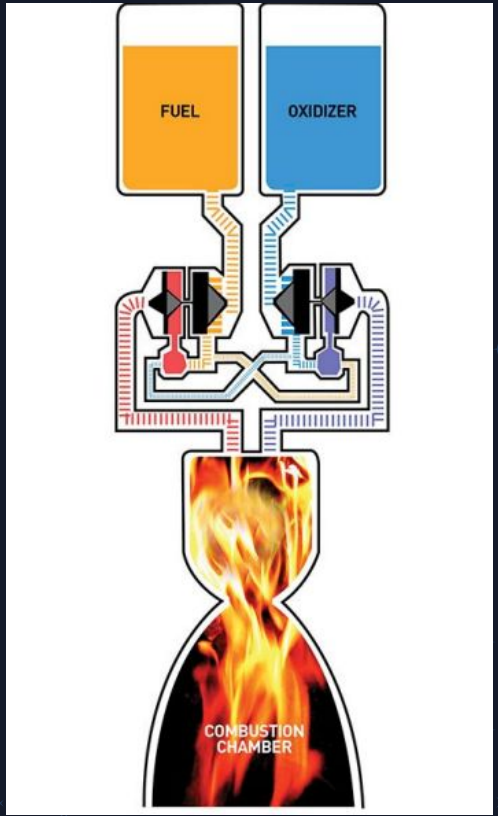
Staged Combustion

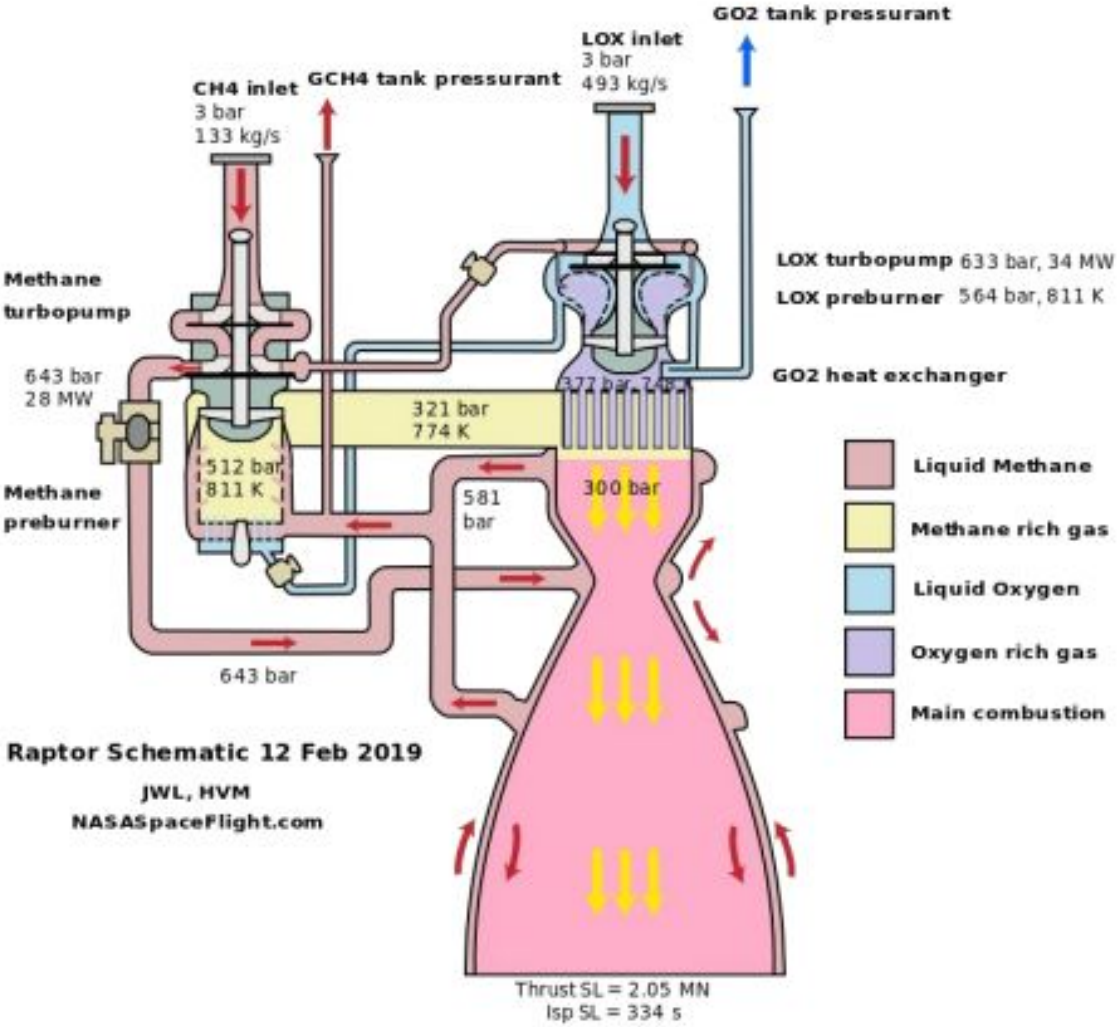
- **Examples:**
  - RS-25(Space shuttle)
  - RD253(Proton)
- Used to reduce the emission of Oxides of Nitrogen

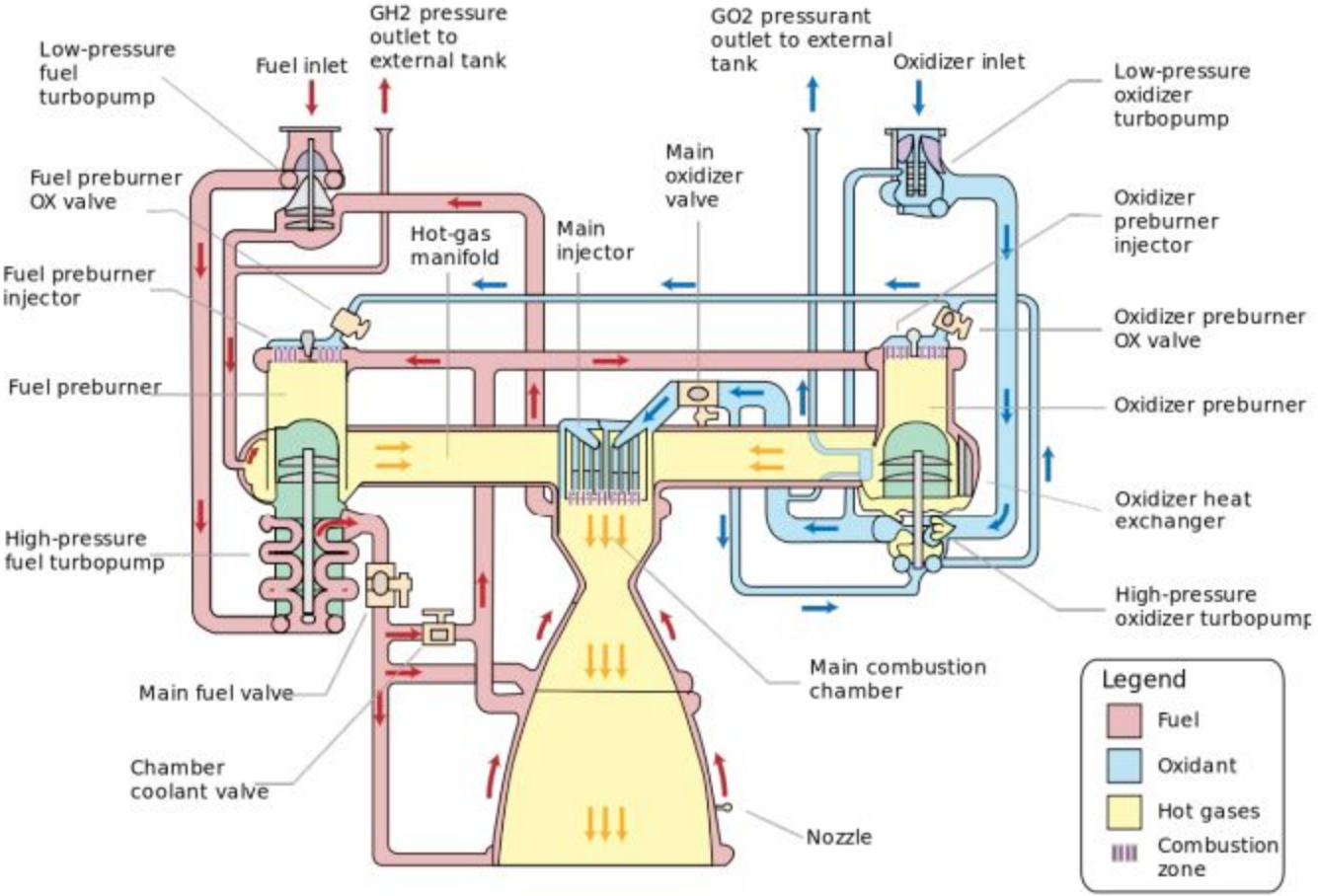


Full Flow Staged Combustion

- **Examples:**
  - Raptor
  - RD270
- Along with all the advantages of Staged combustion
- This is the best engine in terms of efficiency




GO2 tank pressurant
LOX inlet
3 bar
493 kg/s
CH4 inlet
3 bar
133 kg/s
GCH4 tank pressurant
LOX turbopump 633 bar, 34 MW
LOX preburner 564 bar, 811 K
Methane
turbopump
643 bar
28 MW
GO2 heat exchanger
377 bar, 7
321 bar
774 K
512 bar
811 K
Methane
preburner
581
bar
300 bar
643 bar
Liquid Methane
Methane rich gas
Liquid Oxygen
Oxygen rich gas
Main combustion
Raptor Schematic 12 Feb 2019
JWL, HVM
NASASpaceFlight.com
Thrust SL = 2.05 MN
Isp SL = 334 s


Low-pressure fuel turbopump
Fuel inlet
GH2 pressure outlet to external tank
GO2 pressurant outlet to external tank
Oxidizer inlet
Low-pressure oxidizer turbopump
Fuel preburner OX valve
Hot-gas manifold
Main injector
Main oxidizer valve
Oxidizer preburner injector
Fuel preburner injector
Oxidizer preburner OX valve
Fuel preburner
Oxidizer preburner
Oxidizer heat exchanger
High-pressure fuel turbopump
High-pressure oxidizer turbopump
Main combustion chamber
Main fuel valve
Chamber coolant valve
Nozzle
Legend
Fuel
Oxidant
Hot gases
Combustion zone

Engine Instabilities

https://youtu.be/DjWiuMIGVEs