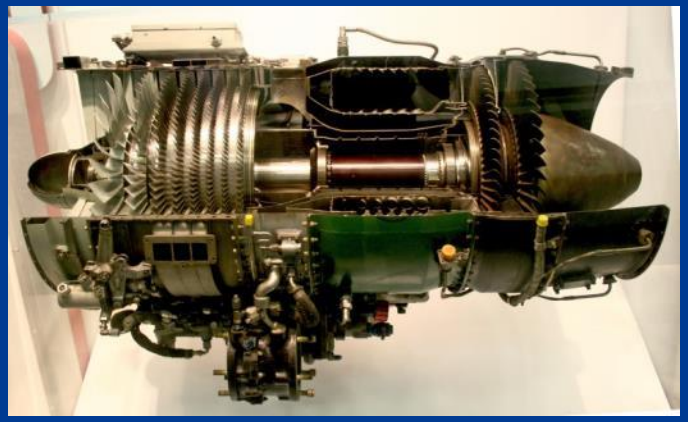
Applied Thermodynamics - II



Gas Turbines – Rocket Propulsion

Sudheer Siddapureddy

sudheer@iitp.ac.in

Department of Mechanical Engineering

Jet Propulsion - Classification

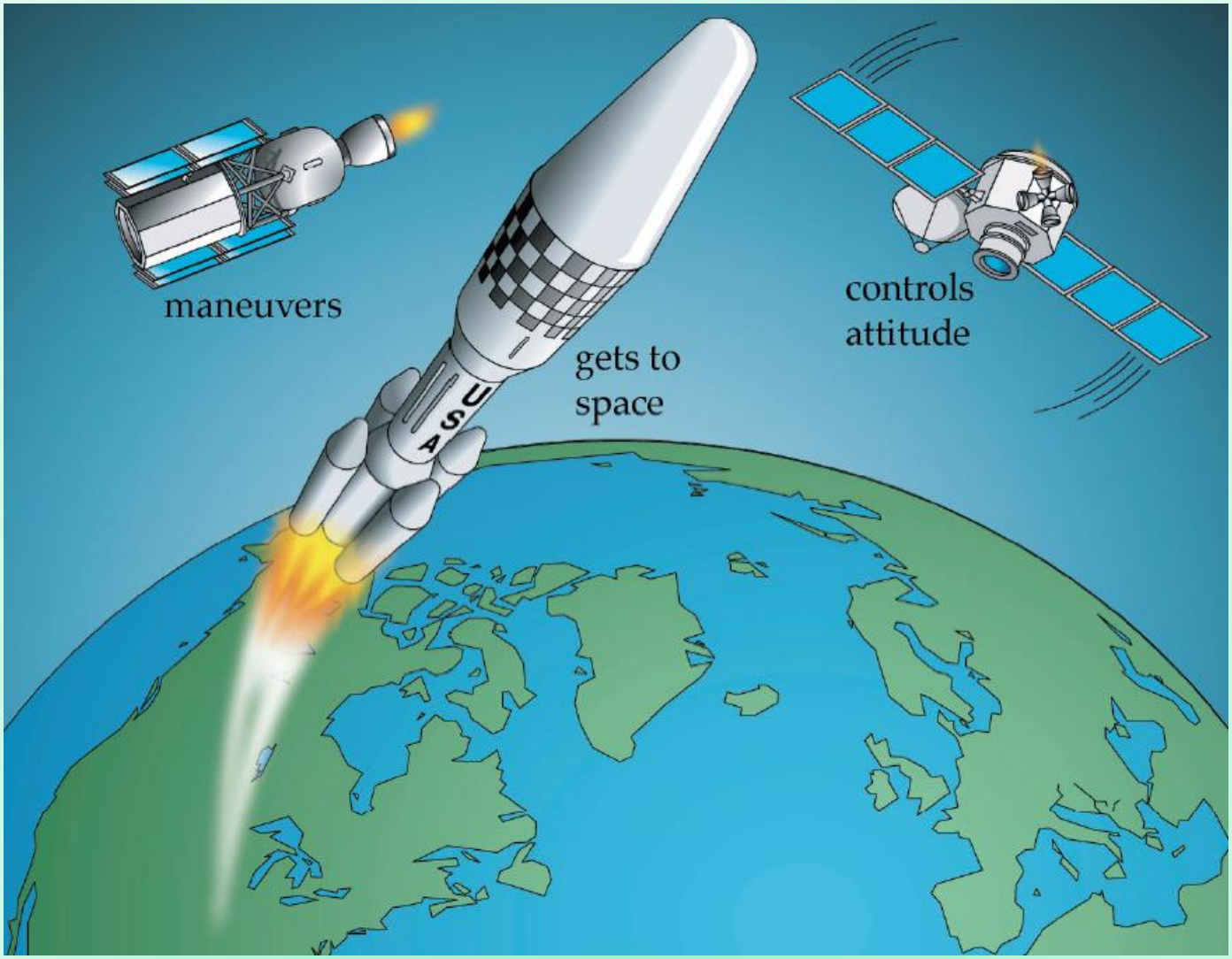
1. A heated and compressed atmospheric air, mixed with products of combustion, air temperature rises to the desired value.
   - Thermal jet
   - **Air breathing engines**
2. Fuel and oxidizer are carried with the system itself, fuel-oxidant mixture is propellant.
   - No air is used. Jet is *Rocket jet*, the equipment wherein the chemical reaction takes place is *Rocket motor*
   - **Rocket engine**

Rocket: Definition

A machine that develops thrust by the rapid expulsion of matter

Rockets

Take spacecraft into orbit, move them, help control their attitude



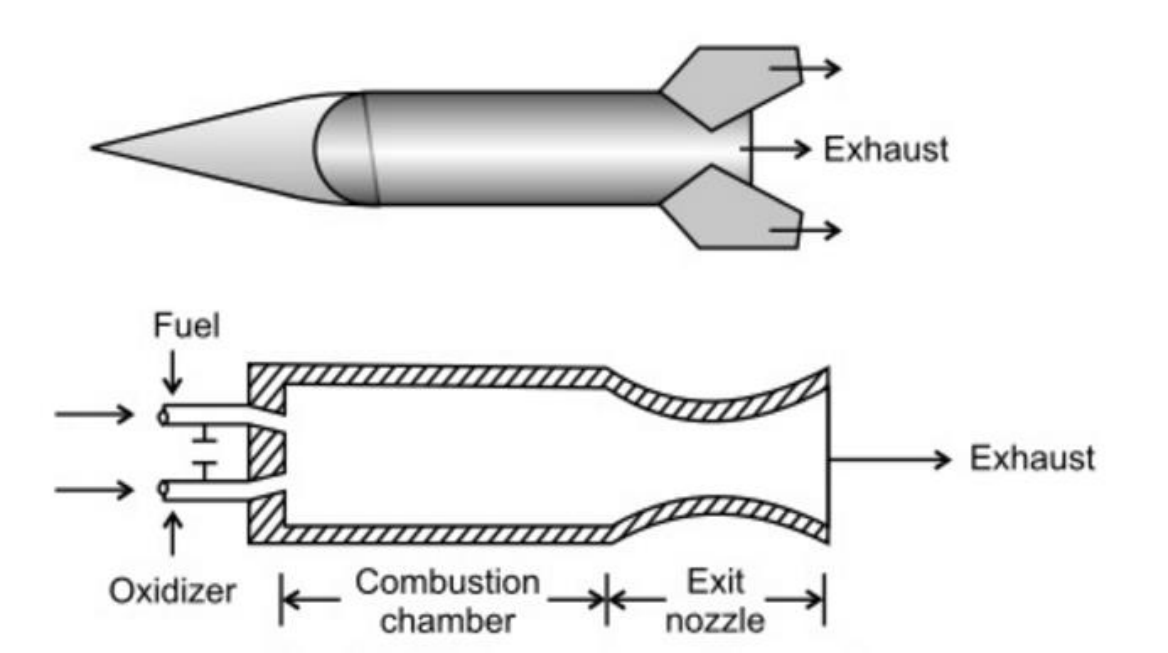
Rockets: Terminology

A rocket is a machine that develops thrust by the rapid expulsion of matter.

- A rocket carries its fuel and oxidizer internally

  Burn in vacuum of space as well as within the Earth's atmosphere
- The cargo is commonly referred to as the payload.
- Rocket is called a launch vehicle when it is used to launch a satellite or other payload into space.
- Rocket becomes a missile when the payload is a warhead & used as weapon.
- At present, rockets are the only means capable of achieving the altitude and velocity necessary to put a payload into orbit.

Principle of Rocket Propulsion



$$F = \dot{m}_p C_e + A_e(P_e - P_a)$$

Maximum thrust is available in vacuum.

Thrust in terms of effective jet velocity:

$$F = \dot{m}_p C_e + A_e(P_e - P_a) = \dot{m}_p C_{ej}$$

Principle of Rocket Propulsion

$$F = \dot{m}_p C_e + A_e(P_e - P_a)$$

Maximum thrust is available in vacuum.

Thrust in terms of effective jet velocity:

$$F = \dot{m}_p C_e + A_e(P_e - P_a) = \dot{m}_p C_{ej}$$

Hence, the effective jet velocity:

$$C_{ej} = C_e + \frac{A_e}{\dot{m}_p}(P_e - P_a)$$

Specific impulse, thrust produced per unit mass flow rate of propellant:

$$I_{sp} = \frac{F}{\dot{m}_p}$$

Principle of Rocket Propulsion

Thrust power in case of rocket of engine:

$$P = FC_a = \dot{m}_p C_{ej} C_a$$

Propulsion efficiency:

$$\eta_{prop} = \frac{P}{P + \text{loss of kinetic energy}}$$

$$= \frac{\dot{m}_p C_{ej} C_a}{\dot{m}_p C_{ej} C_a + \dot{m}_p \frac{(C_{ej} - C_a)^2}{2}}$$

$$= \frac{2(C_a/C_{ej})}{1 + (C_a/C_{ej})^2}$$

Classification

Based on the form of energy transferred to the propellant and converted to high speed exhaust:

1. Thermodynamic rockets – rely on thermodynamic energy (heat and pressure)
2. Electrodynamic rockets – rely on electrodynamic energy (electric charge and electric and magnetic fields)

Based on fuel state:

1. Solid propellant rocket engine
2. Liquid propellant rocket engine

Desired Properties of Propellant

Rocket propellant should:

- have large heating value
- have high density so that storage space required is small
- be capable of having smooth ignition
- have stability and ease of handling and storage
- be non-toxic and non-corrosive
- be environment friendly

Rockets: Applications

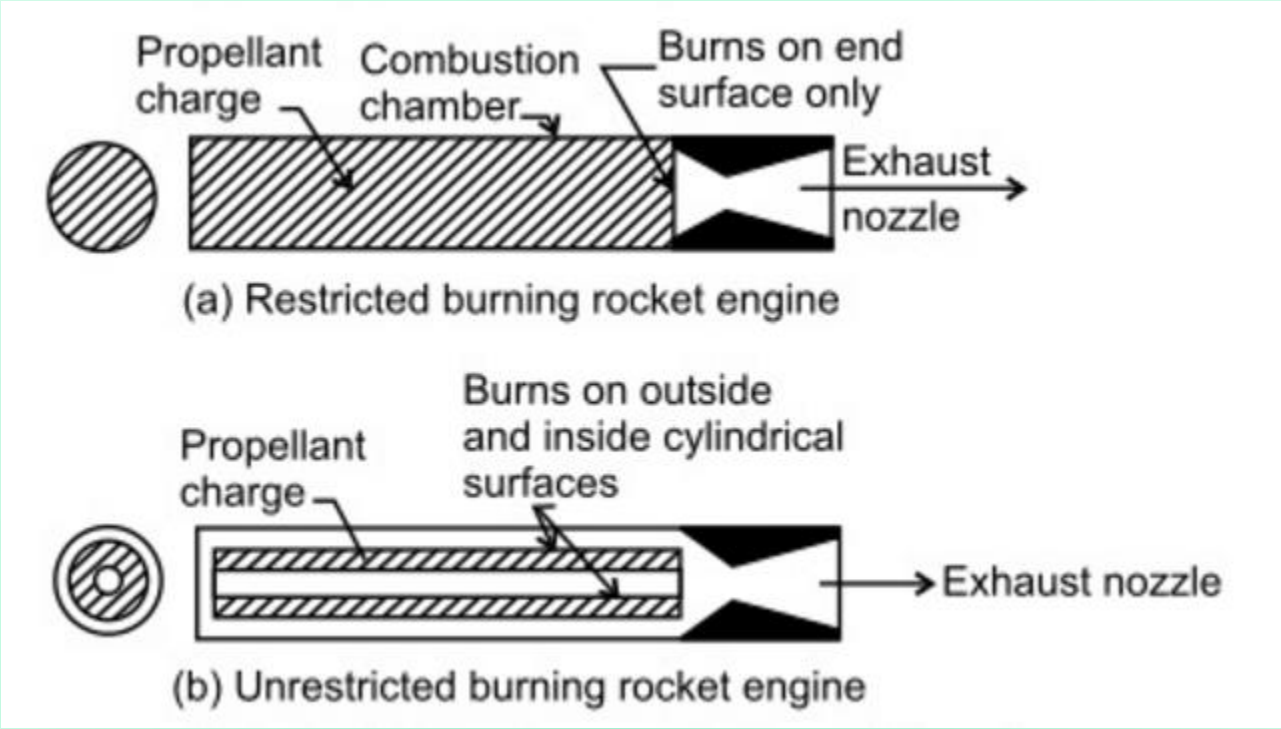
1. Satellites in space serve air communication
2. Spacecraft
3. Missiles
4. Jet assisted air planes
5. Pilotless aircraft

Solid Propellant Rocket Engines

Solid propellants burns using oxidizer present within them.

Propellant should:

- have sufficient compressive and impact strength at low temperature
- give uniform burning
- give high specific impulse



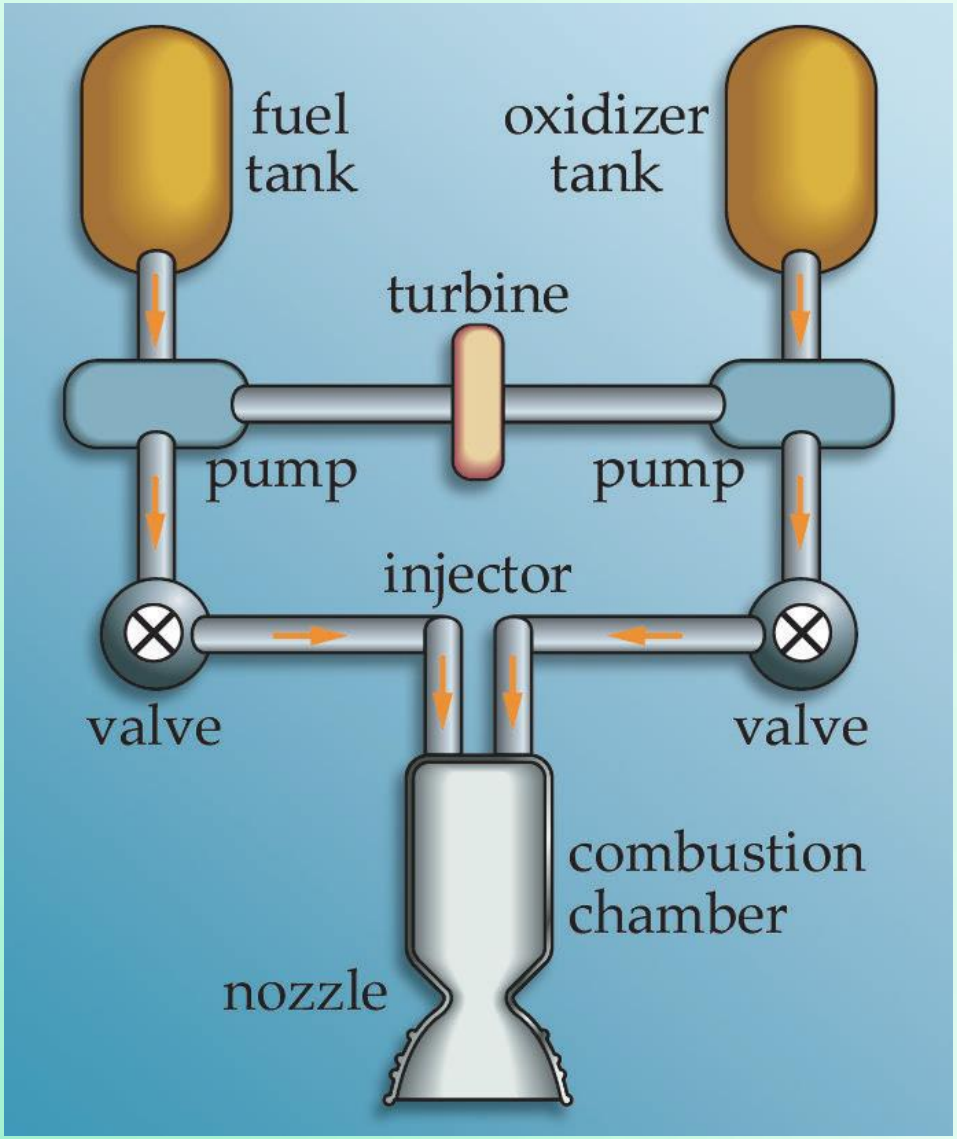
Liquid Propellant Rocket Engines

Bi-propellant

- Fuel – LP1 or LH_2
- Oxygen - LOX

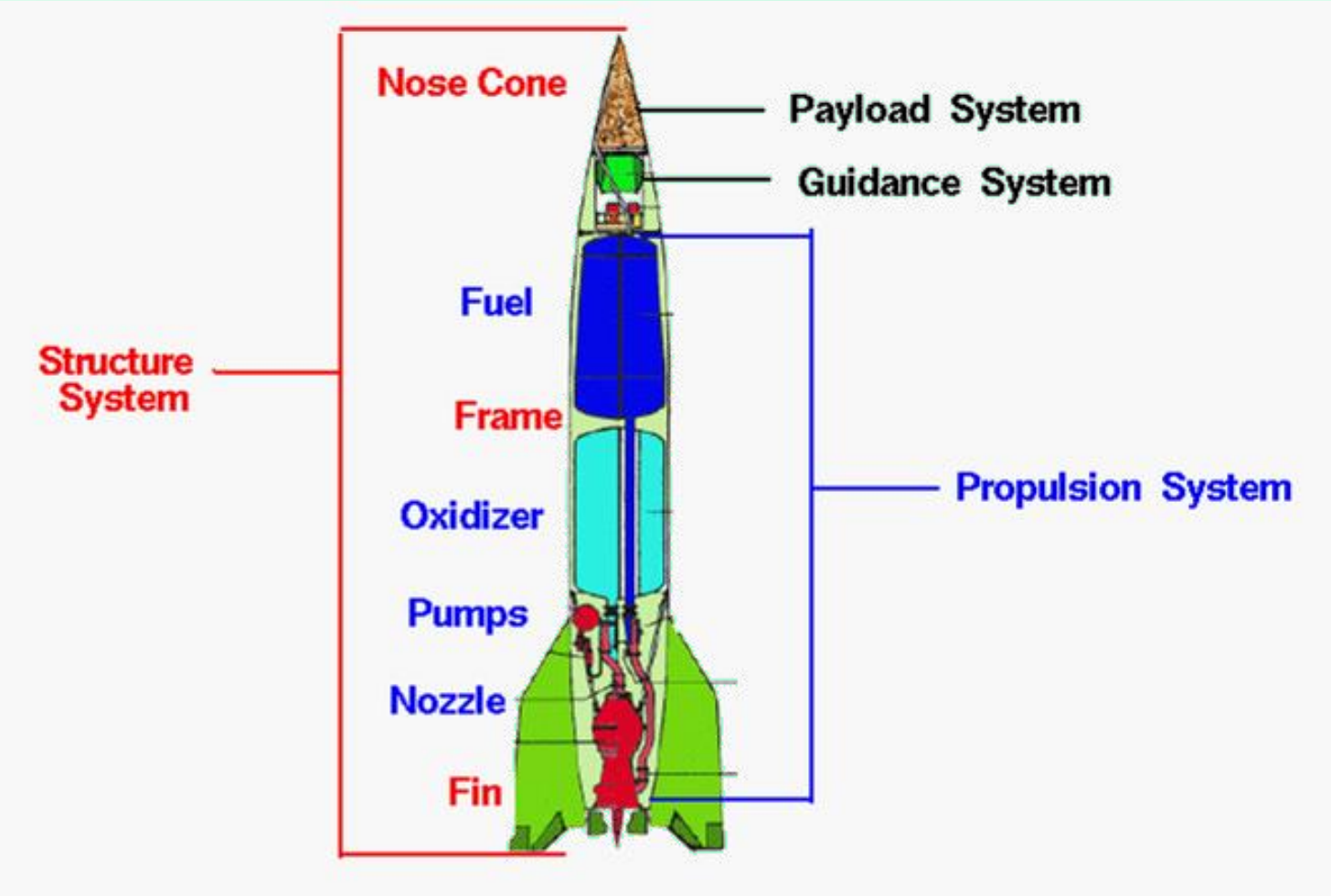
Mono-propellant

- Single propellant
- Unstable
- Easily decompose
- H_2O_2



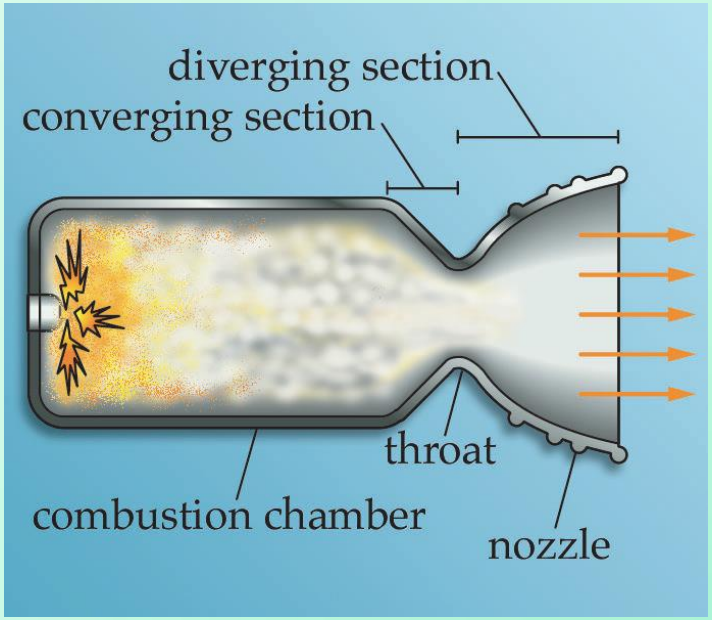
Major Components of Chemical Rocket

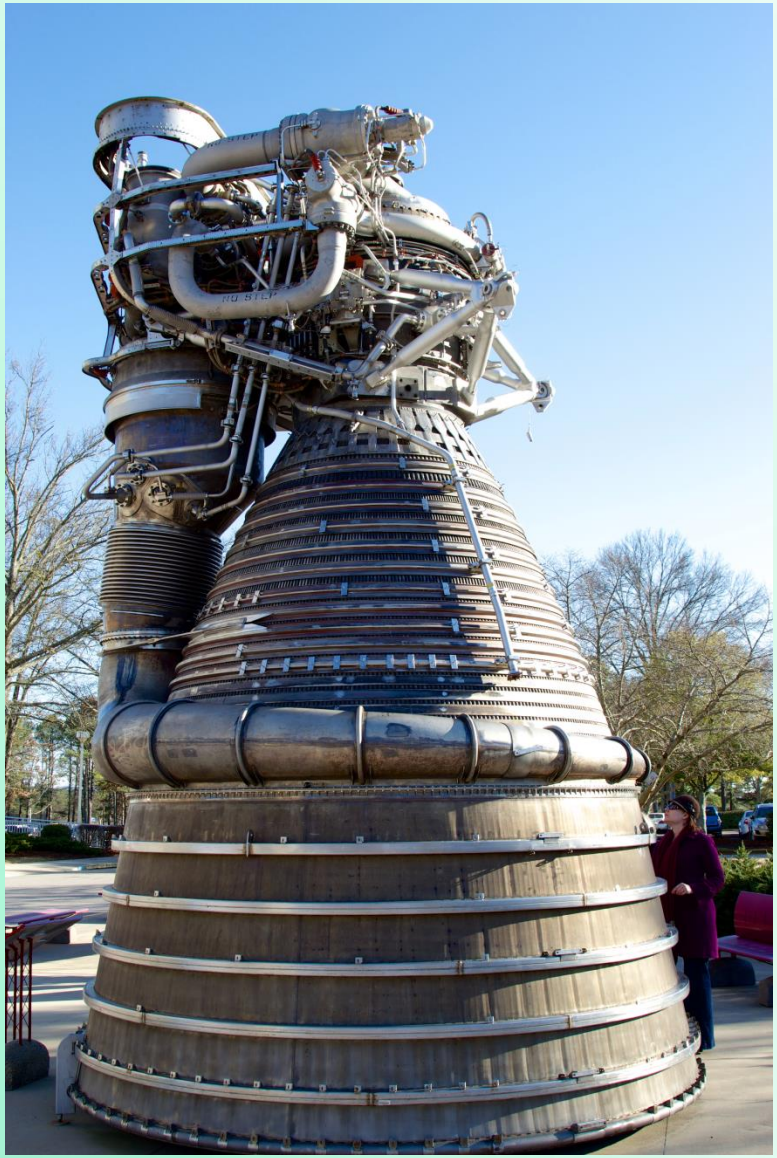
Rocket engine, Propellant consisting of fuel and an oxidizer, Structure, Control systems, Cargo such as a satellite



Thermodynamic Expansion - Nozzles

Most rockets rely on nozzles to convert thermal energy into KE through thermodynamic expansion.





Saturn V Nozzle: 3.7 m dia., 5.6 m ht.