# Blast Off!

Lecture 5

# Engines and Propulsion

# Propulsion

**Liquid Fuels**

- Fuel Composition and types in use
- The Cryogenics
- Monopropellants

**Solid Propulsion**

- Chemicals used
- Internal structure of SRB  Energy Density
- Ignition and Control

# The Idea of Propulsion

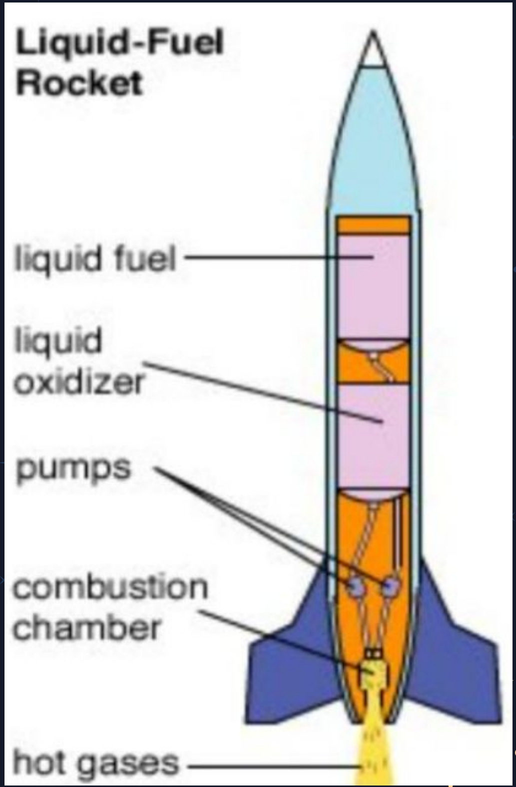
"Throw out as much as mass from the nozzle at maximum velocity possible"

High mass flow rate ➡ High chamber pressure ➡ High exhaust velocity.

But problem is, the chamber pressure!!

# Liquid Propellants

- Liquids are desirable because they have a reasonably high density and high specific impulse aka high speed of exhaust gases.
- Using low density fuels increases the mass of the launch vehicle.
- $V_{rms} = \sqrt{(3kT)/m}$
- Liquid propellants have separate storage tanks - one for the fuel and one for the oxidizer.
- They also have pumps, valves, a combustion chamber, and a nozzle.
- Their flow can be controlled.



# Petroleum Based

- ➢ Refined from crude oil and a mixture of hydrocarbons.
- ➢ RP1, aka highly refined kerosene is widely used.
- ➢ They are used with an oxidiser.
- ➢ Usually produce a Sooty Exhaust but is cheap.
- ➢ The soot makes exhaust glow orange and also helps in cooling the engine. How?

# Cryogens

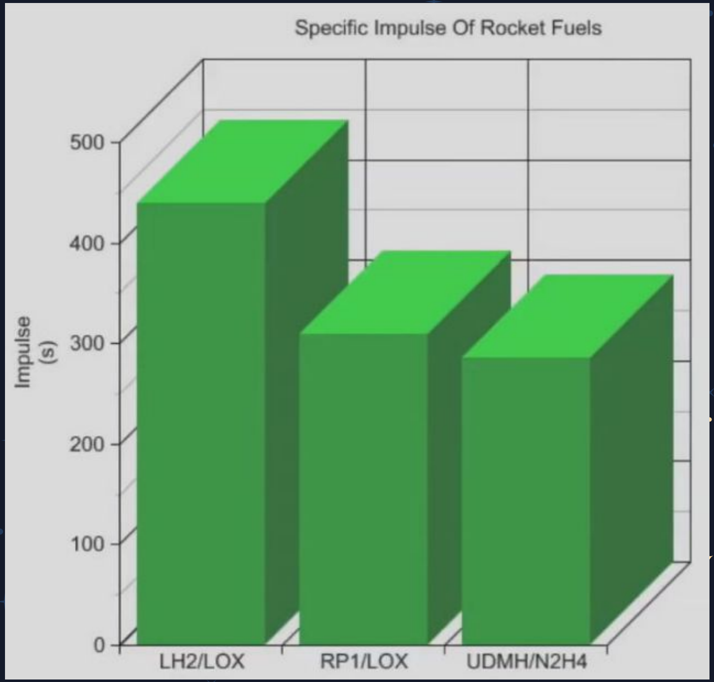
- Liquefied gases stored at a very low temperature.Liquid hydrogen (LH2 ) as the fuel and liquid oxygen (LO2 or LOX) as the oxidizer.
- Because of the low temperatures of cryogenic propellants, they are difficult to store over long periods of time.
- Cryogens usually burn clear and do minimum damage to the environment.

- Liquid Oxygen doesn’t spontaneously combust so need to include extra hardware to ignite the rocket, adding complexity.
- Liquid hydrogen has a very low density (0.071 g/ml) and, therefore, requires a storage volume many times greater than other fuels.
- Liquid hydrogen delivers a specific impulse about 30%-40% higher than most other rocket fuels.
- Offer simplification in the engine cooling system(regenerative cooling).
- Produce the engineering challenge of keeping the fuel tank cool.

For both the space shuttle disasters Cryogenics could also be(partially) put to blame.

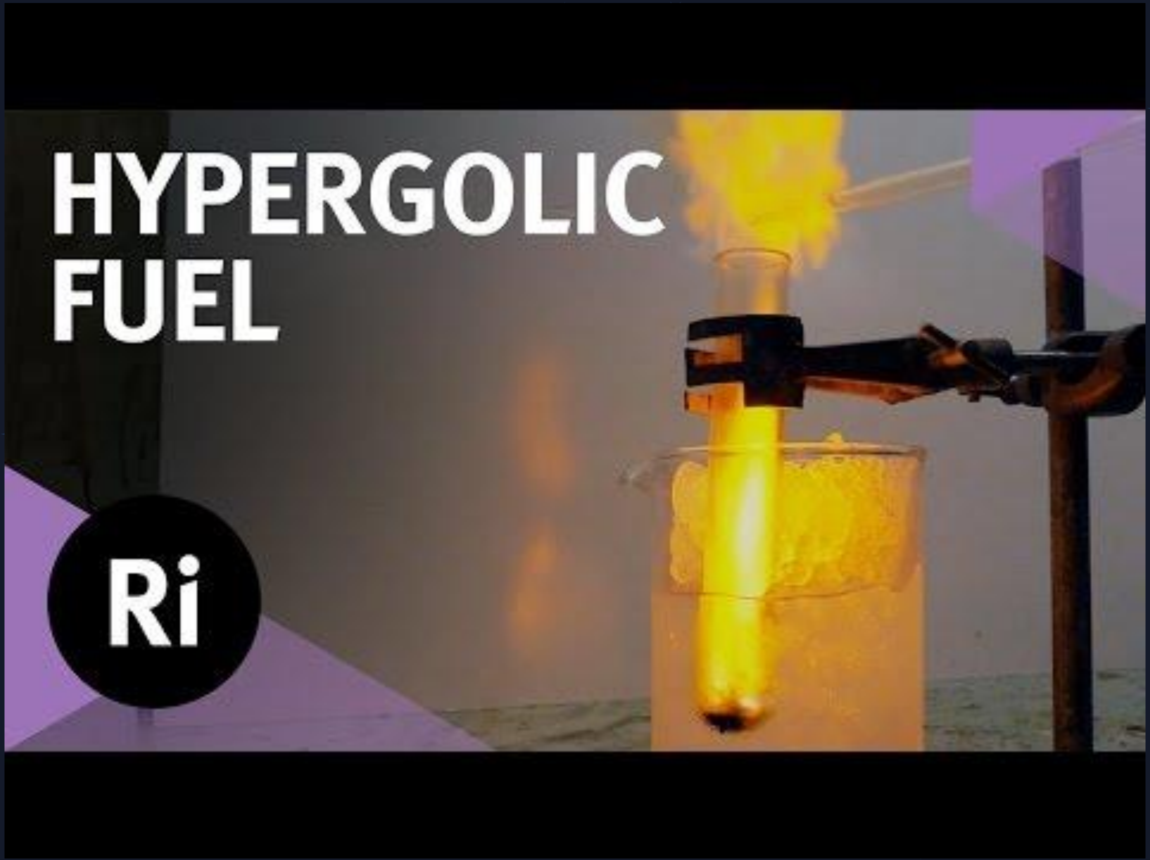
- Best known liquid fuel is $H_2$(liq) + $O_2$(liq) = $H_2O$.
- Highly energetic, $H_2O$ is light so exhaust velocity is very high so high specific impulse.
- Product is non toxic.

| Fuel Type | $I_{sp}$ | Energy density |
|---|---|---|
| LH2 | 455 | 8.5 |
| RP1 | 358 | 33 |



# Hypergols

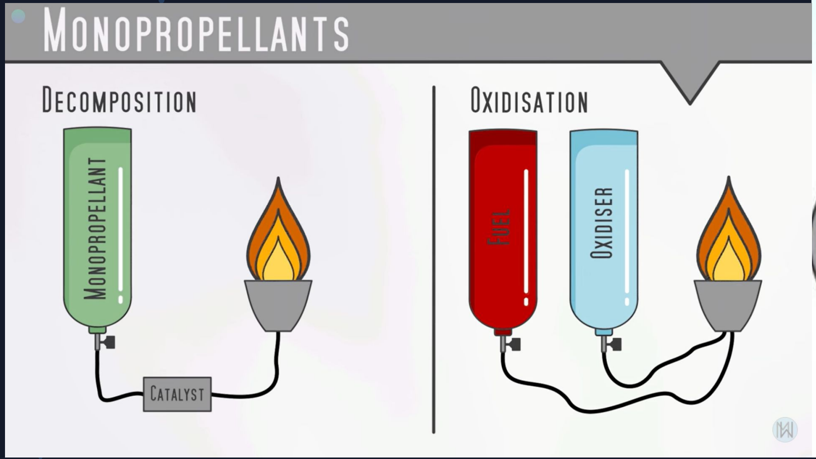
- Propellants that ignite spontaneously on contact with each other and require no ignition source.
- The easy start and restart capability of hypergols make them ideal for spacecraft maneuvering systems. Can be used as an igniter.
- They do not pose the storage problems of cryogenic propellants.
- But they are highly toxic and must be handled with extreme care.
- Hypergolic fuels commonly include hydrazine, monomethyl hydrazine (MMH) and unsymmetrical dimethyl hydrazine (UDMH).
- The oxidizer is usually nitrogen tetroxide (NTO) or nitric acid.
- Usually mixed oxides of nitrogen (MON) is used to lower freezing point.

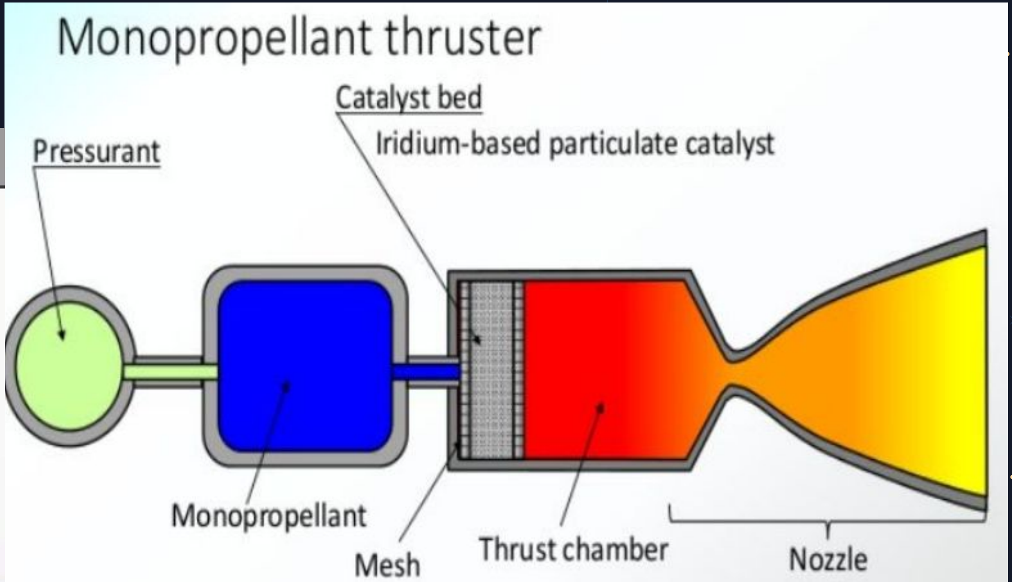



https://youtu.be/IcjYdEW_HLQ?t=140

# MonoPropellants

- ➢ Using single propellant which are pressure pumped.
- ➢ Simple in design(most reliable)
- ➢ Will require Catalysis
- ➢ Usually used in RCS



# Fuel Rich vs Oxygen Rich

- Hydrocarbons have coking issues so their engines are oxygen rich.
- Performance is usually higher in oxidiser rich fuels.
- But oxidisers are generally corrosive and complex metallurgy.
- Mostly fuel rich mixtures are preferred.
- Fuel rich mixtures keep the engine cooler.

# Solid Propellants

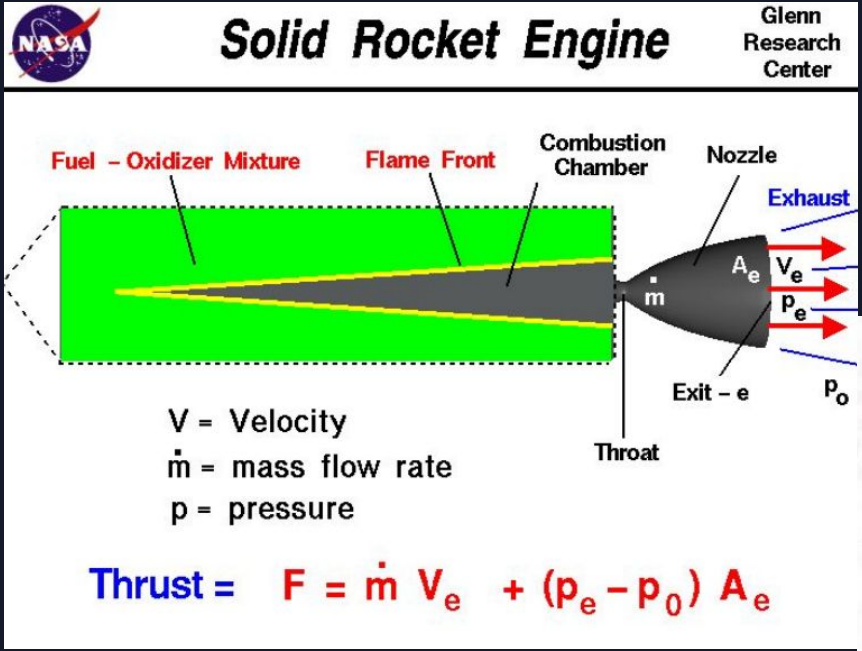
- ➢ These mechanism are being used from an ancient time.
- ➢ Deflagration is the main process via which the fuel is burned.

- ➢ Essentially solid fuel burning rockets are channeled explosions.
- ➢ Different fuels will give different challenges and would require different constructs.

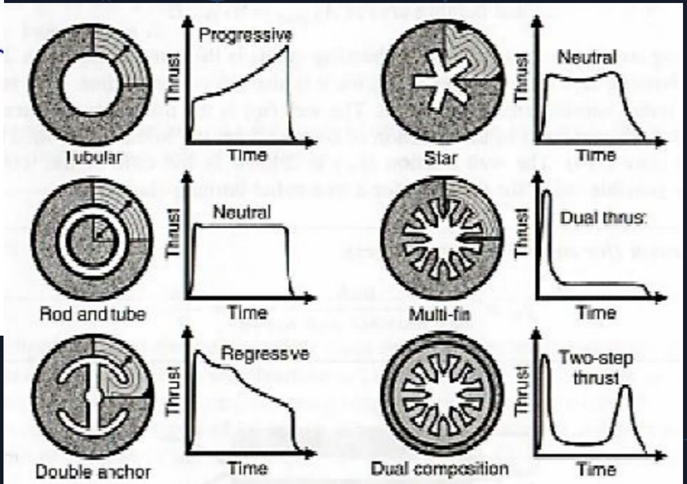
# SRB ( Solid Rocket Booster )


- Used in various missions like the Space shuttles and the SLS program
- Simple and provide a ton of thrust
- SRB in Shuttle produced 12,000 kN of thrust
- Double the power of a single F1 rocket engine
- They can't be switched off once they have been fired.

# Internal Structure of SRBs




Notice the black composite propellant




Different shapes for different thrust profiles