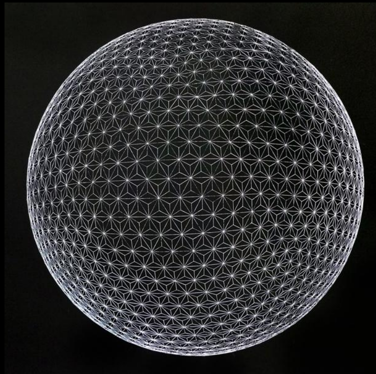
Space Exploration

Propulsion

Mubashshir Uddin
Sunny K. Bhagat
Varun Singh



Content:

- Liquid Fuels:
  - Fuel Composition and types in use
  - The Cryogenics
  - Monopropellants
- Solid Propulsion:
  - Chemicals used
  - Internal structure of SRB
  - Energy Density
  - Ignition and Control

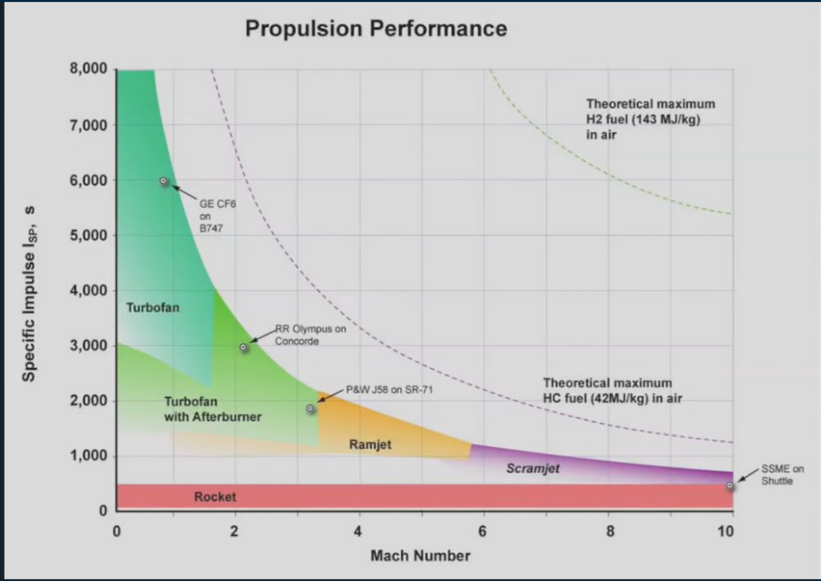
Introduction

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!!



Solid Propellant

The Process:

- These mechanism are being used from an ancient time.
- Deflagration is the main process via which the fuel is burned
- Different fuels will give different challenges and would require different constructs
- Essentially solid fuel burning rockets are channeled explosions.

Deflagration of a firecracker

The material may include anything capable of working as an explosive

aluminium perchlorate

Black Powder

Zinc-Sulphur Prop

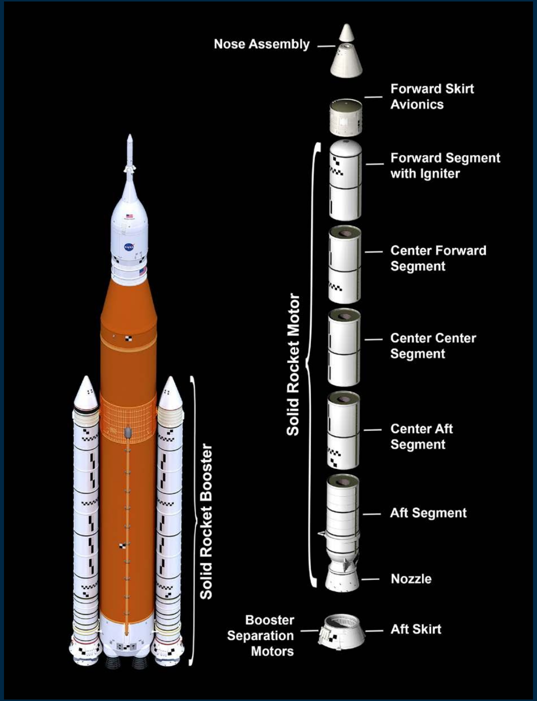
Candy Propellants

Double Base propellants

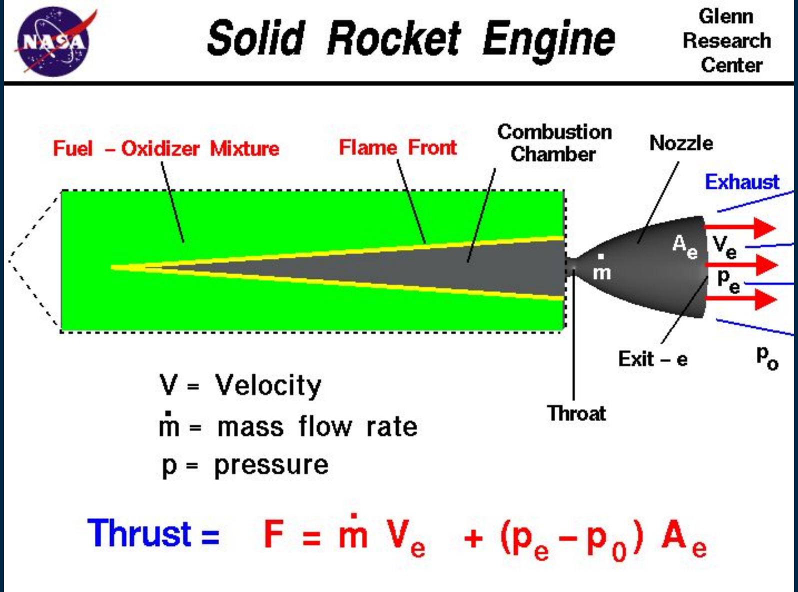
Composite propellants

SRB(The Solid Rocket Booster)

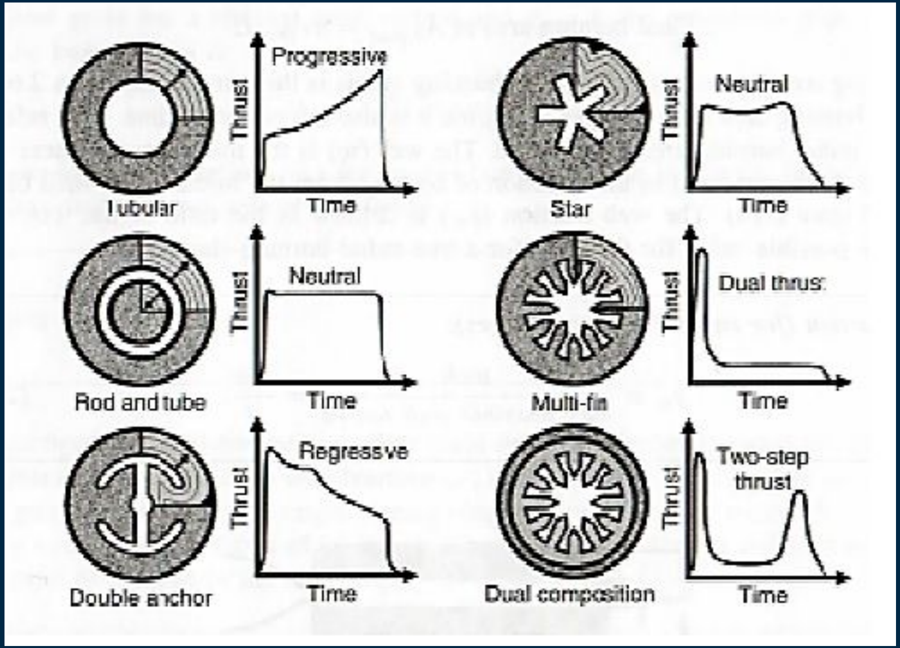
- Used in various missions like the Space shuttles and the SLS program
- Simple and provide a ton of thrust
- SRB in Shuttle produced 12,000 kN of thrust
- Double the power of a single F1 rocket engine
- They can't be switched off once they have been fired



Internal structure of SRB:

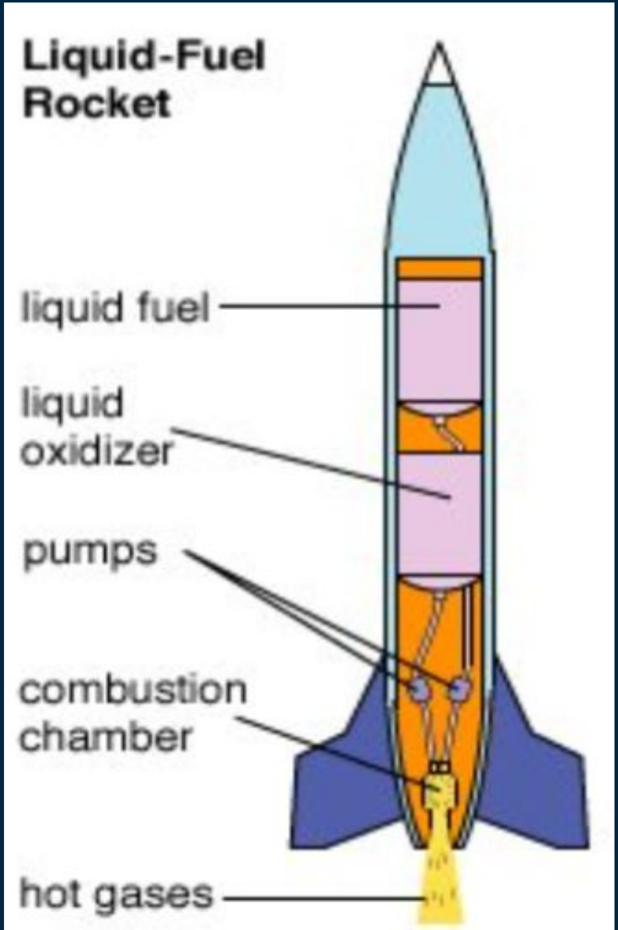


Notice the Black Composite Propellant



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.
- Vrms = √(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.



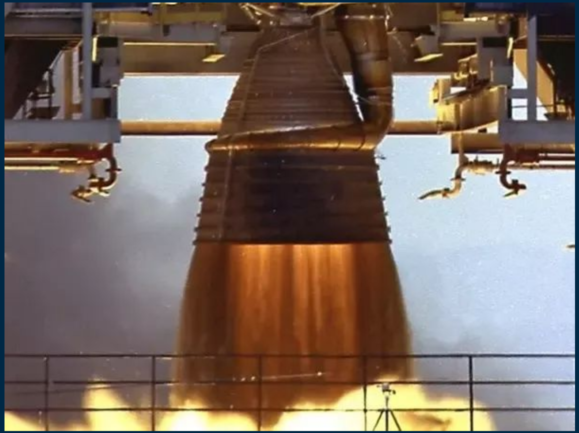
3 Types:

- Petroleum based
- Cryogens
- Hypergols

Petroleum Based

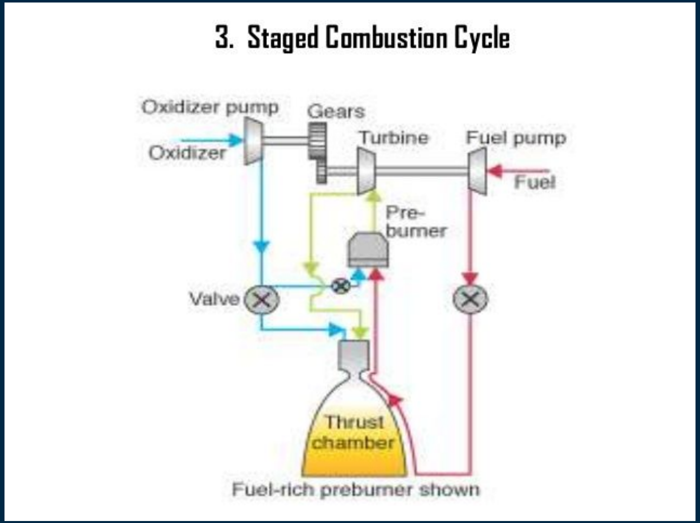
- Refined from crude oil and a mixture of hydrocarbons.
- RP1, aka highly refined kerosene is widely used.
- They are used with an oxidiser.
- Usually produce a Sooty Exhaust but is cheap
- The soot makes exhaust glow orange and also helps in cooling the engine.

An F1 rocket engine burning RP1 (notice the Sooty exhaust)



Cryogens

- Liquefied gases stored at a very low temperature.
- Liquid hydrogen (LH_2) as the fuel and liquid oxygen (LO_2 or LOX) as the oxidizer.



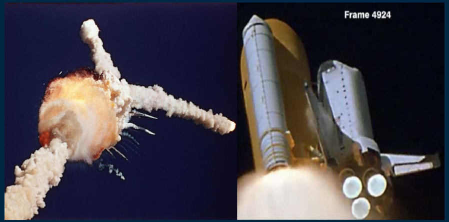
Cryogens

- ❑ Because of the low temperatures of cryogenic propellants, they are difficult to store over long periods of time.
- ❑ 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.

Cryogens:

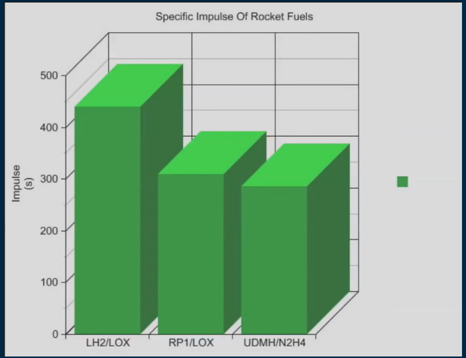
- Cryogens usually burn clear and do minimum damage to the environment.
- Offer simplification in the engine cooling system(regenerative cooling).
- Produce the engineering challenge of keeping the fuel tank cool

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



Two rockets using LOX and H2(notice the clear exhaust)

- 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	ISp	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
FUEL
Ri

Hypergols

- ❑ 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.

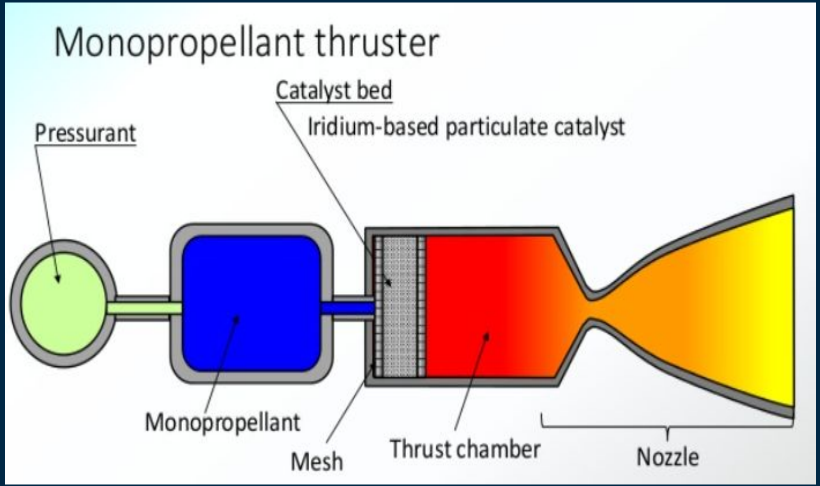
Oxidizer	Fuel	Hypergolic	Mixture Ratio	Specific Impulse (s, sea level)
Liquid Oxygen	Liquid Hydrogen	No	5.00	381
	Liquid Methane	No	2.77	299
	Ethanol + 25% water	No	1.29	269
	Kerosene	No	2.29	289
	Hydrazine	No	0.74	303
	MMH	No	1.15	300
	UDMH	No	1.38	297
	50-50	No	1.06	300
Liquid Fluorine	Liquid Hydrogen	Yes	6.00	400
	Hydrazine	Yes	1.82	338
FLOX-70	Kerosene	Yes	3.80	320
Nitrogen Tetroxide	Kerosene	No	3.53	267
	Hydrazine	Yes	1.08	286
	MMH	Yes	1.73	280
	UDMH	Yes	2.10	277
	50-50	Yes	1.59	280

Fuel Rich vs Oxidiser rich

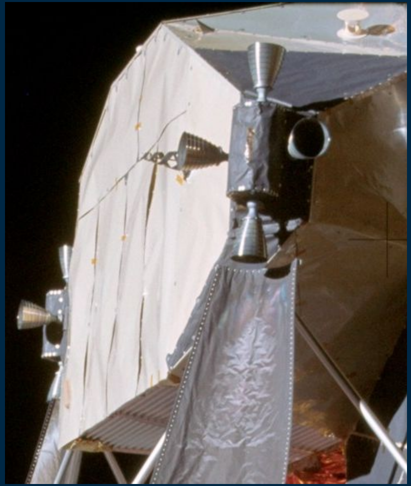
- ❑ Hydrocarbons have coking issues so their engines are oxygen rich.
- ❑ Performance is usually higher in oxidiser rich fuels.
- ❑ But oxidisers are generally corrosive and complex metallurgy.
- ❑ Mostly fuel rich mixtures are preferred.
- ❑ Fuel rich mixtures keep the engine cooler.

MonoPropellants:

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



	H2O2(80%)	N2H4	N2O
Molecular mass, g/mol	34.01	32.05	44
Density kg/m^3	1388	1020	1977.7
Heat of formation (kcal/mole)	-44.88	+12.5	+15.5
Physical properties	Liquid Colorless, Burn skin & flammable	Liquid Colorless Toxic & flammable	Colorless gas
Theoretical Performance (calculated using USAF Isp for Pc=7 bar,area ratio=40)			
Specific impulse, (sec)	160	191	152.7
Combustion Temperature, (K)	1274	896	1609
Molecular weight g/mol	22.677	10.717	29.342
Density specific impulse kg. sec./m^3	266x10^3	228x10^3	222x10^3



THANKS

LET's CONTINUE LATER WITH MORE INTERESTING STUFFS AND FEW MORE CALCULATIONS.