SPACE
The Final Frontier

ABOUT THE PROJECT

To learn some of the fundamental concepts of space exploration, and learn about the tools we use to venture the void.

TIMELINE:

24th - 30th May:
Introductory Design and Structure

1st - 6th June:
Rocket Equation, Re-Entry and Heat Shields.
Assignment 1

7th - 14th June:
Kerbal Space Program Assignment 2A

14th - 21st June:
Propellant, Engines and Aerodynamics of Rocket.
Assignment 2B

22nd - 29th June:
Communication and Deep Space Networks

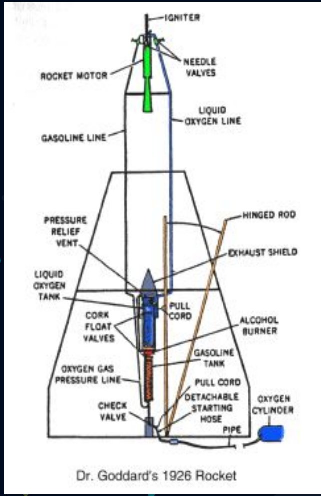
1st - 7th July:
Orbital Dynamics and unusual methods of Propulsion

8th - 14th July:
Habitability and Interstellar Voyage

Goddard’s Contribution:

On March 16, 1926, -Successfully launched the first liquid-fueled rocket

- Used Oxygen (Oxidizer) and Gasoline Fuel
- Used extremely cold liquid oxygen via a network of pipes to keep the combustion chamber cool



Dr. Goddard's 1926 Rocket

1887-1935
Konstantin E. Tsiolkovsky

Tsiolkovsky advocated liquid propellant rocket engines

1912–1977
Dr. Werner von Braun

Development of pre-war Germany’s rocket Program and the V2 project

1926
Robert H Goddard

Built and flew the world’s first liquid propellant rocket on March 16, 1926

1950
Atlas

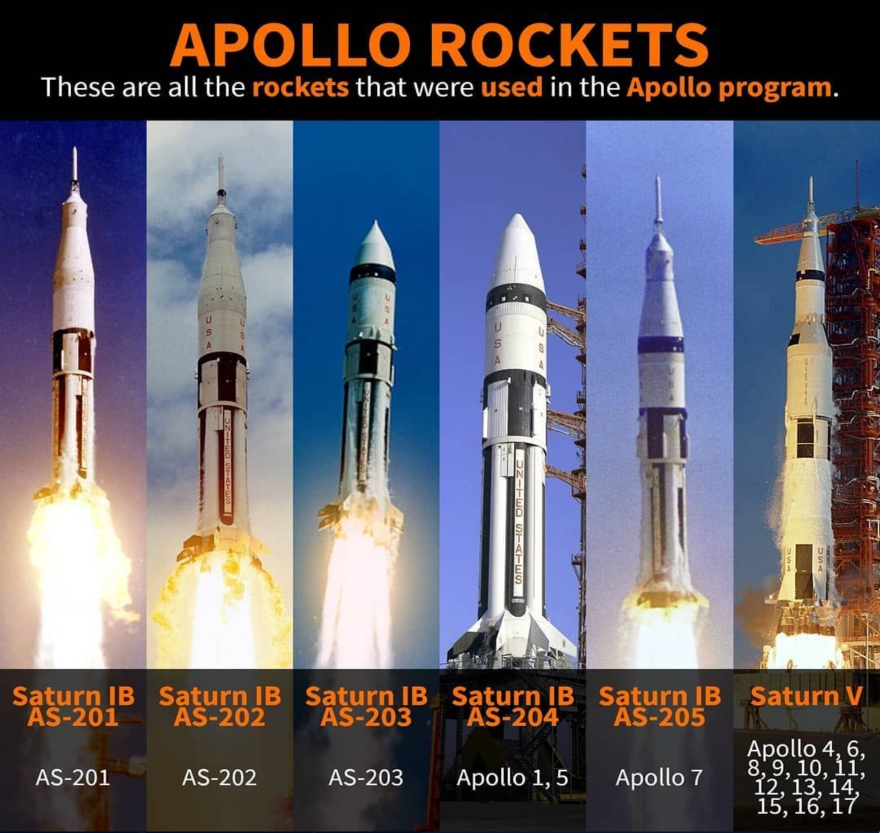
It was adapted to carry John Glenn and 3 other mercury astronauts to space

1960
Delta Family

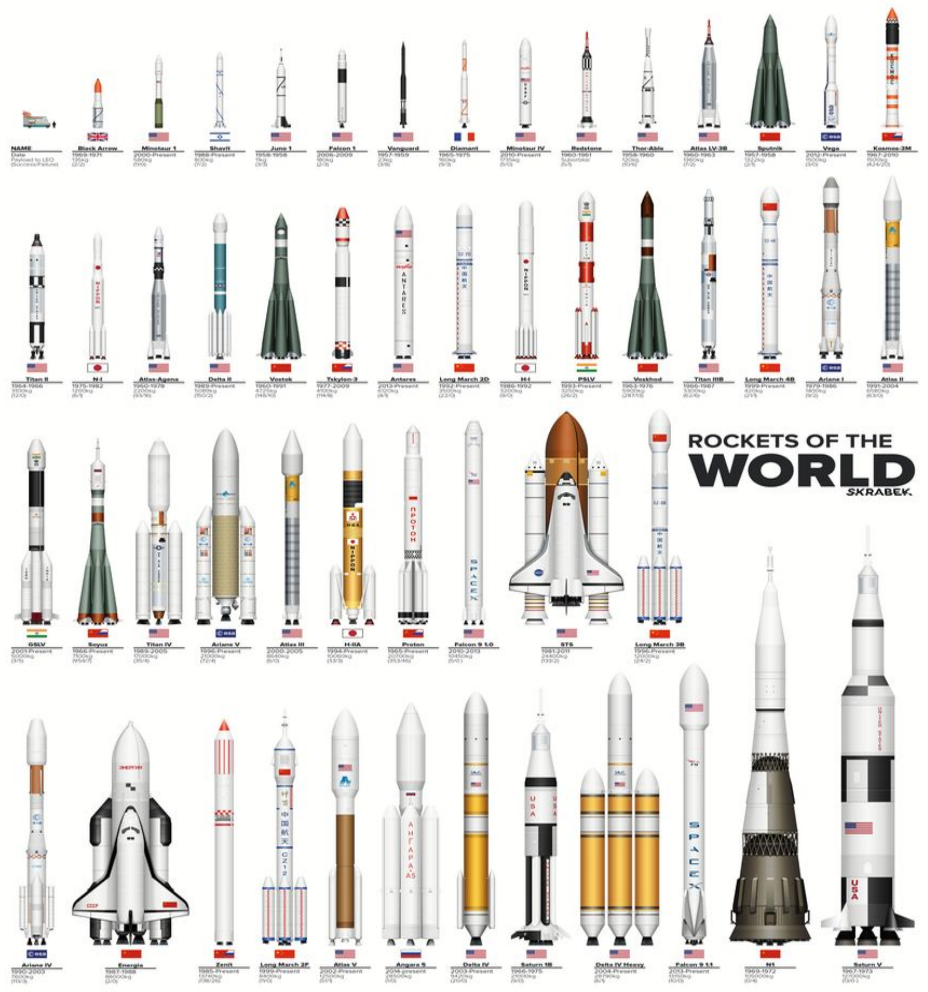
One of the most versatile of the commercial and military payload launch rockets

1969
Apollo 11

On July 16, the Apollo 11 mission launched via a Saturn V rocket



Apollo Mission Rockets



Rocket Design

PAYLOAD

Payload is the carrying capacity of an aircraft or launch vehicle, usually measured in terms of weight. Rocket payload may include cargo, passengers, fuel, etc.

FAIRING

Fairing is the enclosure of the uppermost stage of a rocket and provides protection from heat, atmosphere and biospheric contamination.

BODY

This is the main bulk of the rocket mainly made up from rocket engine, fuel tanks (+ propellant and oxidizer) and the external frame of the rocket.

FINS

Fins are usually attached to the bottom of the rocket to add maneuverability and stability in the upper atmosphere.

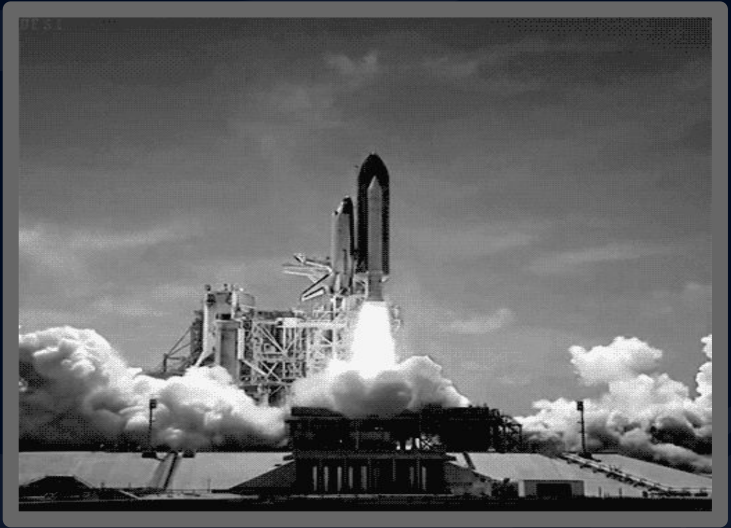
SHOCK DYNAMICS

- As a rocket moves through a gas, the gas molecules are deflected around the rocket.
- As the speed of the object approaches the speed of sound, we must consider compressibility effects on the gas.
- The result is a Shock Wave.

AERODYNAMIC STABILITY OF ROCKET

TWO MAJOR FACTORS OF A ROCKET'S STABILITY:

- LOCATION OF CENTRE OF PRESSURE(C_P)
- LOCATION OF CENTRE OF GRAVITY(C_g)



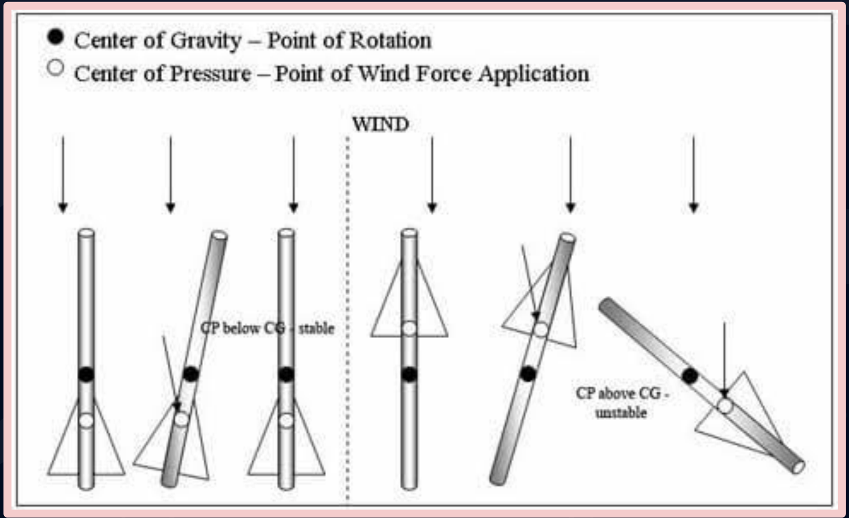
➔ Both follow a certain characteristic nature across the timeline of a rocket.

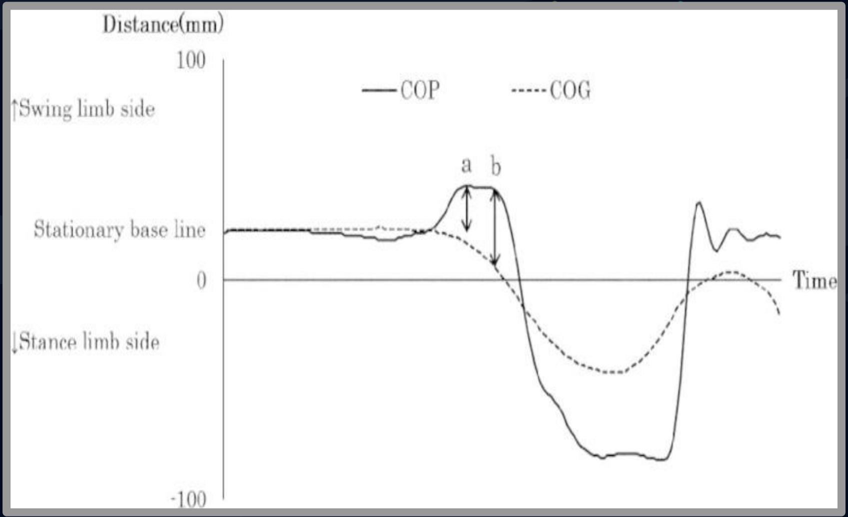
➔ Location of C_P rises as the ratio of (velocity of rocket/speed of sound) increases

While LOCATION OF C_g FALLS WITH THE BURNING OF PROPELLANTS .

LOCATION OF C_P SHOULD ALWAYS BE BELOW THE LOCATION OF C_g TO MAINTAIN THE EFFECT OF RESTORING FORCE AND EVENTUALLY STABILIZE THE ROCKET.

THESE LOCATIONS CHANGE DRASTICALLY WHEN THE ROCKET IS NEAR THE SPEED OF SOUND.





Re-entry Of Rocket

When any object enters atmosphere from space ,it experiences atmospheric drag which puts mechanical stress on the object and causes aerodynamic heating due to compression of air in front of the spacecraft and drag.Hence re-entry should be a guided maneuver and to accomplish this task aerodynamics of the re-entry capsule is such that it minimises the drag.

Types of reentry-

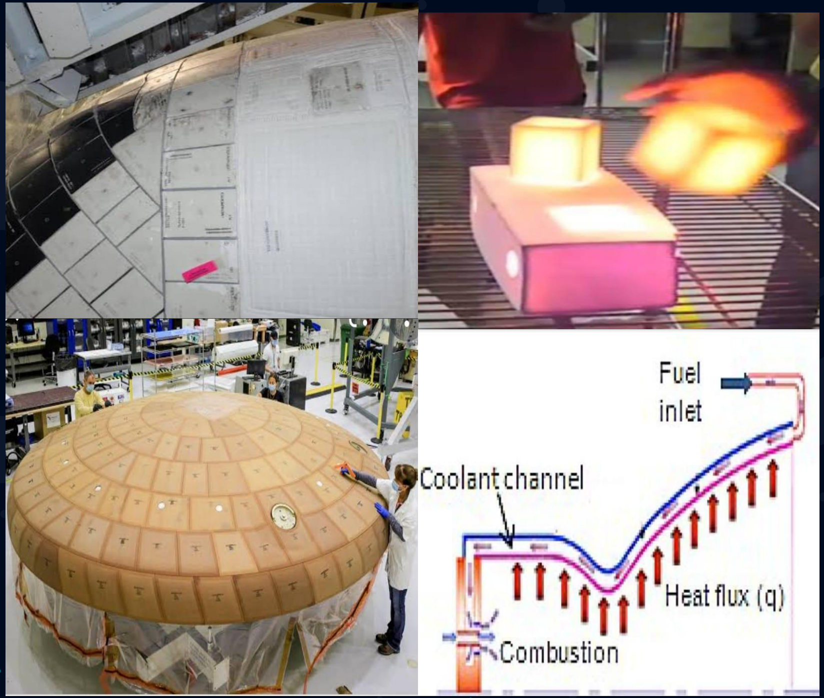
- Ballistic reentry
- Aerodynamic reentry

Heat Shields

It protects the the fuel tank and equipment from the heat produced during the re-entry.

Types of heat shields:

- Insulation blanket
- Insulation tiles
- Reinforced carbon-carbon
- Ablative heat shield
- Regenerative cooling



Rocket Equation

- For the **Ideal case**, not considering drag and gravity :

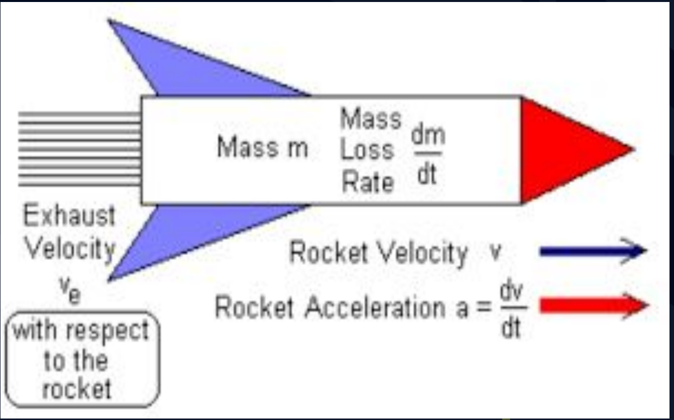
$$M.dv = -dM.v\_ex$$

[Momentum conservation]

Solving the equation further, we have :

$$\Delta v = -V.\ \ln\left(M_0 / M_f\right)$$

[Ideal rocket equation]



- **SPECIFIC IMPULSE (I_{sp})** : A measure of the efficiency of a rocket.

$$I_{sp} = \lim\ (\Delta t \to o)\ [(F_{thrust}.\Delta t)/(m_p.g_o)]$$

- For **Non-Ideal scenarios:**

    - Effect of **gravity**

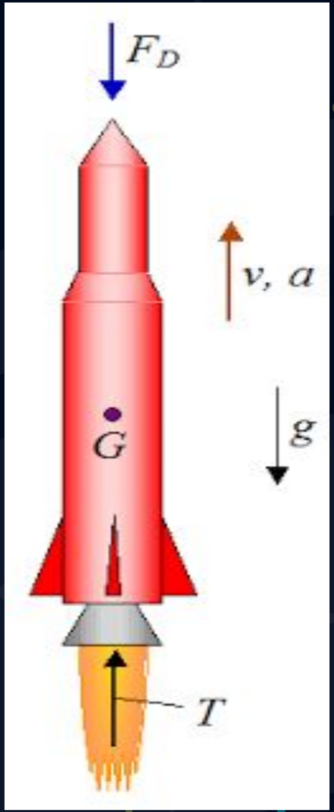
      A **constant gravitational field** acting in the opposite direction to the velocity vector can be incorporated using Newton's laws:

$$M.(dv/dt) = -c(dM/dt) - Mg$$

Integrating and dividing by M_0 ,

$$v = c\ (\ \ln(1/\mu) - (1-\mu)/n\ ]$$

[Velocity of rocket as a function of mass fraction μ]



♦ Effect of **drag**

The effect of the drag force, D, is harder to quantify.

$$D = (½)\rho v^2 AC$$

It turns out that for many important applications drag effects are very small.

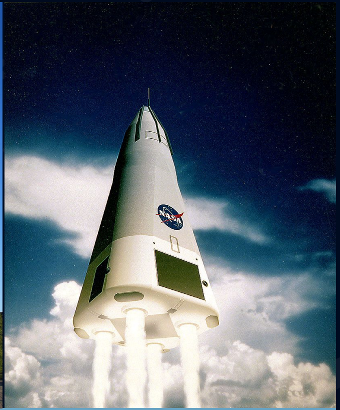
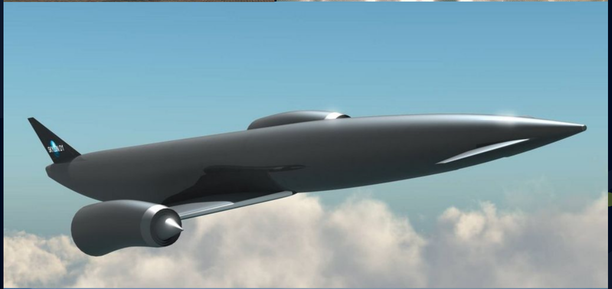
For example:
Considering a rocket of 12, 000 kg with a cross section of A = 1 m^2 and C = 0.2, $\rho \approx 0.25\ kg/m^3$, we can see that the drag force is **only 2%** of the gravitational force.

SSTO

- Single-stage-to-orbit
- Achieves orbital velocity using **ONLY** fuels and propellants without expending any fuel tanks, engines etc.
- Lower atmospheric pressure and weaker gravitational field favour SSTO launch (Moon, Mars)
- Notable example being Skylon, DC-X, etc.

DSTO

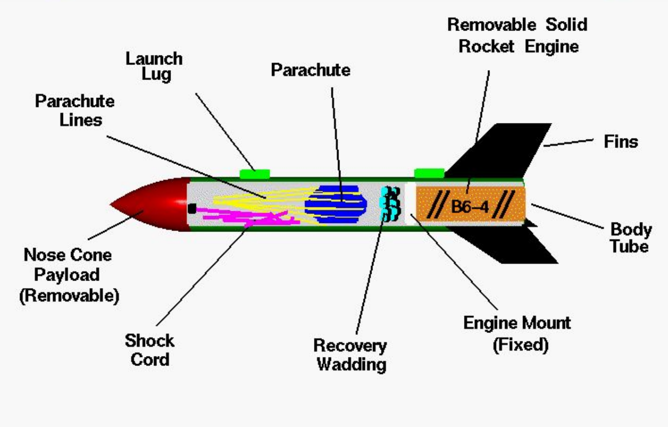
- Double-stage-to-orbit
- Achieves orbital velocity in two stages with each consecutive propulsions and detachment of second stage with first at burnout
- First stage is reusable while second is expendable
- Notable example being Kosmos -3M, Falcon 9, etc.

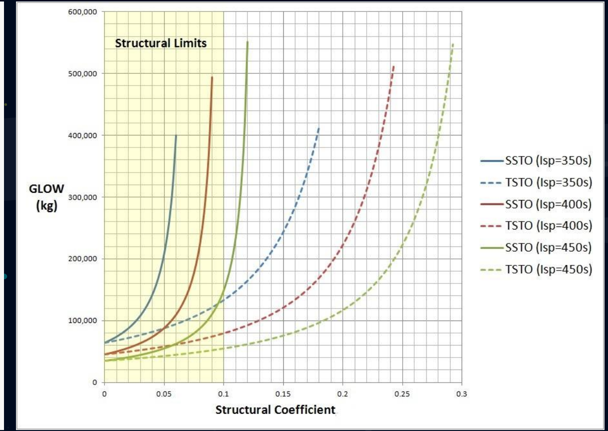




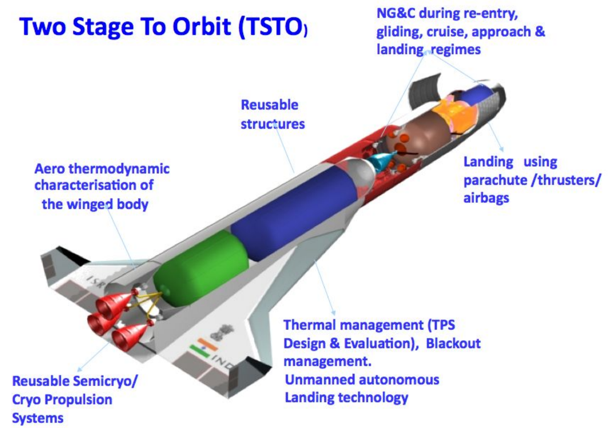

SSTO V/S DSTO

- Comparatively simple design
- Can be made fully reusable
- Low payload ratio
- Smaller structural coefficient

- Complex design
- First stage can be retrieved and reused
- High payload ratio
- Larger structural coefficient





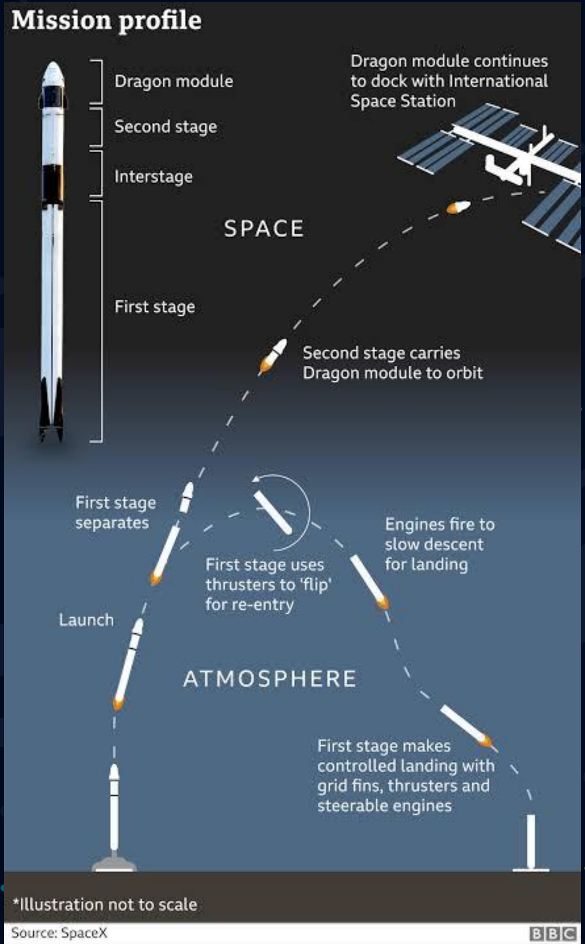


Trajectory Optimization

It uses gravity as the driving force to steer the rocket into a particular trajectory.

Several phases of a two-stage liquid rocket during its ascent trajectory:

1. Vertical Ascent
2. Pitch-over
3. ZLGT (Zero Lift Gravity Turn)
4. Coasting
5. First Burn Stage
6. Coasting-2
7. Second Burn Stage



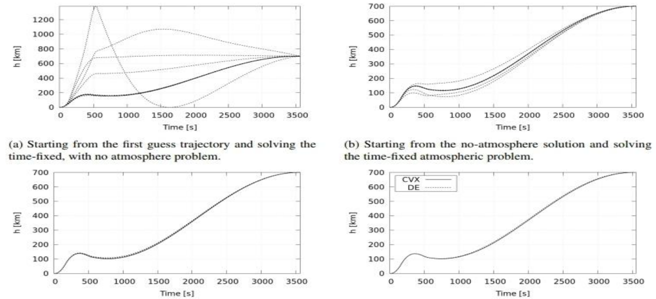
❖ Equation involving state vector(X):

$$X = [\ r\ \theta\ vr\ vt\ m\ ]$$

Main Objectives, MOGA model and future logistics

- ❖ Maximize payload mass -(1)
- ❖ Minimize cost of rocket. -(2)

- ❖ The equation we obtain here is not solvable via integration BUT there exists an analytical solution which is given by MOGA(multi-objective genetic algorithm) which also emphasis on (1) and (2).



(a) Starting from the first guess trajectory and solving the time-fixed, with no atmosphere problem.

(b) Starting from the no-atmosphere solution and solving the time-fixed atmospheric problem.

(c) Starting from the atmospheric time-fixed solution and solving the free-time problem.

(d) Final refined trajectory versus the solution obtained with the DE algorithm.

Figure 3: Altitude profile across the iteration sequences. The dashed curves denote the intermediate solutions while the solid one represents the converged solution.

- ❖ Solution of derivative of equation(1.1) shown in the figure:

The resulting equations of motion $\dot{x} = f(x, u, t)$ are:

$$\dot{r} = v_r$$

$$\dot{\theta} = \frac{v_t}{r}$$

$$\dot{v}_r = \frac{v_t^2}{r} - \frac{\mu}{r^2} + \frac{T_a}{m}\hat{T}_r + \frac{T_b - D}{m}\frac{v_r}{v_{rel}}$$

$$\dot{v}_t = -\frac{v_r v_t}{r} + \frac{T_a}{m}\hat{T}_t + \frac{T_b - D}{m}\frac{v_t - \omega_E r}{v_{rel}}$$

$$\dot{m} = -\frac{T_{vac}}{c}$$

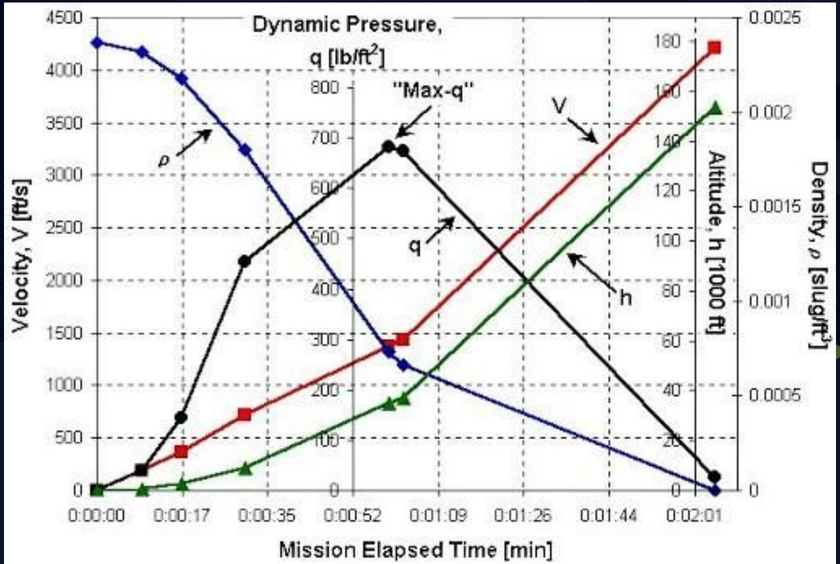
- ❖ We will learn more about MOGA model and future logistics in the coming week

STRUCTURAL SYSTEM

DYNAMIC PRESSURE

AS THE ROCKET LAUNCHES, VELOCITY INCREASES , THUS THE DYNAMIC PRESSURE INCREASES TO A MAXIMUM POINT CALLED THE MAX. Q

$$q=\rho v^2/2$$



MAX. Q

V

ρ

ALTITUDE

BUCKLING

SUDDEN DEFORMATION IN STRUCTURAL COMPONENTS

MATERIALS USED

01

MAINFRAME

Aluminium and Titanium

02

ROCKET BOOSTER

High Density Materials

03

PROTECTION

Thermal Protection System Coating

FUTURE ADVANCEMENTS

01

MAINFRAME

Beryllium and Composite Materials

02

REFRACTORY METAL

Molybdenum

03

OTHER MATERIALS

Ceramics such as Carbide

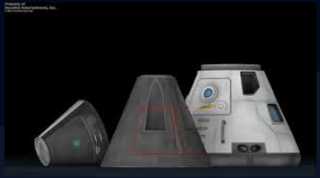
Kerbal Space program

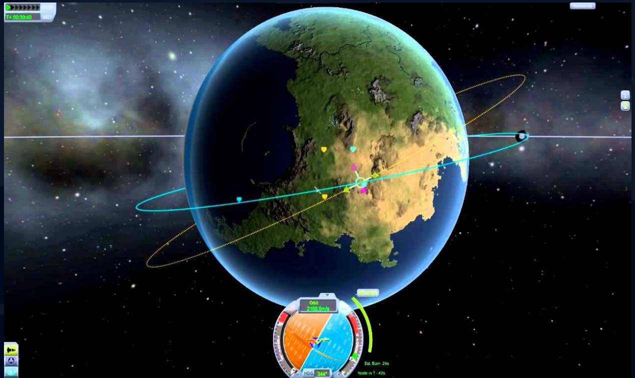
KERBAL
SPACE PROGRAM

Kerbal Space Program

1. What is it?
2. Why are we using it?
3. Limitations
4. Relevance with our project and learnings

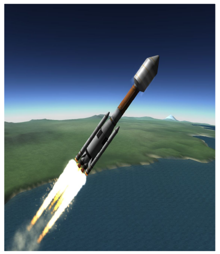
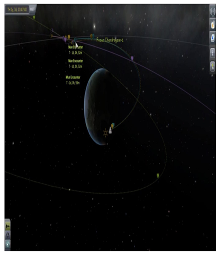
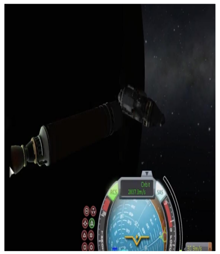
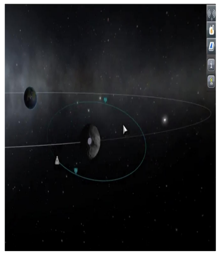
"For anyone who really wants to understand the fundamentals of spaceflight, Kerbal Space Program provides a surprisingly useful simulation that is extremely flexible, humorous and challenging."



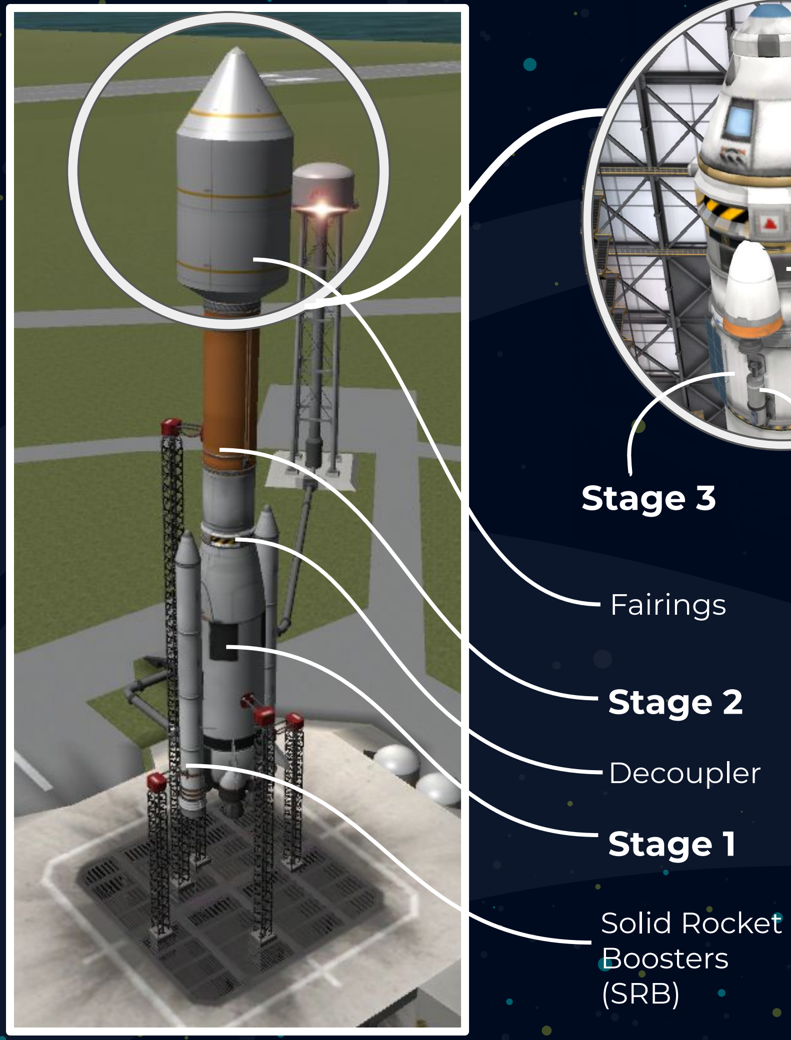


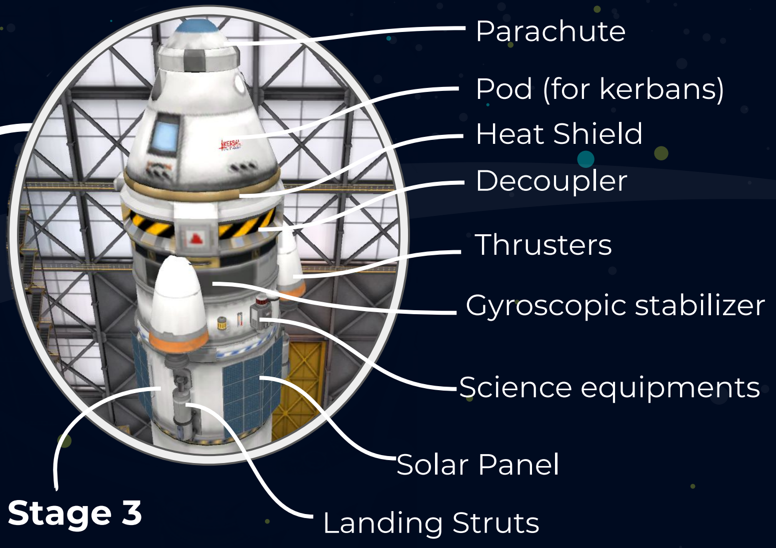
mis

MISSION DETAILS

Liftoff	SRB separation	Fairings removal	1st stage separation	2nd stage separation	Mun Landing	Returning home
The lift off went as expected and the rocket was carrying 3 crew members along with it	SRB separated brilliantly providing our rocket with the required velocity.	Fairings were removed as they were no longer needed and would act as dead weight if carried further	After the separation of the of first stage rocket was in low Kerbin orbit and the 2nd stage ensured trans-mun injection	2nd stage was used for retro-grade motion to slow down around mun and establish a trajectory for landing	3rd stage was used for landing on moon and return leaving the landing struts and unnecessary components behind.	3rd stage was jettisoned and established a lunar orbit and further trans kerbel injection.
						

Components of Rocket





Causes of failure of return to Kerbel

1. Insufficient fuel in later stages of rocket possibly because of uneven distribution.
2. Un-efficient trajectory design which caused loss of more fuel than expected.
3. Minor errors in theoretical and actual burn-out times.

Timeline of mission

00:00:00 - Liftoff
00:02:12 - Separation of SRB’s
00:03:33 - Removal of fairing
00:04:39 -Prograde burn at Kerbal Apoapsis
00:04:58 - Separation of 1st stage
00:04:59 - Ignition of 2nd stage
00:05:41 - Kerbin orbit insertion
00:08:13 - Prograde burn for trans-mun injection
00:09:23 - Separation of 2nd stage
00:09:24 - Orbital navigation Started
00:12:03 - Retrograde burn at Mun periapsis
00:25:00 - Mun Landing
00:25:41 - EVA started
00:26:05 - First steps on Mun
00:29:22 - 3rd Stage jettisoned
00:29:27 - Mun liftoff ignition
00:31:23 - Mun orbit insertion cutoff
00:40:03 - Transkerbin insertion ignition
00:40:09 - Transkerbin ignition cutoff

THANK YOU

AND ALWAYS REMEMBER:

"Cosmos
is Within Us!"