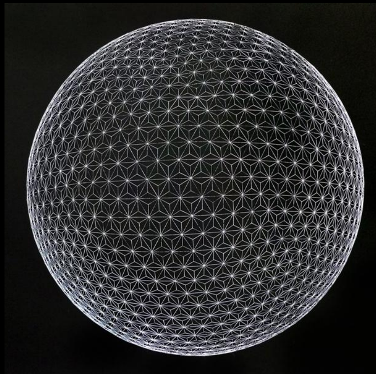
# Space Exploration

Introduction

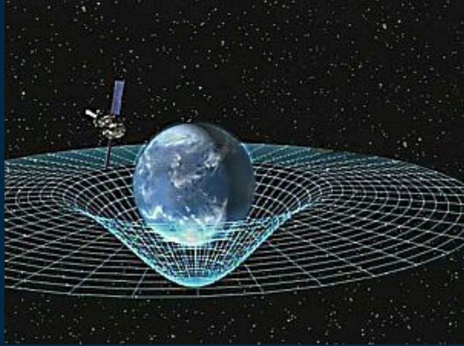
Mubashshir Uddin
Sunny K. Bhagat
Varun Singh



*"It all looked so easy when you did it on paper — where valves never froze, gyros never drifted, and rocket motors did not blow up in your face"*

~Milton W. Rosen

# Basics

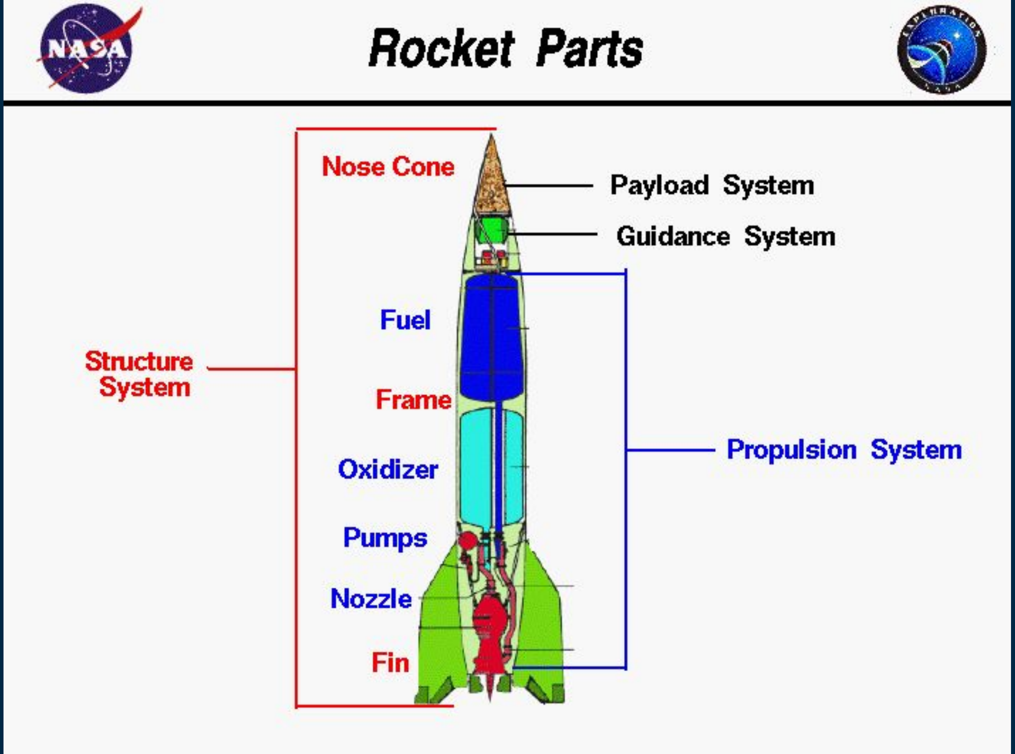


- What is a rocket?
- Why do you Need one?
- Why not use Planes instead of Rockets?
- Of course you can throw objects up, Why not use Giant Slingshots?
- What the rocket pushes against in the vacuum of space?
- Why Do all this!


We Are Wanders
Carl Sagan.

# Anatomy of a Rocket

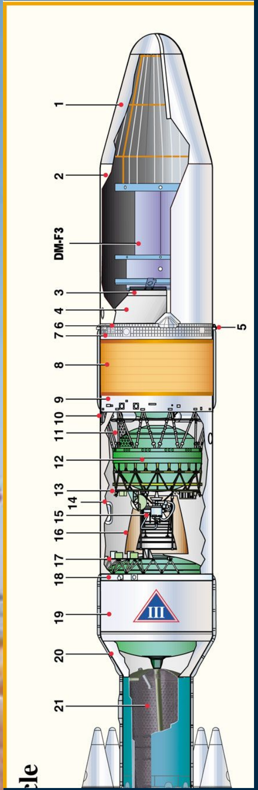
- Payload Bay
- Fairing
- Fins
- Body



# Fairing(Aeroshell)

- Why is the fairing used
- Material
- Shape
- Size
- Structure
- Cost to Mission

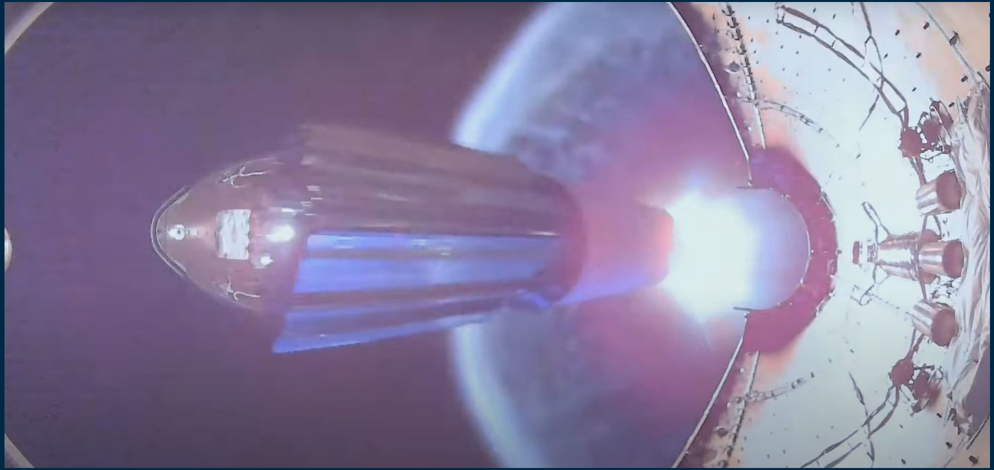
Sometimes Rockets carry Fairing and sometimes they don't...

# Fairing Mechanics

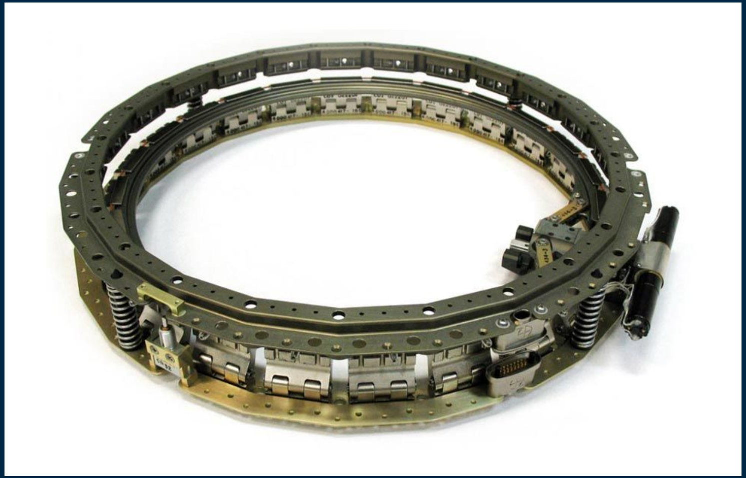
Role of fairing in a mission

- Protection in lower atmosphere
- Protection against biospheric contamination
- Protection against heat



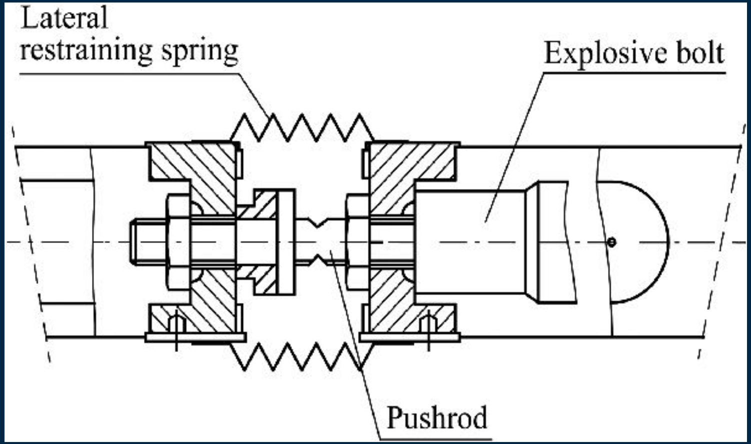
*“Once the launcher leaves the Earth’s atmosphere, approximately three minutes after liftoff, the fairing is jettisoned. This lightens the remaining launcher’s load as it loses approximately two tonnes of this no-longer required structure”* **~ESA**

# Separation Mechanisms



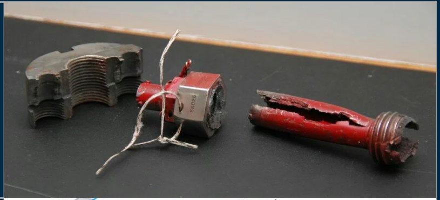
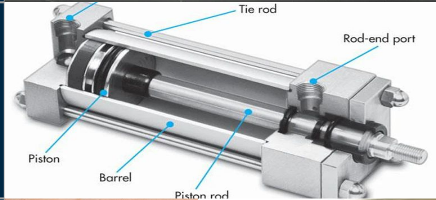
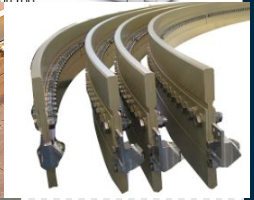
Motorised lightband

## Mechanical Separators



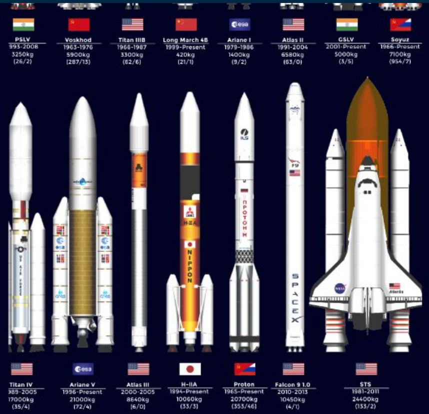

## Pyrotechnic Separators

# A lesson in Seperation

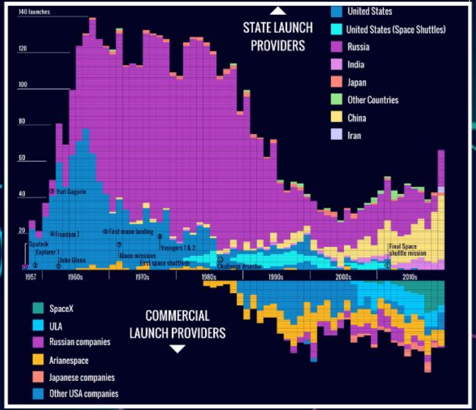
| | | | |
|---|---|---|---|
| Pyro Sep Bolts | Chemical energy | Atlas V |  |
| Thrust rail | Electrical energy | Saturn V |  |
| Frangible joint | Chemical energy | Orion MPCV |   |
| V-Clamp | Mechanical energy | Atlas V |   |

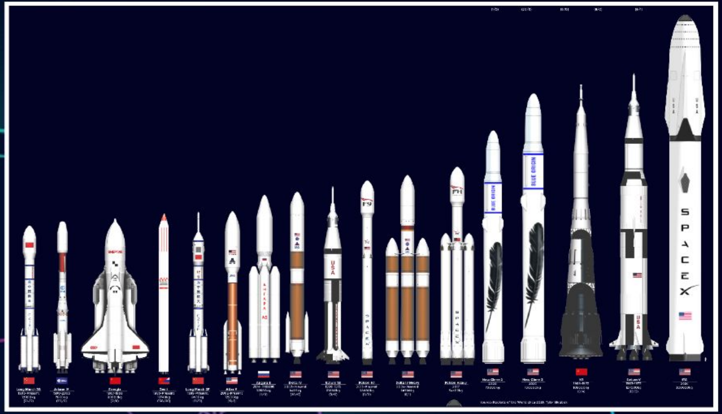
# Newer Innovation

# HISTORY OF ROCKETS




Man has been studying rocketry for more than 2,000 years.

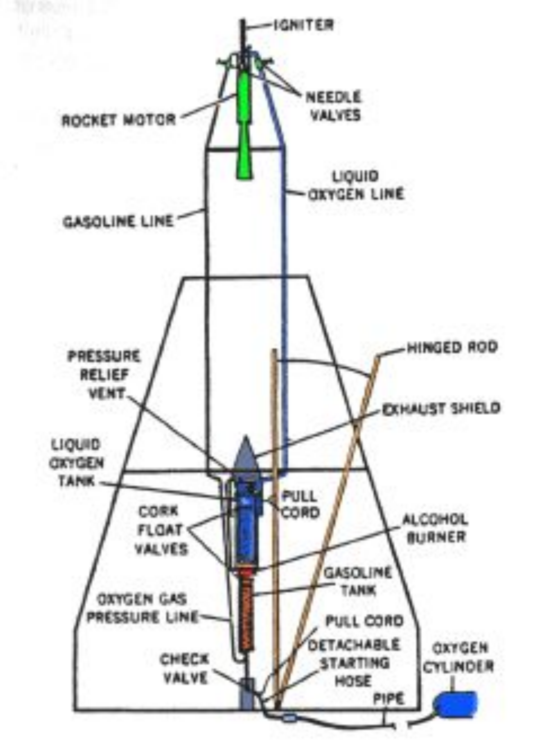


*“Every vision is a joke until the first man accomplishes it; once realized, it becomes a common place”*

~Robert H. Goddard

- In 1898, Tsiolkovsky proposed the idea of liquid propelled rockets. He is called the father of the modern astronautics.
- Early in the 20th century, an American, Robert H. Goddard, conducted practical experiments in rocketry.
- While working on solid-propellant rockets, Goddard became convinced that a rocket could be propelled better by liquid fuel.
- He achieved the first successful flight on March 1926, with oxygen and gasoline as fuel.



Dr. Goddard's 1926 Rocket

- Gasoline was used as a fuel and oxygen was used as an oxidiser.

But Hol’ Up!!

Pure Oxygen + Gasoline + ignition = 

- He figured out a way to keep the combustion chamber from exploding by making a revolutionary modification, which is still used in modern rocketry!!
- He used extremely cold liquid oxygen via a network of pipes to keep the combustion chamber cool and making rocket more efficient since less energy is lost as heat.

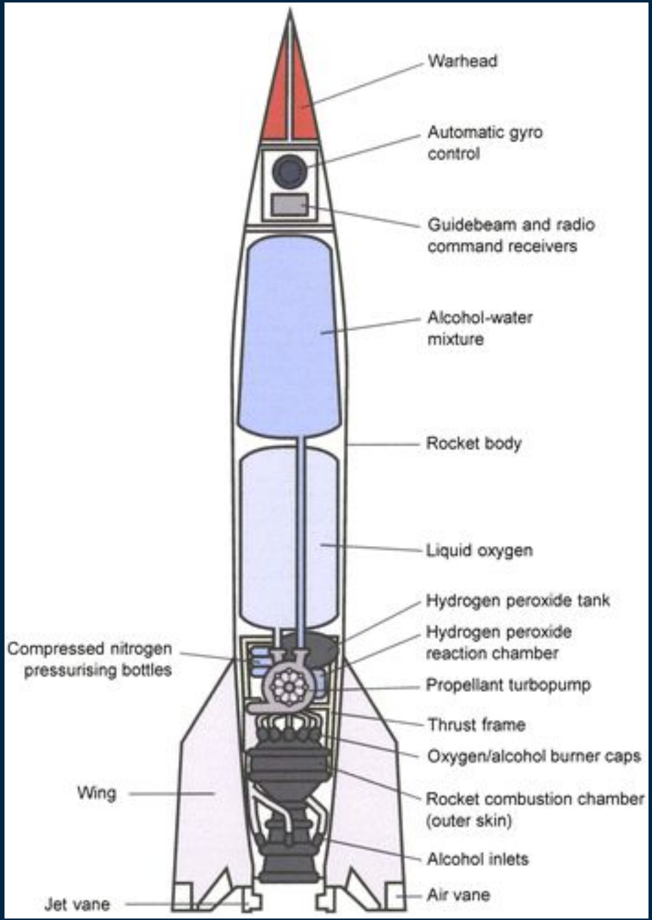
- The rocket's combustion chamber is the small cylinder at the top, the nozzle is visible beneath it.
- The fuel tank is directly beneath the nozzle and is protected from the motor's exhaust by an asbestos cone.
- Asbestos-wrapped aluminum tubes connect the motor to the tanks, providing both support and fuel transport.
- Asbestos is a natural fiber which provided thermal insulation but is very dangerous.
- But this design was not stable and the combustion chamber and the nozzle was later put at the bottom

So the Big question. Why was the earlier design rejected?

*“One good test is worth a thousand expert opinions”*

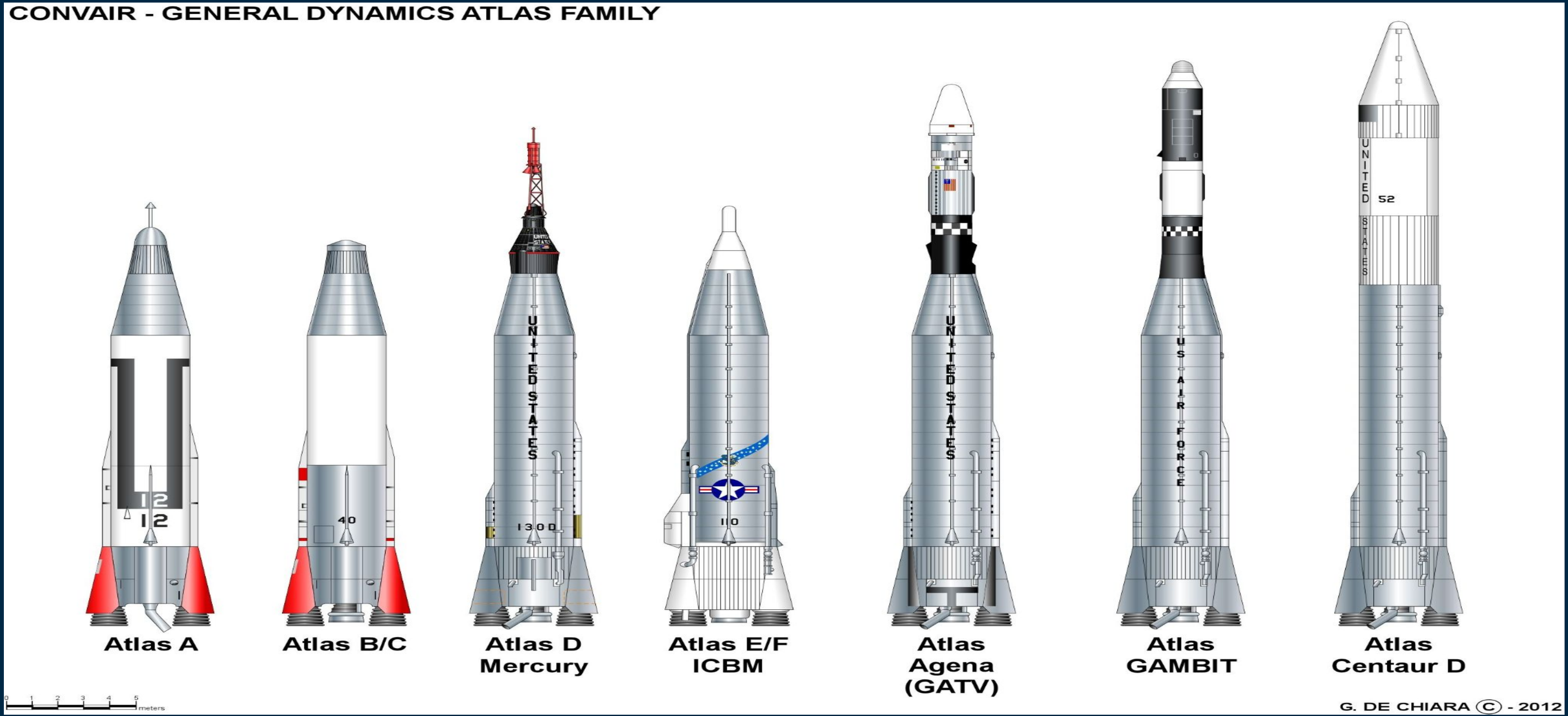
~Wernher von Braun

- He was the pioneer of the famous V-2 rocket.
- It used 75% Ethanol/ 25% water(as coolant) mixture for fuel and liquid oxygen as an oxidiser.
- The pump was driven by a steam engine which carried fuel and oxygen to the combustion chamber.
- Sodium permanganate was used as a catalyst to make steam from hydrogen peroxide.



# ATLAS (ROCKET FAMILY)

- It is a family of US missiles and space launch vehicles that originated from SM-65 Atlas (first ICBM).
- It was a liquid propellant rocket burning RP-1 fuel with liquid oxygen configured in a parallel staging design.
- RP is shorthand for rocket propellant which is nothing but highly refined kerosene.
- The family consists of rockets (A-G)
- More powerful and better designs came in future, like Atlas I, II, etc.




2 engines

3 engines, so better

More powerful engines

Used as a war missile

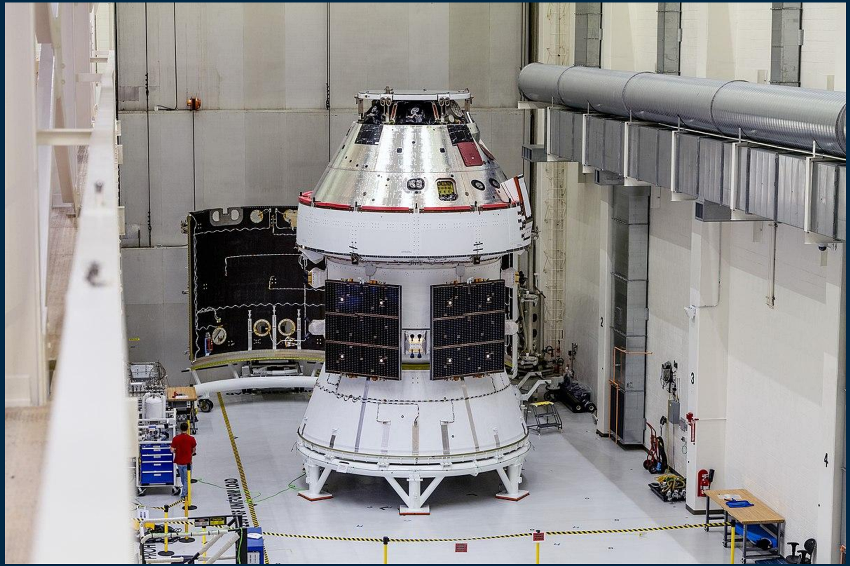
Used hypergolic fuels

Used to carry observation satellite

More powerful. 1st use of $H_2$ engine in space

# ORION PROGRAM

- NASA's Orion spacecraft is built to take humans farther than they've ever gone before. Orion serves the purpose of exploration vehicle that will carry the crew to space, provide emergency abort capability, sustain the crew during the space travel, and provide safe re-entry from deep space return velocities.

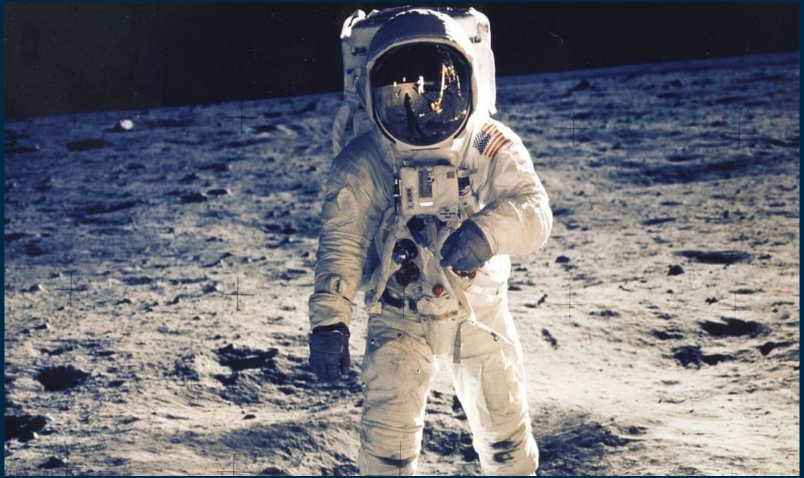


# CONSTELLATION PROGRAM

- It is a cancelled crewed spaceflight program developed by NASA, from 2005 to 2009. The major goals of the program were "completion of the International Space Station" and a "return to the Moon no later than 2020" with a crewed flight to the planet Mars as the ultimate goal.
- However it got cancelled. The main concern was that the program was excessively costly.

# APOLLO PROGRAM

- It was the third human spaceflight program which succeeded in landing the first humans on moon from 1969-1972.
- Several planned missions of the Apollo crewed Moon landing program of the 1960s and 1970s were canceled for a variety of reasons, including changes in technical direction, the Apollo 1 fire, hardware delays, and budget limitations.
- It is highly recommended to watch Apollo 11 documentary!

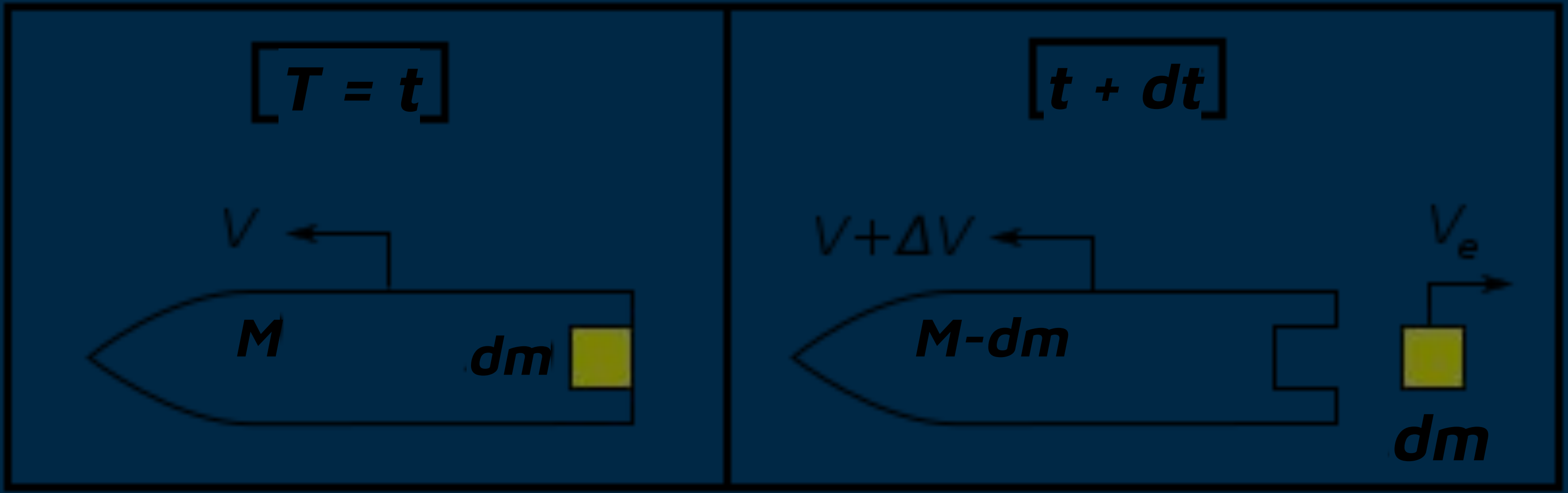


# OK!! A BREAK!!

# [Let’s go something Mathematical]

# THE ROCKET EQUATIONS

# Let's start with something called "Ideality"!!




**[SITUATION]**

**NOTE : "M" is total mass of Rocket**

# SOME RIGOROUS DERIVATIONS :

Two Major Considerations :

1) Mass Conservation
2) Momentum conservation-------> Birthway for Rocket Equation :-:

## (MASS CONSERVATION)

→ Well valid and is considered to be universal identity :

→ @T=t and T= t+dt ; **mass** is "M" and "(M-dM)+dM" for **entire system** respectively......and you can see why it's universal !!

**"M = (M-dM) + dM"**

# Continued....

**<u>MOMENTUM CONSERVATION</u>**

@T=t ; Momentum = M.[v]---------------> (1)

@T=t+dt ; Momentum = (M-dM).[v+dv] - dM*[V_e]--------> (2)

So; By Momentum Conservation Equate (1) and(2)

*NOTE* : Till now we had written equations in 3D but we are actually interested in NUMBERS (Idealistically) so Converting the vector eqn. Into 1-D problem.

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**"M.v = (M-dM).(v+dv) - dM*(V_e)"**

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**P.S. : [-] notations are for vectorial notations.**

# CONTINUED......

Let's try to simplify previous slides MOMENTUM CONSERVATION equation a little :

$\rightarrow M.v = M.v + M.dv + dM.v + \cancel{dM.dv} - dM.V_e \rightarrow$ (3)

$\rightarrow M.dv + dM.v - dM.V_e = 0 \rightarrow$ (4)

$\rightarrow M.dv + dM.v - dM\,.(v + v_{ex}) = 0 \rightarrow$ (5) [*Note : $V_e = v + v_e$ at $t+dt$*]

$\rightarrow M.dv - dM.v_{ex} = 0 \rightarrow$ (6)

$$\mathbf{M.(dv/dt) = (dM/dt).v_{ex}} \rightarrow (7)$$

$$M.(dv/dt) = (dM/dt).v\_ex \rightarrow (7)$$

# The Initial rigorous rocket equation

# [MOST IDEAL ASSUMPTION]

**P.S. : Sign Conventionally; v_ex is already embedded with a minus sign in it; so basically it's [--Exhaust Velocity = v_ex]**

<---------------------->

# Can SOLVE Further & Let's do that :

V_ex  is somewhat constant at the steady state arrival hence;

$\rightarrow \int (dV) = v\_ex \int ((1/M).\, dM) \rightarrow (8)$

$\rightarrow$ NOTE : Limits from v to v+Δv (L.H.S.) and $M_o$ to $M_f$ ; also replace v_ex = (-)V_exhaust and we get ;

$$\Delta v = V\_exhaust.\ \ln (M_o / M_f) \rightarrow (9)$$

# CONTINUED...

$$M_f = M_o \exp(-\Delta v/V\_exhaust) \rightarrow (10)$$

P.S. : $M_o$=M and $M_f$ = M- ΔM; so :

$$(M- \Delta M)/M = \exp(-\Delta v/V\_exhaust) \rightarrow (11)$$

**Hence;**

$$\Delta M/M = 1 - \exp(-\Delta v/V\_exhaust) \rightarrow (12)$$

THINK : What is this ΔM ??

# FEW QUESTIONS FROM OUR SIDE :

(1) Did you find where was the Thrust force in entire derivation and Yeah, What parameters it's dependent on ??
(2) What is the domain for the equations you used? Is it always valid ? Umm…Think !!
(3) So; Can you tell me sometimes in idealistic domain like HOW much is the propellant required to be loaded?
(4) Great Derivation but what about if we try implementing "General Relativistic Models" ??
(5) What about Specific Impulse for Idealistic System? Any Idea?
(6) REAL WORLD Is Different!! Any Comments :P

# SPECIFIC IMPULSE [Efficiency]

→ Specific Impulse is actually termed in ROCKET SCIENCE to be "efficient use of propellants in rockets/spacecrafts and fuels in jet engines".

→ Some Formulation :

$$I_{sp} = \lim (\Delta t \to 0) \{(F_{thrust}.\Delta t)/(m_p.g_o)\} \to (13)$$

→ Check By Definition of Impulse.

→ $I_{sp} = F_{thrust}/[(dm/dt).g_o] \to (14)$

→ $\Delta v = I_{sp}.g_o.\ln (M_o / M_f) \to (15)$ [Change in velocity in terms of specific impulse]. Note :[ $\int (F_{thrust})dt = I$ *and to make it specific just divide by* $m_p$ ]

NOW IT’s YOUR TURN :P

QUESTIONS??

# THANKS

LET's CONTINUE TOMORROW WITH MORE INTERESTING STUFFS AND FEW MORE CALCULATIONS