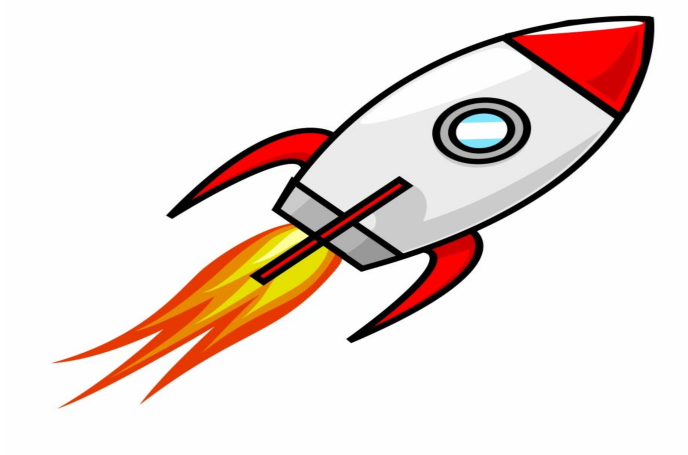
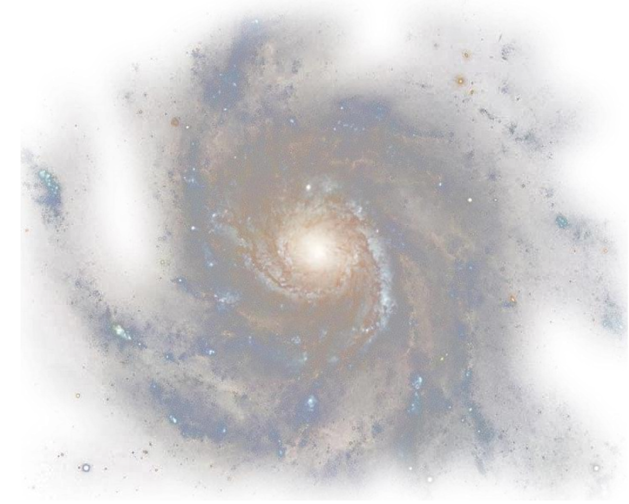


What Propulsion Methods are utilized in Space?



By Sanskar Muley

Abstract

In this research poster we are going to explore the effects of two propulsion methods used in space. In addition to this, we will be looking at some of NASA's planned deep space propulsion techniques that are yet to be used. As part of this research, graphs will be analysed to discuss any correlations shown. The two predominant methods that we will be looking at are "Electro thermal" and "Chemical Rockets". In order to contemplate these techniques further, their benefits and drawbacks will also be investigated. Therefore, this would allow the scientific community to make a clear decision regarding their use of propulsion methods on the subsequent space mission.

How does Propulsion work in Space?

Rockets and engines adhere to Newton's third law. When a rocket shoots fuel out one end, this propels the rocket forward without any air. In order to provide enough thrust, more fuel is required which adds to the cost. Instead of any propulsion, many spacecraft use the plant's gravity to provide a speed boost. As a result this shortens the time of flight and conserves fuel.

In addition to that, this leads on to the principle of conservation of momentum. If you have hot gas propelled backwards then you have must something propelling forwards in order to conserve momentum.

Rocket Equation

To correctly compute the change in speed, we need to use calculus.

Here's the answer written in two ways:

$$\Delta v = c_e \ln\left(1 + \frac{m_{fuel}}{m_{rocket}}\right) \qquad \frac{m_{fuel}}{m_{rocket}} = e^{\left(\frac{\Delta v}{c_e}\right)} - 1$$

m_{fuel} = fuel mass
m_{rocket} = payload + structure mass
c_e = exhaust speed
Δv = change in spacecraft's speed

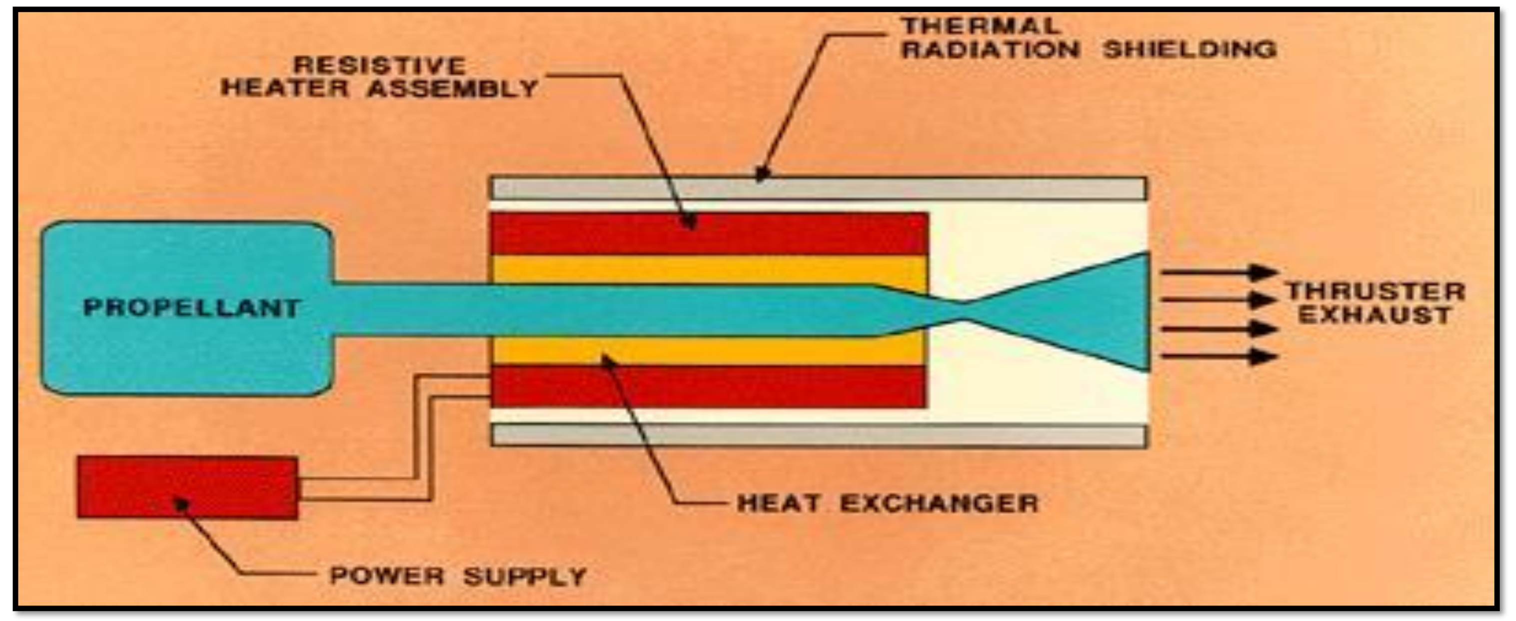
Analysis of Elctro thermal and Chemical Rockets

What is Electro-thermal propulsion?

These engines use electrical energy to create a super-heated plasma and fire it through a supersonic nozzle to generate thrust.

These kinds of engines have been used in Russian satellites since the 1970s and by Lockheed Martin A2100 satellites, using hydrazine as fuel. extremely low, meaning their only likely use will be to orient satellites in orbit.

These engines are efficient, but the thrust they generate is less



Resistojet v Arcjet

Two basic types of electro thermal thruster are in use today: the resistojet and the arcjet. In both, material characteristics limit the effective exhaust velocity to values similar to those of chemical rockets. In the resistojet propulsion a propellant is injected into the resistojet assembly, heated by a power supply and radiative heat transfer, and then expelled through a compressive exhaust nozzle. Electro thermal resistojet has an approximate 150 to 700 Isp range, efficiency levels between 35% and 90%, and thrust between 5 and 5,000 mN.

Whereas on the other hand the arcjet relies upon a centrally located cathode surrounded by an anode; a high voltage electric field is generated between the cathode and anode, while the propellant is injected between the two electrodes. Comparatively large Isp ranges, between 280 and 2,300, give significant advantages over resistojet propulsion methods, while a comparable thrust range of 50 to 5,000 mN further indicates the viability of the arcjet propulsion system. However, resistojet thruster system provides a significantly higher energy conversion efficiency range, of approximately 35% to 90% compared with the arcjet efficiency range of 30% to 50%. Additionally, the arcjet is prone to electrode erosion and massive power

What are chemical Rockets?

Chemical propulsion is propulsion in which the thrust is provided by the product of a chemical reaction, usually burning (or oxidizing) a fuel. Generally, the reaction also releases heat which will warm up the product. Since when you heat a substance it expands (try this with a crayon and a magnifying glass), the heat produced by the chemical reaction heats up the product, making it expand. As it expands, it gets too big for the reaction chamber and pushes out the back of the rocket. This provides thrust for the rocket. There are three main types of chemical rockets; solid propellant, liquid propellant, hybrid rockets.

Solid propellant

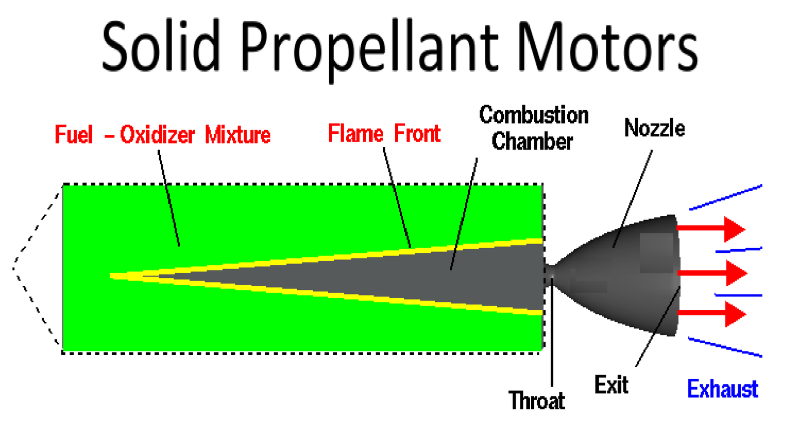
Fuel and oxidizer are mixed together to form a grain. This mixture is ignited to start the burn leading to an exhaust speed of 2.8 km/s. Some of the benefits include ; very simple design, long storage times, low costs whereas the drawback are impossible to turn off and a low exhaust speed.

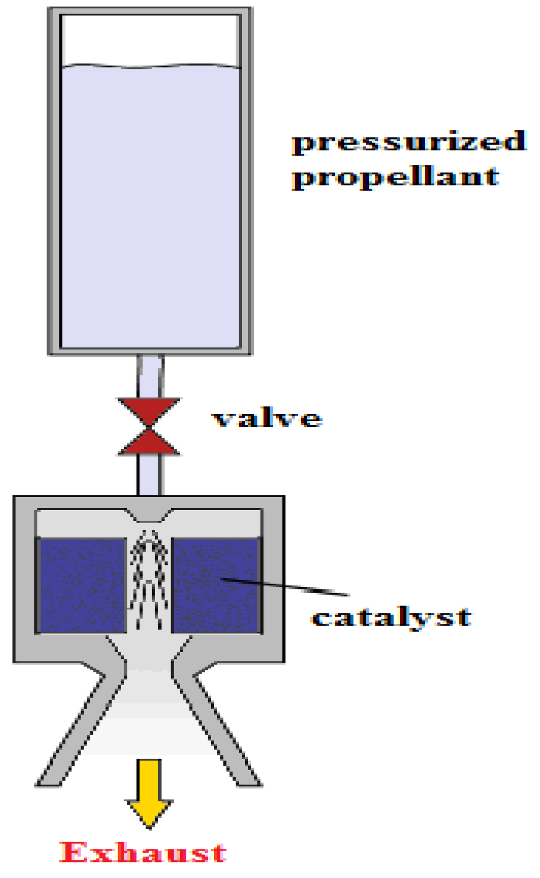
Liquid Propellant

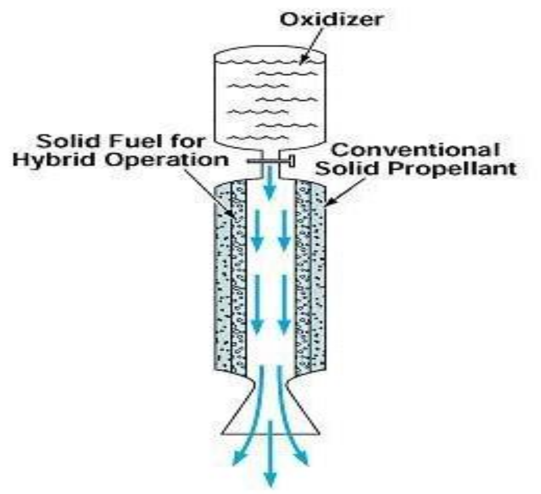
A monopropellant is passed through a catalyst. The catalyst causes a reaction which releases heat and therefore the heated products of this reaction are expelled through a nozzle, thus generating thrust. This result in an exhaust speed of 2.3 km/s

Hybrid Rockets

A solid fuel is used but a liquid oxidizer is pumped into the thrust chamber where the solid fuel grain resides. A combustion reaction occurs heating the reactants, which are expelled through a nozzle







Benefits and Drawbacks of Chemical Rockets Propulsion?

Benefits:
- Simple design
- Compact
- Reliable
- Long storage times
- Low costs
- Can turn off liquid propellant
- Not a lot of plumbing
- Simple to use
- Safe propellants

Drawbacks:
- Impossible to turn off
- Low exhaust speed
- Air pockets can explode which ruptures the casing
- Most fuels are toxic
- Low thrust
- Catalyst lifetime issues
- Cryogenic systems often needed
- Difficulty storing
- Complex structures

Mission	Required Δv*	$m_{initial} / m_{payload}$ (c_e = 5 km/s)
Earth orbit to Mars and return	14 km/s	16
Earth orbit to Mercury and return	31 km/s	148
Earth orbit to Jupiter and return	64 km/s	$3.6\text{x}10^5$
Earth orbit to Saturn and return	110 km/s	$3.6\text{x}10^9$

What are NASA's planned propulsion methods?

Continuous Fission:
Fusion-powered rockets effectively try to recreate the power of the Sun by super-heating fuel to hundreds of millions of degrees until the atomic nuclei fuse, and generate even more energy. However, this idea requires a lot of research and development as well as funding.

Antimatter:
Antimatter also has the highest energy density of any known substance. And if used as fuel, it could provide by far the most efficient propulsion system, with up to 40% of the fuel's mass energy being converted directly into thrust.

Plasma Propulsion Engine
This includes a non-reactive fuel, magnetic currents and electrical potentials which accelerate ions in a plasma to generate thrust.

Thermal Fission:
A fission reactor could heat a propellant to extremely high temperatures to generate thrust.