DEPARTMENT OF AEROSPACE ENGINEERING

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UNIT VI - FUNDAMENTALS OF ROCKET PROPULSION

Chemical Rocket Propulsion System Types and Applications

Chemical propellants, like fuel and an oxidizer, create energy through combustion. This energy heats gases to very insane high temperatures (around 2500 to 4100 degrees Celsius or 4500 to 7400 degrees Fahrenheit). These hot gases are then pushed out through a supersonic nozzle, making them move fast (around 1800 to 4300 meters per second or 5900 to 14,100 feet per second).

Types of propellants include:

Liquid propellant rocket engines use propellants stored as liquids that are fed under pressure from tanks into a thrust chamber.

- The bipropellant consists of a liquid oxidizer (e.g., liquid oxygen) and a liquid fuel (e.g., kerosene).

- A monopropellant is a single liquid that decomposes into hot gases when properly catalyzed.

In a solid propellant rocket motor, all the ingredients needed for burning are already stored inside a combustion chamber. The solid propellant, called the grain, contains everything needed for burning. When ignited, it burns smoothly at a set rate on its surfaces. As it burns, the internal

cavity expands, and hot gases flow through a supersonic nozzle to create thrust. The burning process continues in an organized way until almost all the propellant is used up.

Gaseous propellant rocket engines use a stored high-pressure gas, such as air, nitrogen, or helium, as working fluid:

- **Cold gas thrusters** were used in many early space vehicles for low-thrust maneuvers and attitude-control systems.

- In a **Warm gas propellant rocket propulsion,** the gas is heated with electrical energy or by the combustion of certain monopropellants in a chamber to improve their performance.

Hybrid propellant rocket propulsion systems use both liquid and solid propellant storage.

Nuclear Rocket Engines

These are special rocket engines that use liquid propellant, but instead of burning chemicals, they get their power from a single nuclear reactor. Nuclear energy originates in the transformation of mass within atomic nuclei and is generated either by fission or fusion.

Rocket engines that use nuclear power have been explored but concerns about accidents spreading radioactive materials on Earth led to the termination of this work. It's unlikely that nuclear rocket engines will be developed in the next few decades.

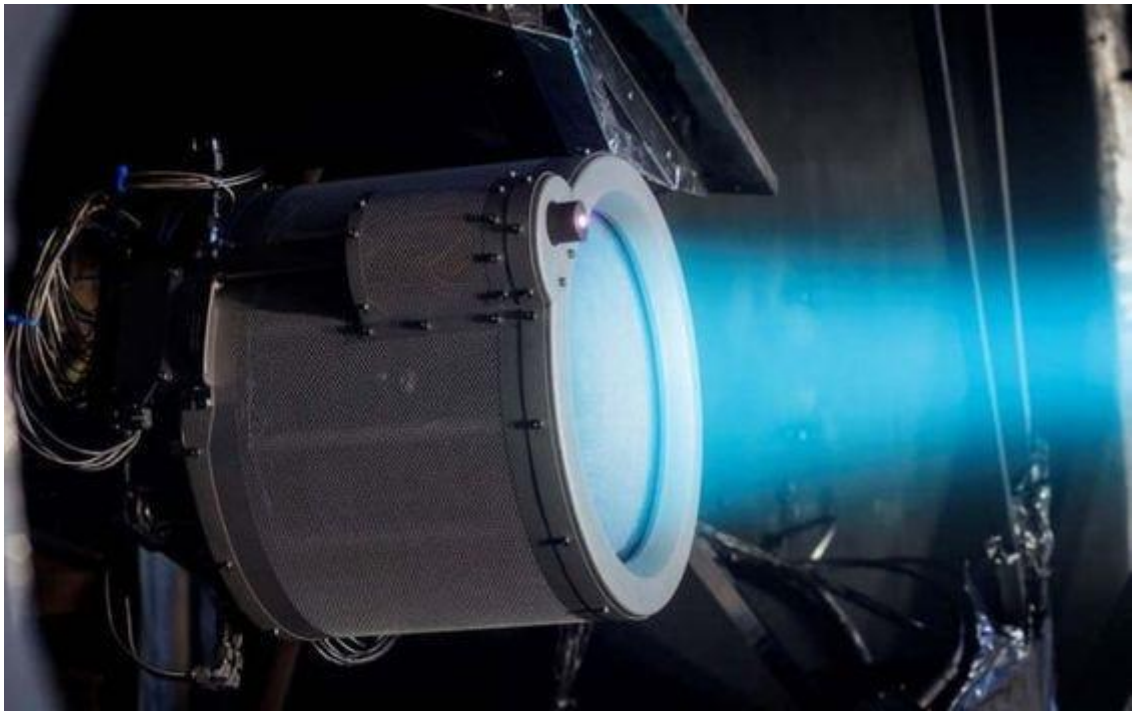
Despite the discontinuation of nuclear fission rocket engines, research on nuclear fusion rocket engines continues. Lockheed Martin is a leading company in this exciting field.


NERVA

Electric Rocket Propulsion

Electric propulsion offers good thrust with less propellant but is limited by current power supplies. It's unsuitable for Earth launches due to massive and less efficient power sources, making it better for spacecraft where power can be shared with other systems.

Unlike chemical propulsion, electric propulsion uses energy sources like nuclear power, solar radiation, or batteries that are separate from the propellant being used. It is used in spacecraft with longer mission durations and low thrust levels for tasks like orbit maintenance.



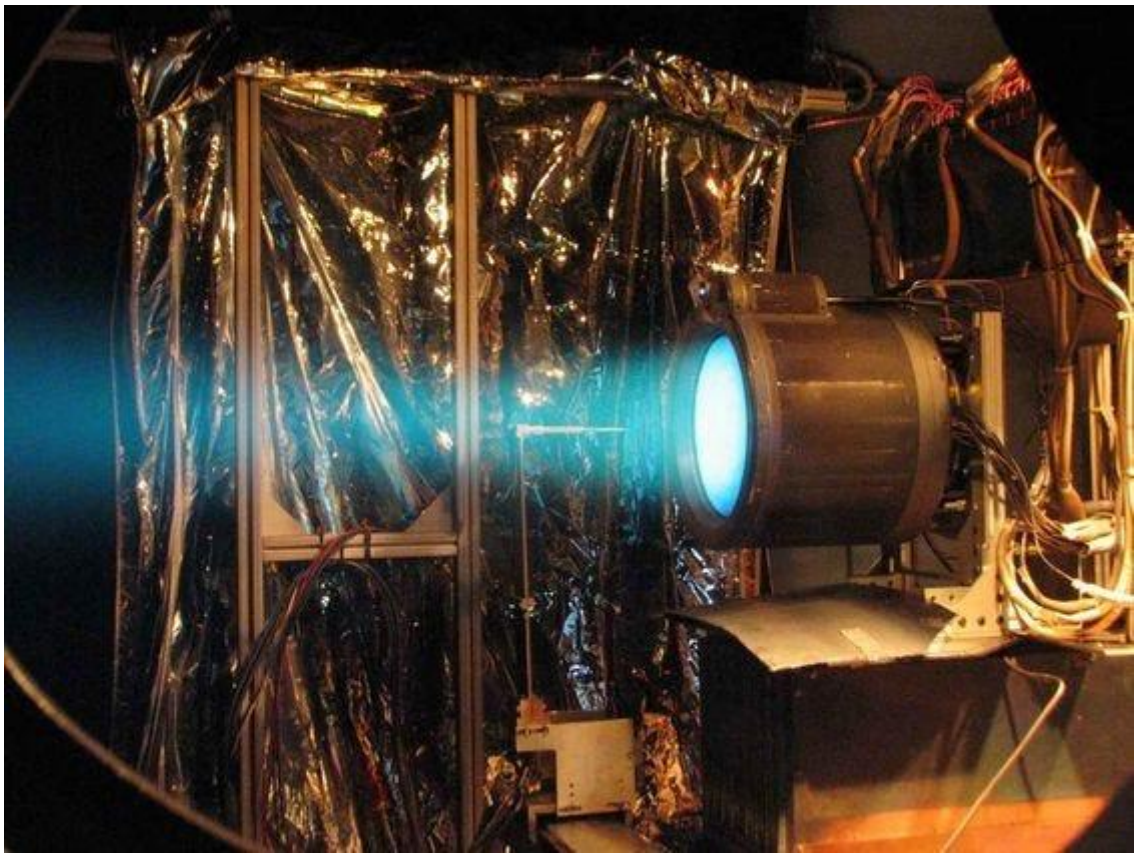
Types:

Electrothermal rocket propulsion is similar to the liquid-propellant chemical rockets we talked about earlier. In electrothermal thrusters, a propellant is heated using electricity (using solid resistors or electric arcs). Then, the hot gas is pushed out through a supersonic nozzle to create thrust.

These thrusters have a thrust range from 0.01 to 0.5 N and can reach exhaust velocities of 1000 to 7800 m/s. They use different materials like ammonium, hydrogen, nitrogen, or hydrazine for the propellant.

Electrostatic or ion propulsion thrusters and **electromagnetic or magneto plasma thrusters:** Here, no thermodynamic gas expansion in a nozzle is necessary, and they both work in a vacuum.

In an ion thruster, a special gas like xenon is turned into ions (atoms missing some electrons). Then, using electric fields, these ions are given super high speeds (from 2000 to 60,000 meters per second!). After that, to keep things balanced, the ions are made neutral again by adding back the missing electrons to prevent the buildup of a "space charge" on the vehicle.



In electromagnetic thrusters, a plasma (a special kind of energized gas with ions, electrons, and neutral particles) is accelerated using electric currents and magnetic fields. This plasma is then ejected at really high speeds (from 1000 to 75,000 meters per second!).

Solar Rocket Propulsion

One idea is the solar thermal rocket. It uses big mirrors or lenses to concentrate the sun's rays onto a special receiver made of high-temperature metal. The metal heats a working fluid like

hydrogen, and then the hot gas is used to produce thrust. This type of rocket can perform better than chemical rockets and has low thrust levels.

The big mirrors must always face the sun, so adjustments are needed if the spacecraft orbits around planets. These rockets work best in space, not in the atmosphere. One such system was

tested in 2012, but it's not widely used yet due to some challenges like lightweight mirror structures and hydrogen storage.

The solar sail is like a big shiny mirror that reflects sunlight to move. It gets its power from the sun, but it can only go away from the sun. Some ideas have been suggested to use lasers or microwaves from Earth to give it energy, but they haven't been tested yet.

Solar radiation may originate from other sources than the sun like:

- Transmission of energy by ground-based microwaves.
- Laser beams.