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# Electrically Powered Spacecraft Propulsion

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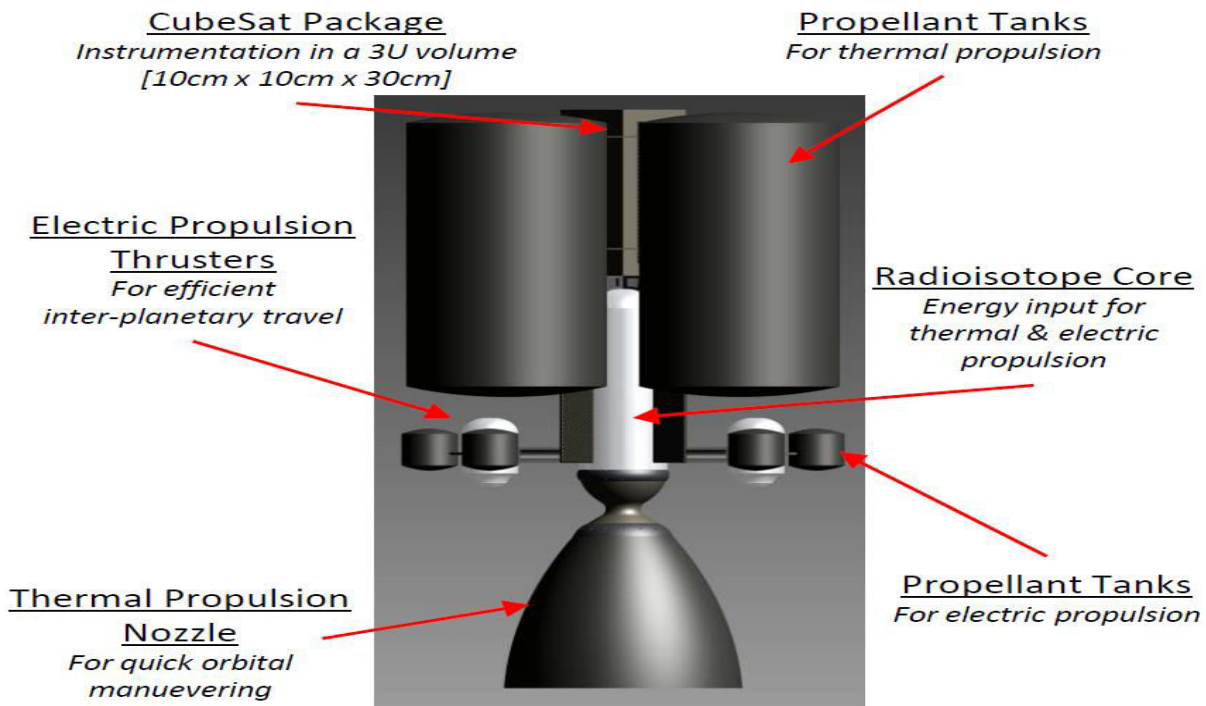
**ABSTRACT:** An electrically powered spacecraft propulsion system uses electrical energy to change the velocity of a spacecraft. Most of these kinds of spacecraft propulsion systems work by electrically expelling propellant (reaction mass) at high speed, but electrodynamic tethers work by interacting with a planet's magnetic field. Electric thrusters typically use much less propellant than chemical rockets because they have a higher exhaust speed (operate at a higher specific impulse) than chemical rockets. Due to limited electric power the thrust is much weaker compared to chemical rockets, but electric propulsion can provide a small thrust for a long time. Electric propulsion can achieve high speeds over long periods and thus can work better than chemical rockets for some deep space missions. Electric propulsion is now a mature and widely used technology on spacecraft. Russian satellites have used electric propulsion for decades and it is predicted that by 2020, half of all new satellites will carry full electric propulsion. As of 2013, over 200 spacecraft operated throughout the Solar System use electric propulsion for station keeping, orbit raising, or primary propulsion. In the future, the most advanced electric thrusters may be able to impart a Delta-v of 100 km/s, which is enough to take a spacecraft to the outer planets of the Solar System (with nuclear power), but is insufficient for interstellar travel. An electric rocket with an external power source (transmissible through laser on the photovoltaic panels) has a theoretical possibility for flight. Thus, through electrical propeller the weight and fuel problem can be solved easily in efficient way economically.

**KEYWORDS:** Ion thrust, Solar propulsion, Electromagnetic energy, spacecraft propulsion.

## I.INTRODUCTION

Spacecraft propulsion is any method used to accelerate spacecraft and artificial satellites. Space propulsion or in-space propulsion exclusively deals with propulsion systems used in the vacuum of space and should not be confused with launch vehicles. Several methods, both pragmatic and hypothetical, have been developed each having its own drawbacks and advantages. Propulsion means to add speed or acceleration to an object, by an engine or other similar device. The word 'propulsion' can be used with many other words (such as jet, rocket, spacecraft) to become-'jet propulsion', 'rocket propulsion', or 'space craft propulsion' etc. Spacecraft propulsion is used to change the velocity of spacecraft and artificial satellites. There are many different methods. Each method has drawbacks and advantages, and spacecraft propulsion is an active area of research. Most spacecraft today are propelled by heating the reaction mass and allowing it to EJECT out from the back/rear of the vehicle. This sort of engine is called a rocket engine.

Most satellites have simple reliable chemical thrusters (often monopropellant rockets) or resist jet rockets for orbital station-keeping and some use momentum wheels for attitude control. Soviet bloc satellites have used electric propulsion for decades, and newer Western geo-orbiting spacecraft are starting to use them for north-south station-keeping and orbit rising. Interplanetary vehicles mostly use chemical rockets as well, although a few have used Ion thrusters and Hall Effect thrusters (two different types of electric propulsion) to great success.



*\*Artist concept of proposed propulsion system*

Fig 1:- Concept of propulsion system

## II. TYPES OF ELECTRIC PROPULSION

**Ion and plasma drives** : This type of rocket-like reaction engine uses electric energy to obtain thrust from propellant carried with the vehicle. Unlike rocket engines, these kinds of engines do not necessarily have rocket nozzles, and thus many types are not considered true rockets. Electric propulsion thrusters for spacecraft may be grouped into three families based on the type of force used to accelerate the ions of the plasma:

**Electrostatic** : If the acceleration is caused mainly by the Coulomb force (i.e. application of a static electric field in the direction of the acceleration) the device is considered electrostatic.

**Electro thermal**: The electro thermal category groups the devices where electromagnetic fields are used to generate a plasma to increase the temperature of the bulk propellant. The thermal energy imparted to the propellant gas is then converted into kinetic energy by a nozzle of either solid material or magnetic fields. Low molecular weight gases (e.g. hydrogen, helium, ammonia) are preferred propellants for this kind of system. An electro thermal engine uses a nozzle to convert the heat of a gas into linear motion in its molecules, so it is a true rocket even though the energy producing the heat comes from an external source. Performance of electro thermal systems in terms of specific impulse (Isp) is somewhat modest (500 to ~1000 seconds), but exceeds that of cold gas thrusters, monopropellant rockets, and even most bipropellant rockets. In the USSR, electro thermal engines were used since 1971; the Soviet "Meteor-3", "Meteor-Prroda", "Resurs -O" satellite series and the Russian "Electro" satellite are equipped with them.[18] Electrothermal systems by Aerojet (MR-510) are currently used on Lockheed Martin A2100 satellites using hydrazine as a propellant.

**Electromagnetic** : If ions are accelerated either by the Lorentz force or by the effect of electromagnetic fields where the electric field is not in the direction of the acceleration, the device is considered electromagnetic..

### Non-ion drives

**Photonic**: Photonic drive does not expel matter for reaction thrust, only photons. See Laser propulsion, Photonic Laser Thruster, Photon rocket.

**Electrodynamics tether**: Electrodynamics tethers are long conducting wires, such as one deployed from a tether satellite, which can operate on electromagnetic principles as generators, by converting their kinetic energy to electric energy, or as motors, converting electric energy to kinetic energy.[19] Electric potential is generated across a conductive tether by its motion through the Earth's magnetic field. The choice of the metal conductor to be used in an





electrodynamics tether is determined by a variety of factors. Primary factors usually include high electrical conductivity, and low density. Secondary factors, depending on the application, include cost, strength, and melting point

### III. SUBSTITUTE FOR ELECTRICAL PROPULSION: SOLAR PROPULSION SYSTEM

Solar electric propulsion (SEP) refers to the combination of solar cells and an electric thrusters to propel a spacecraft through outer space. This technology has been exploited in a variety of spacecraft by the European Space Agency, the Japanese Space Agency, Indian Space Research Organization and NASA. SEP has a significantly higher specific impulse than normal chemical rockets, thus requiring less propellant mass to be launched with a spacecraft and it has been evaluated for missions to Mars. Solar electric propulsion combines solar panels on spacecraft and one or more electric thrusters, used in tandem. There are many different types of electric thrusters, including a so-called ion thruster, a term that is often incorrectly used to describe all types of electric thrusters.

It is also possible to generate electricity from the Sun without using photovoltaic panels, such as with solar concentrators and a Sterling engine. A 50-kilowatt SEP system was studied in the 2010s for a mission to an asteroid. In February 2012 NASA awarded a contract for a Solar Electric Propulsion Flight System. An example of work on this type of technology is Advanced Electric Propulsion System. The NASA Solar Technology Application Readiness (NSTAR) ion engine has been used with photovoltaic solar panels, which was tested on the Deep Space 1 mission along with Solar Concentrator Arrays (Launched in 1998 as part of the New Millennium Program). SEP has been studied as a technology for a mission to Mars. The high specific impulse of the ion engines could lower overall mass and avoid having to use nuclear technology for power when coupled with solar panels. A 1998 study for SEP for a human mission suggests that a human-sized spacecraft would need 600 to 800 kilowatts of electrical power coupled with ion engines with a specific impulse of 2000 to 2500 seconds.

**Ion Thruster :** An ion thruster or ion drive is a form of electric propulsion used for spacecraft propulsion. It creates thrust by accelerating ion by using electricity. An ion thruster ionizes a neutral gas by extracting some electrons out of atoms, creating a cloud of positive ions. These ion thrusters rely mainly on electrostatics as ions are accelerated by the Coulomb force along an electric field. Temporarily stored electrons are finally re-injected by a neutralizer in the cloud of ions after it has passed through the electrostatic grid, so the gas becomes neutral again and can freely disperse in space without any further electrical interaction with the thruster. Electromagnetic thrusters on the contrary use the Lorentz force to accelerate all species (free electrons as well as positive and negative ions) in the same direction whatever their electric charge, and are specifically referred as plasma propulsion engines, where the electric field is not in the direction of the acceleration.

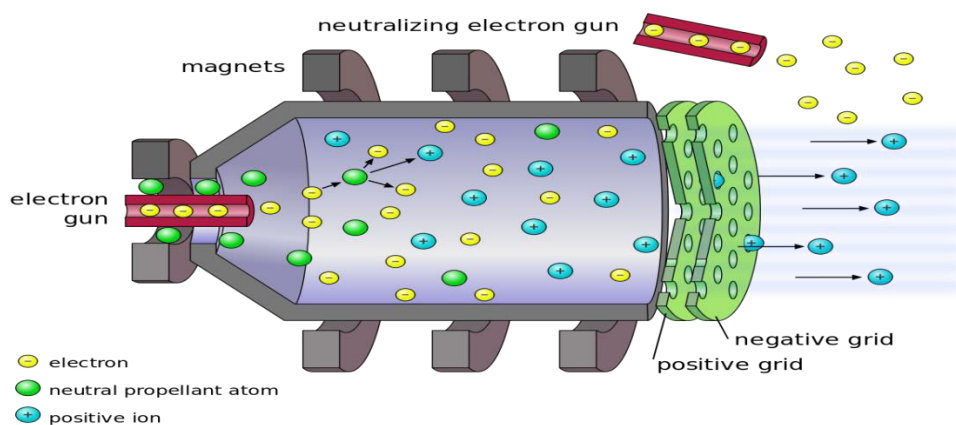


Fig 2:- Internal working of ion thruster

Ion thrusters in operational use have an input power need of 1–7 kW (1.3–9.4 hp), exhaust velocity 20–50 km/s (45,000–112,000 mph), thrust 25–250 millinewton (0.090–0.899 ozf) and efficiency 65–80% [3][4] though experimental versions have achieved 100 kilowatts (130 hp), 5 Newton (1.1 lbf).

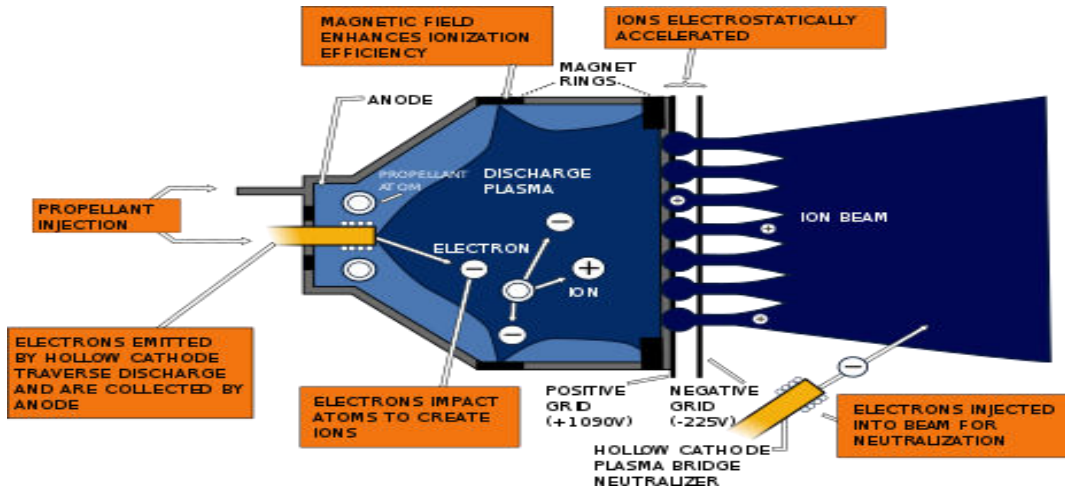


Fig 3:- Parts of Ion thruster

1. The Deep Space 1 spacecraft, powered by an ion thruster, changed velocity by 4.3 km/s (9,600 mph) while consuming less than 74 kg (163 lb) of xenon. The Dawn spacecraft broke the record, with a velocity change of 11.5 km/s (26,000 mph).
2. Applications include control of the orientation and position of orbiting satellites (some satellites have dozens of low-power ion thrusters) and use as a main propulsion engine for low-mass robotic space vehicles (such as Deep Space 1 and Dawn).
3. Ion thrust engines are practical only in the vacuum of space and cannot take vehicles through the atmosphere because ion engines do not work in the presence of ions outside the engine. Additionally, the engine's minuscule thrust cannot overcome any significant air resistance. Spacecraft rely on conventional chemical rockets to initially reach orbit.

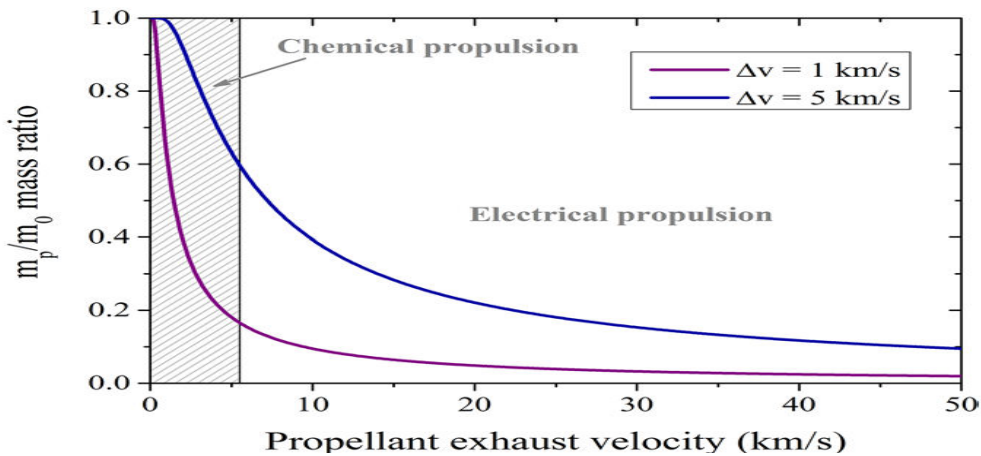


Fig 4. Graph for propellant exhaust velocity

An Electric Propulsion System is composed by three different building blocks

4. The thruster components,
5. The propellant components or fluidic management system,
6. The power components, which includes the PPU

#### IV. GENERAL WORKING OF ION THRUSTERS

Ion thrusters use beams of ions (electrically charged atoms or molecules) to create thrust in accordance with momentum conservation. The method of accelerating the ions varies, but all designs take advantage of the charge/mass ratio of the ions. This ratio means that relatively small potential differences can create high exhaust



velocities. This reduces the amount of reaction mass or propellant required, but increases the amount of specific power required compared to chemical rockets. Ion thrusters are therefore able to achieve high specific impulses. The drawback of the low thrust is low acceleration because the mass of the electric power unit directly correlates with the amount of power. This low thrust makes ion thrusters unsuited for launching spacecraft into orbit, but effective for in-space propulsion.

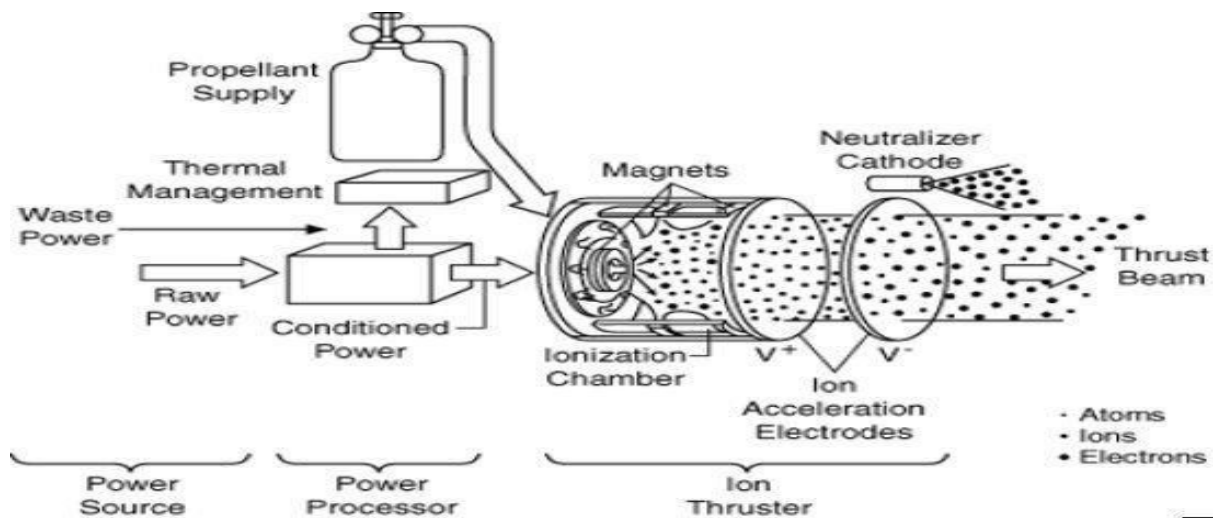


Fig 5. Power stages of Ion thrusters

Ion thrusters are categorized as either electrostatic or electromagnetic. The main difference is the method for accelerating the ions.

1. Electrostatic ion thrusters use the Coulomb force and accelerate the ions in the direction of the electric field.
2. Electromagnetic ion thrusters use the Lorentz force to move the ions.

Power supplies for ion thrusters are usually electric solar panels, but at sufficiently large distances from the Sun, nuclear power is used. In each case, the power supply mass is proportional to the peak power that can be supplied, and both provide, for this application, almost no limit to the energy

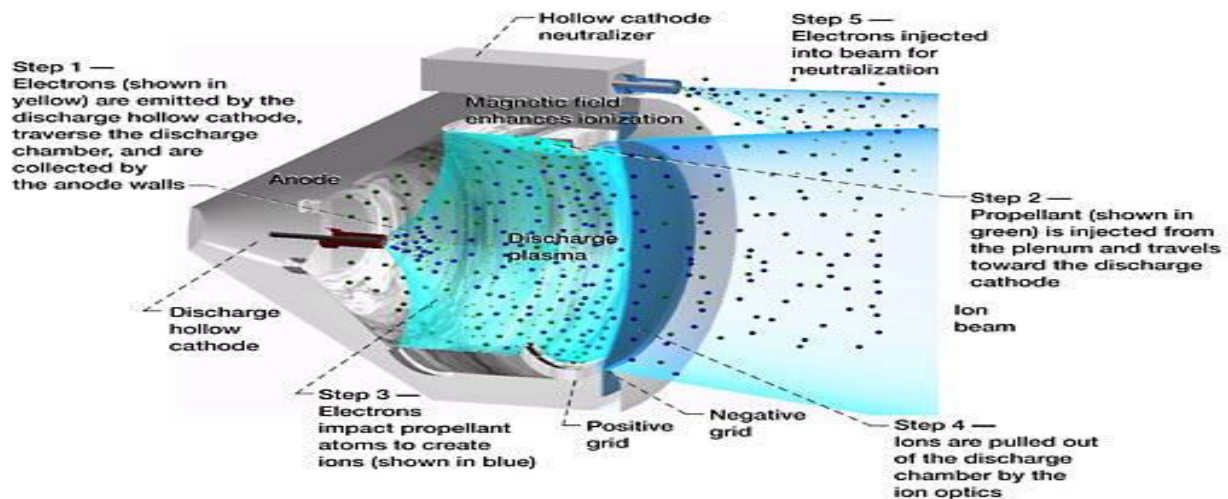


Fig 6. Step by step working of Ion Thruster

## VI.CONCLUSION

Thus, from the above case study we can conclude that Electric Propulsion, when compared with chemical propulsion, is not limited in energy, but is only limited by the available electrical power on-board the spacecraft. Therefore, EP is suitable for low-thrust (micro and milli-newton levels) long-duration applications on board spacecrafts. The propellant

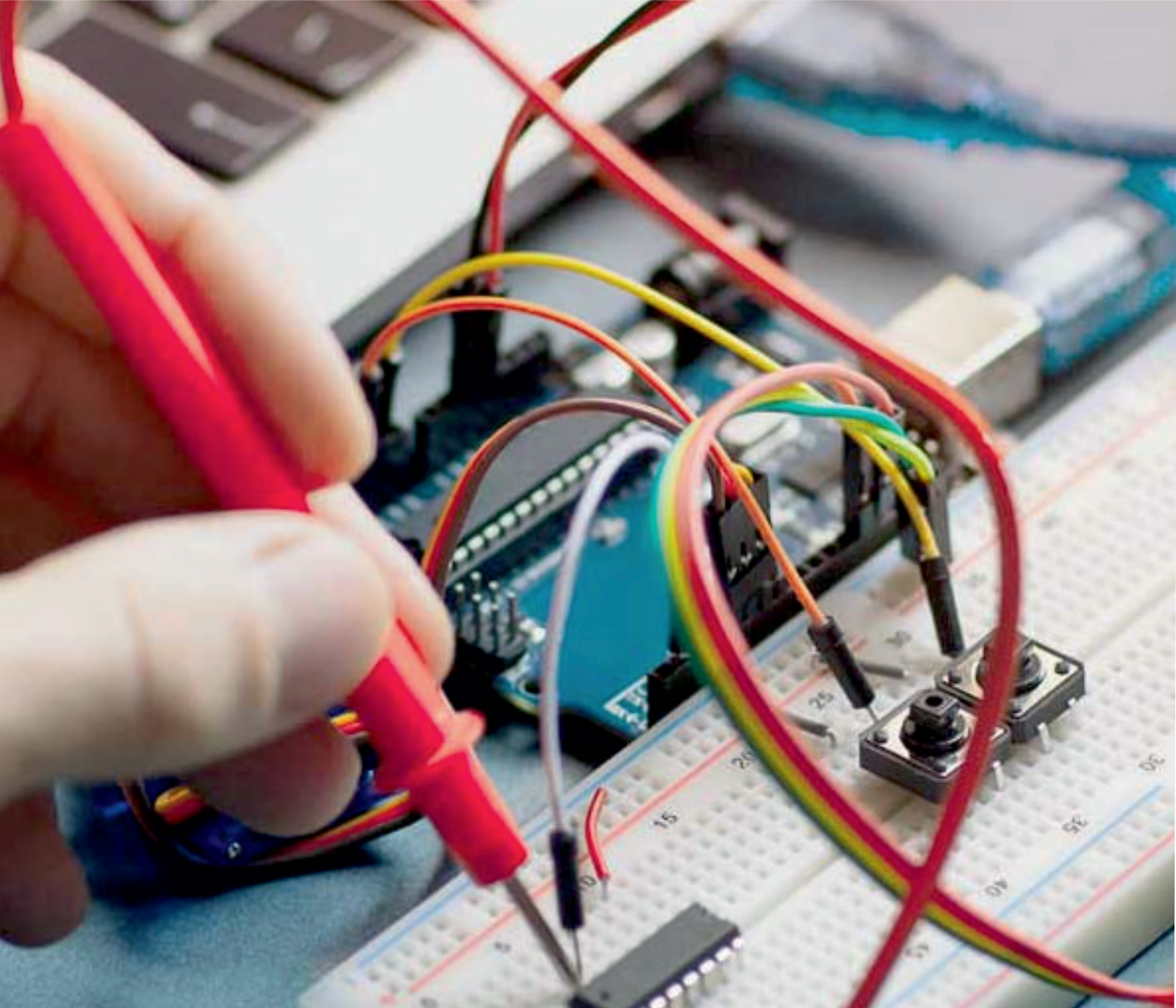


used in EP systems varies with the type of thruster and can be a rare gas (i.e., xenon or argon), a liquid metal or, in some cases, a conventional propellant.

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