

Electrically powered spacecraft propulsion

An **electrically-powered spacecraft propulsion** system uses electrical, and possibly also magnetic fields, 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.^[1]

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.^[2] 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 duration of time.^[3] Electric propulsion can achieve high speeds over long periods and thus can work better than chemical rockets for some deep space missions.^[2]

Electric propulsion is now a mature and widely used technology on spacecraft. [Russian](#) satellites have used electric propulsion for decades^[4] and it is predicted that by 2020, half of all new satellites will carry full electric propulsion.^[5] As of 2019, over 500 spacecraft operated throughout the [Solar System](#) use electric propulsion for [station keeping](#), orbit raising, or primary propulsion.^[6] 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](#).^{[2][7]} An electric rocket with an external power source (transmissible through [laser](#) on the [photovoltaic panels](#)) has a theoretical possibility for [interstellar flight](#).^{[8][9]} However, electric propulsion is not a method suitable for launches from the Earth's surface, as the thrust for such systems is too weak.

Types^[edit]

Ion and plasma drives^[edit]

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.^[citation needed]

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^[edit]

Main article: [ion thruster](#)

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.

- [Gridded ion thruster](#)
 - [NASA Solar Technology Application Readiness](#) (NSTAR)
 - [HiPEP](#)
 - [Radiofrequency ion thruster](#)
- [Hall effect thruster](#)
 - [SPT – Stationary Plasma Thruster](#)
 - [TAL – Thruster with Anode Layer](#)
- [Colloid ion thruster](#)
- [Field Emission Electric Propulsion](#)
- [Nano-particle field extraction thruster](#)

Electrothermal^[edit]

The electrothermal 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 electrothermal 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 electrothermal 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](#), electrothermal engines were used since 1971; the [Soviet "Meteor-3"](#), "Meteor-Priroda", "Resurs-O" satellite series and the [Russian "Elektro"](#) 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.

- [Arcjet](#)
- Microwave arcjet
- [Resistojet](#)
- [Variable specific impulse magnetoplasma rocket](#) (VASIMR)

Electromagnetic^{[[edit](#)]}

Main article: [Plasma propulsion engine](#)

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.

- [Electrodeless plasma thruster](#)
- [Magnetoplasmadynamic thruster](#)
- [Pulsed inductive thruster](#)
- [Pulsed plasma thruster](#)
- [Helicon Double Layer Thruster](#)

Non-ion drives^{[[edit](#)]}

Photonic^{[[edit](#)]}

Photonic drive does not expel matter for reaction thrust, only photons. See [Laser propulsion](#), Photonic Laser Thruster, [Photon rocket](#).

Electrodynamic tether^{[[edit](#)]}

Main article: [Electrodynamic tether](#)

Electrodynamic 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 electrodynamic 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.

Controversial^{[[edit](#)]}

A number of propulsion methods have been proposed, where it is unclear that they can work according to the currently-understood laws of physics, including:^[20]

- [Quantum Vacuum Plasma Thruster](#)
- [EM Drive or Cannae Drive](#)

Steady vs. unsteady^{[[edit](#)]}

Electric propulsion systems can also be characterized as either **steady** (continuous firing for a prescribed duration) or **unsteady** (pulsed firings accumulating to a desired [impulse](#)). However, these classifications are not unique to electric propulsion systems and can be applied to all types of propulsion engines.

Dynamic properties^{[[edit](#)]}

Further information: [Reaction engine § Energy use](#)

Electrically-powered rocket engines provide lower thrust compared to chemical rockets by several [orders of magnitude](#) because of the limited electrical power possible to provide in a spacecraft.^[3] A chemical rocket imparts energy to the combustion products directly, whereas an electrical system requires several steps. However, the high

velocity and lower [reaction mass](#) expended for the same thrust allows electric rockets to run for a long time. This differs from the typical chemical-powered spacecraft, where the engines run only in short intervals of time, while the spacecraft mostly follows an [inertial trajectory](#). When near a planet, low-thrust propulsion may not offset the gravitational attraction of the planet. An electric rocket engine cannot provide enough thrust to lift the vehicle from a planet's surface, but a low thrust applied for a long interval can allow a spacecraft to maneuver near a planet.