NASA Facts

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Pulsed Plasma Thrusters

Introduction

Pulsed plasma thrusters (PPTs) are high-specific-impulse, low-power electric thrusters. Pulsed plasma thrusters are ideal for applications in small spacecraft for attitude control, precision spacecraft control, and low-thrust maneuvers. Ablative PPTs using solid propellants provide mission benefits through system simplicity and high specific impulse. These systems exploit the natural properties of plasma to produce thrust and high velocities with very low fuel consumption.

What is Plasma?

An *ion* is simply an atom or molecule that is electrically charged. *Ionization* is the process of electrically charging an atom or molecule by adding or removing electrons. Ions can be positive (when they lose one or more electrons) or negative (when they gain one or more electrons). A gas is considered ionized when some or all the atoms or molecules contained in it are converted into ions. *Plasma* is an electrically neutral gas in which all positive and negative charges—from neutral atoms, negatively charged electrons, and positively charged ions—add up to zero. Plasma exists everywhere in nature; it is designated as the fourth state of matter (the others are solid, liquid, and gas). It has some of the properties of a gas but is affected by electric and magnetic fields and is a good conductor of electricity. Plasma is the building block for all types of electric propulsion, where electric and/or magnetic fields are used to push on the electrically charged ions and electrons to provide thrust. Examples of plasmas seen every day are lightning and fluorescent light bulbs.

PPT in operation.

PPT Operation

The PPT contains two electrodes positioned close to the propellant source. An energy storage unit (ESU) or capacitor placed in parallel with the electrodes is charged to a high voltage by the thruster's power supply. The first step for initiating a PPT pulse is ignition. The thruster's igniter, mounted close to the propellant, produces a spark that allows a discharge of the ESU between the electrodes to create a plasma. This plasma is called the *main discharge*. The main discharge ablates and ionizes the surface portion of the solid propellant, creating a propellant plasma. This plasma is then accelerated out of the thruster by the Lorentz force. The Lorentz force is a force created by the interaction of a magnetic field and an electric current. As the propellant is consumed, a spring forces the remaining solid propellant forward, providing a constant fuel source.

The Electric Propulsion System

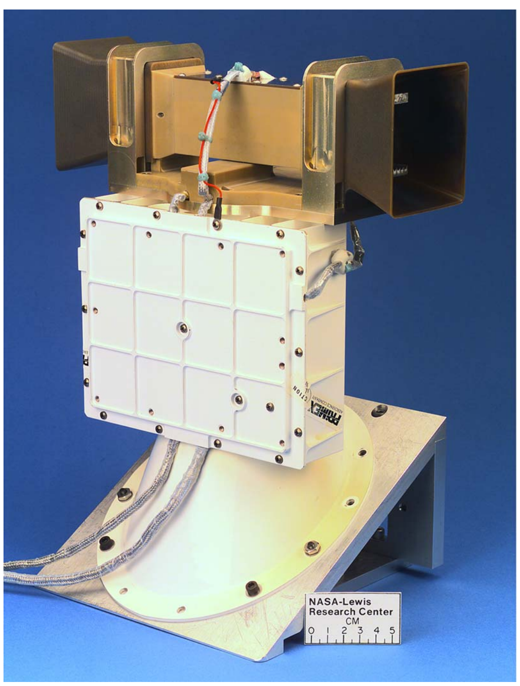
The PPT system includes a power source, power processing unit (PPU), energy storage unit, and the thruster itself. The power source can be any source of electrical power. Solar cells are generally used, since the thruster operates at low power levels. The PPU converts the spacecraft power to charge the PPT energy storage unit. The energy storage unit provides high-current pulses through the thruster to perform work.

Past

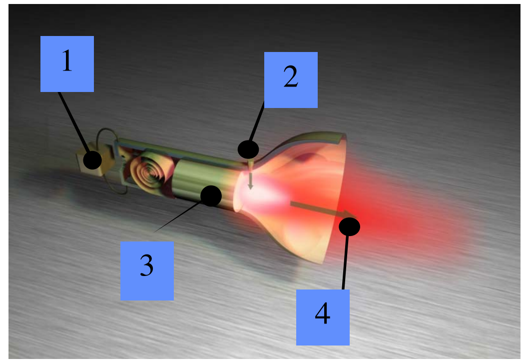
The Zond 2 spacecraft, launched by the Soviet Union in 1964, was the first use of PPTs in space. In 1968, the United States launched its own PPT system aboard the LES–6 satellite. The LES–8 and 9 satellites launched in 1976 and tested PPTs for stationkeeping maneuvers. The Transit Improvement Program (TIP) spacecraft used PPTs for drag correction maneuvers on TIP II (launched in 1975) and TIP III (launched in 1976). The U.S. Navy developed the Navy Navigation Satellites (NNS), which became the first navigation satellite system. Three NNS satellites (Nova 1 launched in 1981, Nova 3 launched in 1984, and Nova 2 launched in 1988) used PPTs for drag correction maneuvers.

Present

The Earth Observing 1 (EO–1) spacecraft, launched in 2000, uses one dual-axis PPT for pitch axis control and momentum management. The EO–1 PPT was developed at the NASA Glenn Research Center and produced by Primex Aerospace Company. Several tests of the EO–1 thruster were performed at Glenn to demonstrate life capability, characterize contamination of spacecraft surfaces, and verify performance. EO–1's PPT is capable of producing a thrust of 860 micro-Newtons (0.0002 pounds) and an exhaust velocity over 13,700 meters per second (30,600 miles per hour (mph)), while consuming only 70 watts of power. To put these numbers into perspective: the force of this level of thrust on the spacecraft is the same as the force you would feel by holding a 2- by 2-inch piece of paper in your hand, and this exhaust velocity, in a space environment devoid of atmosphere, can achieve a top speed almost twice that of the space shuttle (18,000 mph).



EO–1 Earth orbiter flight pulsed plasma thruster.



Overview of PPT operation. (1) Energy storage unit. (2) Ignitor. (3) Fuel rod. (4) Plasma acceleration region.

Future

NASA's research of PPTs focuses on verifying systems and components for space flight applications. Component life tests are underway at Glenn as a combined effort with Unison Industries to advance the state of the art in PPUs, energy storage units, and improved fuels. As research continues, more efficient, longer life PPTs will be developed. These advancements will enable spacecraft to conduct precise maneuvers efficiently and allow extended missions.

For more information
visit the GRC Lorentz Force Accelerators Web site at
http://www.grc.nasa.gov/WWW/lfa

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