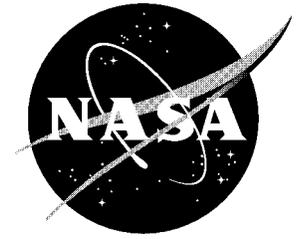


NASA Facts



National Aeronautics and
Space Administration

Glenn Research Center
Cleveland, Ohio 44135-3191

FS-2004-11-022-GRC

Magnetoplasmadynamic Thrusters

Introduction

Once existing only in the realm of science fiction, electric propulsion has proven to be an excellent option for the future of space exploration. The magnetoplasmadynamic (MPD) thruster is currently the most powerful form of electromagnetic propulsion. The MPD's ability to efficiently convert megawatts of electric power into thrust makes this technology a prime candidate for economical delivery of lunar and Mars cargo, outer planet rendezvous, and sample return, and for enabling other bold new ventures in deep space robotic and piloted planetary exploration. With its high exhaust velocities, MPD propulsion offers distinct advantages over conventional types of propulsion for each of these mission applications. MPDs expel plasma to create propulsion. MPDs can process more power and create more thrust than any other type of electric propulsion currently available, while maintaining the high exhaust velocities associated with ion propulsion.

What Is an Ion?

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.

MPD Operation

In its basic form, the MPD thruster has two metal electrodes: a central rod-shaped cathode, and a cylindrical anode that surrounds the cathode. Just as in an arc welder, a high-current electric arc is struck between the anode and cathode. As the cathode heats up, it emits electrons, which collide with and ionize a propellant gas to create plasma. A magnetic field is created by the electric current returning to the power supply through the cathode, just like the magnetic field that is created when electrical current travels through a wire. This self-induced magnetic field interacts with the electric current flowing from the anode to the cathode (through the plasma) to produce an electromagnetic (Lorentz) force that pushes the plasma out of the engine, creating thrust. An external magnet coil may also be used to provide additional magnetic fields to help stabilize and accelerate the plasma discharge.

MPD Past

Initially investigated in the 1960s and funded periodically over the last few decades, high-power MPD thrusters have achieved slow but steady improvements in performance. A variety of thruster geometries have been investigated using different types of gas propellants, with lithium vapor propellant providing the most efficient performance to date. Lithium-fed MPD thrusters developed in Russia have operated at power levels of 100 kilowatts, with efficiencies of up to 45 percent and plasma exhaust velocities approaching 50,000 meters per second (over 100,000 miles per hour (mph)). Facilities to



Magnetoplasmadynamic (MPD) thruster in operation.

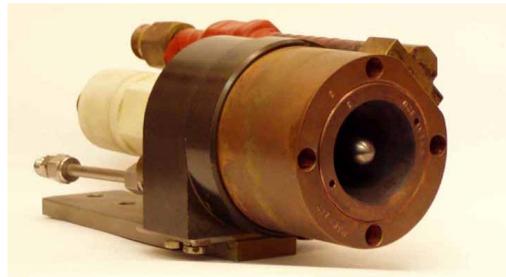
investigate lithium-fed MPD thrusters have been established in the United States at the NASA Jet Propulsion Laboratory and Princeton University. Hydrogen-based test facilities have been established at the NASA Glenn Research Center.

Current Research

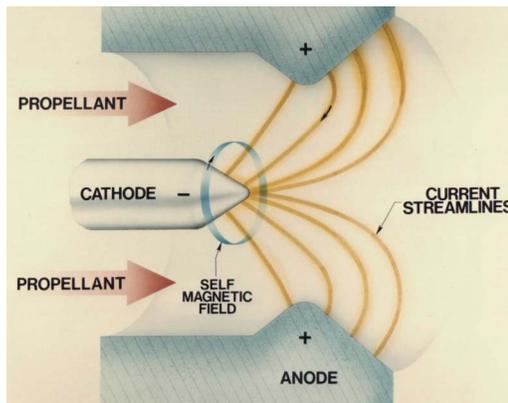
NASA is currently researching both pulsed and continuous forms of MPDs with hydrogen or lithium as a propellant. While attractive from an efficiency standpoint, lithium is a condensable propellant and may coat spacecraft surfaces and power arrays. MPD thrusters using noncondensable hydrogen propellant will eliminate these concerns and provide higher exhaust velocities than lithium-fueled thrusters. Glenn is currently developing high-specific-impulse, megawatt-class, hydrogen-fueled MPD thruster technology. Research at Glenn encompasses a combination of systems analysis, numerical modeling, and high-power experiments that investigate pulsed versions of both self-field and applied-field MPD thrusters. Testing for these thrusters has demonstrated exhaust velocities of 100,000 meters per second (over 200,000 mph) and thrust levels of 100 Newtons (22.5 pounds) at power levels of 1 megawatt. For perspective, this exhaust velocity will allow a spacecraft to travel roughly 11 times the top speed of the space shuttle (18,000 mph).

Future Uses

Future power-rich robotic and piloted outer planet missions will require exhaust velocities approaching 100,000 meters per second (over 200,000 mph). These higher velocities can be achieved using noncondensable hydrogen plasmas, which are currently under investigation at NASA Glenn. As research continues, the efficiency of the MPD thruster will be increased, which will allow missions with reduced propellant requirements or increased range. Higher exhaust velocities and thrust levels will lead to shorter trip times and reduced mission cost, which is especially beneficial for cargo and piloted missions. As large amounts of power become available in space, MPD thrusters may become the method of propulsion that carries humans to other planets in our solar system.



200-kilowatt MPD thruster.



Overview of magnetoplasmadynamic (MPD) thruster operation.



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

or contact
Eric Pencil
NASA Glenn Research Center
Cleveland, Ohio 44135
E-mail: Eric.J.Pencil@grc.nasa.gov

or
Information and Publications Office
NASA Glenn Research Center
Cleveland, Ohio 44135
216-433-5573