# A PLASMA ROCKET DEMONSTRATION ON THE INTERNATIONAL SPACE STATION

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The Advanced Space Propulsion Laboratory at the NASA Johnson Space Center has been engaged in the development of a magneto-plasma rocket for several years. This type of rocket could be used in the future to propel interplanetary spacecraft. One feature of this concept is the ability to vary its specific impulse so that it can be operated in a mode that maximizes propellant efficiency or a mode that maximizes thrust. For this reason the system is called the Variable Specific Impulse Magneto-plasma Rocket or VASIMR. This ability to vary specific impulse and thrust will allow for optimum low thrust interplanetary trajectories and results in shorter trip times than is possible with fixed specific impulse systems while preserving adequate payload margins.

In the development of the VASIMR technology, a series of ground-based experiments and space demonstrations are envisioned. A ground-based experiment of a low-power VASIMR prototype rocket is currently underway at the Advanced Space Propulsion Laboratory. The next step is a proposal to build and fly a 25-kilowatt VASIMR rocket as an external payload on the International Space Station. This experiment will provide an opportunity to demonstrate the performance of the rocket in space and measure the induced environment. The experiment will also utilize the space station for its intended purpose as a laboratory with vacuum conditions that cannot be matched by any laboratory on Earth.

The VASIMR experiment will also blaze the trail for the wider application of advanced electric propulsion on the space station. An electric propulsion system like VASIMR, if provided with sufficient electrical power, could provide continuous drag force compensation for the space station. Drag compensation would eliminate the need for reboosting the station, an operation that will consume about 60 metric tons of propellant in a ten-year period. In contrast, an electric propulsion system would require very little propellant. In fact, a system like VASIMR can use waste hydrogen from the station's life support system as its propellant. This waste hydrogen is otherwise dumped overboard. Continuous drag compensation would also improve the microgravity conditions on the station. So electric propulsion can reduce propellant delivery requirements and thereby increase available payload capacity and at the same time improve the conditions for scientific research.

The VASIMR rocket produces a plasma exhaust that creates a conducting path between the station and the space environment. This is a beneficial effect that prevents a charge buildup on the station. The station already operates two dedicated non-propulsive plasma contactor devices for this purpose. A VASIMR rocket would function as an additional plasma contactor.

A preliminary design of the VASIMR space station experiment has been completed and is shown in Figure 1. The device would be delivered to orbit in the Space Shuttle payload bay. It would be mounted on a standard payload attachment structure. After removal from the payload bay by the shuttle robotic arm, it would be handed to the space station robotic arm which would place it at an external payload attach site on the station truss. A mating device for power and data connections exists at the payload site. The experiment would receive one to three kilowatts of power from the station. About 600 watts would be used for cryogenic cooling and control devices. Additional power would be stored in a set of batteries.

The batteries are designed to provide 24 kilowatts of power for up to ten minutes when fully charged. The VASIMR experiment would be operated for short periods when the batteries can provide power to the amplifiers that feed radio-frequency power to the thruster assembly.

The thruster assembly is composed of an inner tube in which the neutral propellant is injected and ionized and a larger tube, which supports the radio frequency antennas, which ionize the gas and heat the plasma. Electromagnet coils that provide the magnetic field to constrain the flow of the plasma and form the magnetic exit nozzle surround these tubes.

Although the VASIMR could operate with waste hydrogen gas from the space station, no connections to this supply are planned for the experiment. The experiment will carry two dedicated propellant tanks which each have the capacity to store all the propellant needed for an experimental program lasting several months. With two propellant tanks, the opportunity exists to perform experiments with more than one type of propellant. Hydrogen is the primary choice for propellant but deuterium and helium are also of interest and might also be included. All the propellant is stored and used in gaseous form at ambient temperature.

Thermal control is the most significant engineering challenge in the design of the flight version of the rocket. There is a superconducting electromagnet that will need to be maintained at cryogenic temperatures in order to operate properly. The magnet is in close proximity to the plasma so a combination of compact insulation and passive and active heat transport techniques will be employed.

The experiment will be designed for delivery, deployment, and operation with no extra-vehicular activity requirements. However, provisions will be included to capitalize on the presence of humans in case repairs or servicing is required. The batteries, propellant tanks, and electronic components will be designed for on-orbit removal and replacement, if necessary.

Following a successful experiment it would be feasible to build an operational VASIMR unit which could be located on the station to provide useful thrust for drag compensation. In order to provide power for continuous thrusting, it may be necessary to augment the power generation system for the station. Another attractive possibility is to develop an electric propulsion testbed for the space station. This testbed could be used for testing and certifying a variety of propulsion systems at various stages of maturity while providing thrust for the space station. This station facility would be a valuable asset for commercial and government space transportation programs.

The flight testing of the VASIMR on the International Space Station will be an early step leading to more powerful and capable propulsion systems that will be demonstrated on free-flying spacecraft in near-Earth space and eventually on missions to the planets.