VASIMR: The Future of Spaceflight

While many aspects of spaceflight have changed throughout the years, the propulsion systems of spacecraft have remained relatively the same. Since Goddard's first rocket launch in 1926, spacecraft have always used solid or liquid fueled chemical rockets. These chemical rockets have proved to be an expensive and inefficient method of space travel, but until recently there have not been any promising designs that would provide the needed power to travel quickly through space. Ad-Astra Rocket Company hopes to change that with its Variable-Specific-Impulse Magnetoplasma Rocket (VASIMR) engine. Their VASMIR uses plasma to produce thrust instead of the chemical reactions that power conventional rockets. The VASMIR promises to reduce spacecraft costs, increase cargo loads, and revolutionize space propulsion.

The Ad-Astra Rocket Company

Former astronaut Franklin Chang-Diaz is the founder of the Ad-Astra Rocket Company. Chang-Diaz served as the director of the Advanced Space Propulsion Laboratory at Johnson Space Center for twelve years and has a Ph.D. in applied plasma physics and fusion technology. It was at Johnson Space Center where the first VASIMR prototype was constructed, the VX-50. The VX-50 was used mainly to test the basic operation of the VASIMR device. Chang-Diaz left NASA in 2005 to open Ad-Astra, which is devoted to the development of the VASIMR. The next prototype, the VX-100, was built by Ad-Astra and tested in its Houston, Texas facility. The new VX-200 is the most powerful VASIMR engine yet, and is capable of reaching 200 KW of power. The VX-200 is the first self-contained VASIMR and can be moved to other facilities without being dismantled (Figure 1). The next engine, the VX-200-1 is under development. The VX-200-1 is first engine that Ad-Astra plans to send into space.

Figure 1: The VX-200 is prepared for a test in the Houston facility

VASIMR Design

Conventional rockets use a chemical reaction between a fuel and an oxidizer to create thrust. Instead of a chemical reaction, the VASIMR uses accelerated plasma to produce thrust. Plasmas are ionized and superheated gases. The electrons of plasmas are constantly moving from atom to atom. The movement of the electrons causes plasma to be strongly influenced by magnetic and electrical field. The VASMIR creates plasma mainly from argon, but could use hydrogen or virtually any other type of gas. The gas used by the engine would be stored on board the spacecraft. The gas is first injected into the quartz tube of the VASIMR. The quartz tube stores the gas before it becomes ionized. Next, the gas passes through the Helicon antenna. The Helicon antenna ionizes the gas and frees electrons from the atoms with radio waves. The radio waves that pass through the gas strip the electrons from the gas atoms to create cold plasma. The cold plasma continues from the Helicon antenna to the ion cyclotron range of frequencies (ICRF) antenna. The ICRF antenna produces ion cyclotron waves. These waves heat and energize the plasma. At the end of the VASMIR is the magnetic nozzle. As the energized plasma exits the engine through the nozzle, it accelerates up to speeds of 200 km/s (Glover). This extremely fast moving plasma produces thrust that propels the spacecraft.

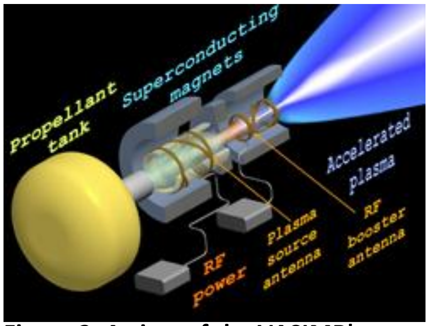

Figure 2: A view of the VASIMR's internal components

The energized plasma in VASIMR has the potential to destroy the entire engine if it comes in contact with the inner surface of the engine. To prevent this from happening, the designers took advantage of plasma's sensitivity to magnetic fields. A system of electromagnets is used to contain the plasma within VASIMR. The electromagnets around the nozzle of the engine are used to direct the plasma stream to increase the maneuverability of the spacecraft (Figure 3). A complex computer system controls both the flow of gas into the VASMIR and the amount of electricity that is used to power the Helicon antenna, ICRF antenna, and the electromagnets.

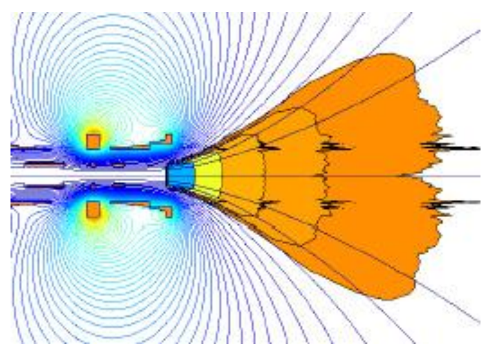

Figure 3: The magnetic field of the VASIMR

The Advantages of VASIMR

In conventional liquid rockets, the fuel and oxidizer are stored in liquid form. The two chemicals take up large amounts of space and weigh down the rocket. The weight and large amount of space used by rocket fuel has always limited the power and payload of spacecraft. The VASIMR does not use the chemicals that conventional rockets do. The gas used to produce plasma only takes up 5% of the VASIMR's total weight. The light weight of the propellant used by VASIMR opens up more space and allows for a larger payload than conventional powered spacecraft. Another drawback of conventional rockets is their low specific impulse. Specific impulse is a way of measuring how efficiently a rocket or jet engine converts its fuel into trust. The higher a rocket's specific impulse, the more efficiently it uses its fuel to produce thrust. Conventional rockets have a low specific impulse between three and five hundred. An advantage of having a low specific impulse is that these rockets are able to produce enormous amounts of thrust which are needed to escape the Earth's gravity during a launch. In space, where there is no gravity, the large amounts of thrust produced by most chemical rockets are unnecessary, and huge amounts of fuel are wasted with these inefficient rockets. The VASIMR is designed to change its specific impulse to maximize efficiency and speed, like gears in a car. When a spacecraft is moving slowly, the VASIMR would create large amounts of plasma moving at a slow speed. As the spacecraft speeds up, less plasma is ejected from the engine, but at higher speeds. The VASIMR can reach specific impulses in the ten thousands, over twenty-five times higher than conventional rockets (Billings). The VASIMR does not produce much thrust, so it cannot be used to launch spacecraft and acceleration in space is slow, but the high velocity of the plasma coming from the engine allows a VASIMR powered spacecraft to go faster than a conventionally powered one.

Ion engines are another type of engine that has been designed to augment conventional rockets. Ion engines produce thrust by expelling ions instead of plasma. A typical ion engine ionizes xenon gas by bombarding it with electrons. The xenon ions pass through two electrically charged grids. The differences in the charges on the grids accelerate the ions out of the engine to produce thrust. These ion engines have a number of drawbacks that the VASIMR does not. Xenon gas is used in ion engines because it takes little energy to ionize. However, xenon is not widely available, and costs about $2000 per kg ("Executive Summary"). The argon propellant in the VASIMR is fifty times cheaper at only $40 per kg. The grids that are used to propel ions are exposed to corrosive plasma. They are slowly eroded by the plasma and ions and limit the life of the ion engine. The grids also limit ion engines thrust;

at high power settings they would disintegrate. The VASIMR does not have any parts exposed to the plasma flow, so it can run at higher powers than ion engines while still retaining a longer life expectancy.

Future Roles of the VASIMR

The high efficiency and ability to vary its power allows the VASIMR to fill many roles that would normally be filled by conventional rockets. Ad-Astra and NASA have arranged to test the VX-200-1 on the International Space Station to evaluate its ability in space by 2013. If the test goes well, the VASIMR could be used to keep the ISS in orbit. Every few months the ISS needs to be boosted to remain in orbit. When the ISS is complete, it will cost over $150 million to send up rocket fuel every few months to power the booster ("Executive Summary"). By using a VASIMR on the ISS, the station would be able to remain in orbit for 1/20 of the current projected price (Glover). The VASIMR would get electricity to run from the space station's solar panels, and it could use waste gas from the station to use as propellant. Another use of the VASIMR will be to act as a space tug. Satellites could be repositioned with a VASIMR engine at a lower price than conventional methods. VASIMRs could take cargo launched from the Earth and send it to resupply a base on the Moon.

The biggest potential for the VASIMR though, lies in interplanetary travel. It is currently estimated that a trip to Mars would take six months with conventional rockets. In this time, astronauts would become weak from the prolonged exposure to zero gravity. A VASIMR powered mission would arrive at Mars in only thirty-nine days. Arriving on Mars this quickly would solve many of the problems with a trip to Mars. Additionally, the magnetic field produced in the VASIMR would protect the astronauts inside from deadly radiation once they exit the Earth's protective magnetic field. Past Earth, the intensity of sunlight is too low to provide sufficient power for a VASIMR running off solar power. To make a trip to Mars, future space craft will need to be fueled by nuclear power.

The VASIMR engine has shown to have enormous potential. It is more efficient then conventional rockets. The VASIMR will enable spacecraft to carry a larger payload then ever before while still cutting costs. Its use in interplanetary travel will cut months and eventually years off travel time. It will cut costs, provide rapid transport between planets, and revolutionize space travel.

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Images

Figure 1: “Plasma rocket engine VASIMR VX-200 first stage achieves full power rating” http://blog.thetruthontheweb.com/2008/10/27/plasma-rocket-engine-vasimr-vx200-first-stage achieves-full-power-rating.aspx

Figure 2: “Rocket Engine Testing to Ocorr at the ISS <http://www.satnews.com/cgi-bin/story.cgi?number=200236858>

Figure 3: "Propulsion Systems of the Future." <http://www.nasa.gov/vision/space/travelinginspace/future_propulsion.html>