Plasma propulsion technology heats up at Advanced Space Propulsion Laboratory

The VASIMR research team at the ASPL standing, from left: Dr. Andrew Ilin, Lockheed Martin; Tim Glover, Rice University; Dr. Jared Squire, Muniz Engineering; Dr. Franklin Chang-Díaz, JSC/NASA; Garland "Buddy" Goebel, Boeing; Greg McCaskill, Lockheed Martin; Scott Winter, JSC/NASA; front: Jeff George, JSC/NASA; Tri Nguyen, JSC/NASA; Tim Graves, Texas A&M University; Kristy Stokke, MIT; Carol Dexter, MSFC/NASA; Andy Petro, JSC/NASA. Several government partner organizations such as MSFC, GSFC, GRC, LaRC, and the Department of Energy's Oak Ridge National Lab also contribute to VASIMR research.

By Nicole Cloutier

Student researchers teamed with veteran scientists and engineers at the Advanced Space Propulsion Laboratory at the Sonny Carter Training Facility are developing a new method for propelling spacecraft. Known as the Variable Specific Impulse Magnetoplasma Rocket (VASIMR), this new propulsion technology promises faster space travel, the ability to go farther with increased load capability and possible creation of artificial gravity in space, as well as effective radiation protection for astronauts.

Contrary to the conventional rockets in use today, which use chemical reactions for their power, VASIMR represents a revolutionary new rocket technology that uses plasma as a propellant.

How it works

Sometimes known as the fourth state of matter, plasma is a gas heated to a very high temperature (tens of thousands to millions of degrees). Although plasma is relatively scarce on Earth, appearing as the glowing material inside flames and lightning, it makes up 99 percent of the universe including the Sun and stars.

In this case, hydrogen or helium is used as the gas. Hydrogen is preferred because it produces the highest exhaust velocity. And because hydrogen is the best insulator against most types of space radiation, it will be stored externally on the VASIMR to protect the crew from radiation exposure.

The gas is released into a feeder tube that is surrounded by a special antenna called a helicon. The helicon produces radio waves that excite the atoms and heat the gas to approximately 50,000 °F. At that temperature, the electrons and ions separate from the atoms and plasma is created.

The plasma is further heated by electromagnetic waves to temperatures of 1 million degrees or higher. At those extreme temperatures there is no known material that can endure contact with the hot plasma, so researchers use a magnetic field to contain and guide the plasma toward the exhaust cell of the VASIMR.

In this cell, the magnetic field forms a magnetic nozzle that both accelerates the plasma and ensures its efficient separation from the guiding field. At this stage, the plasma heat is converted to kinetic energy and produces thrust.

"One key feature of the VASIMR is its capability to vary the properties of the exhaust over a wide operational range," said Dr. Franklin Chang-Díaz, NASA astronaut. "This enables the rocket to 'adapt' to the conditions of flight similar to the way an automatic transmission adapts the car engine to the hills and valleys of the road. In space we travel in hilly terrain, the hills and valleys of the gravitational fields of the Sun, planets and moons."

> *We should continue to develop technology with something bigger in mind: to bring the entire solar system within human reach within our lifetime, and eventually the stars.*
> – Franklin Chang-Díaz

Current work

All of the work on VASIMR is done with interplanetary travel in mind.

"VASIMR has better gas mileage for interplanetary travel," said Dr. Mark Carter, a collaborating researcher from the Department of Energy. "It needs less propellant and yet is able to fly faster with increased payloads."

Proposed use of VASIMR technology includes travel to Mars in a popular concept dubbed "split-sprint." The first mission uses an automated VASIMR vehicle to transport a large payload of supplies, fuel and habitat to Mars. The second shipment, faster and with a smaller payload, delivers crew and additional supplies to the Mars site.

After more than two decades of research and testing in the lab environment, VASIMR is slated for its debut space flight in 2003.

The proposed flight is the Radiation and Technology Demonstration mission. VASIMR will be one of two experimental propulsion devices flown by the RTD spacecraft several thousand kilometers above the Earth.

"This is an exciting time for everyone on the team," said Andrew Petro, NASA integration engineer. "We have VASIMR physics pretty well understood. Now we're concentrating on the engineering and design challenges."

"The work we are doing here makes me think of what it must have been like in the 'old days' when physics and engineering were going hand in hand and discovery was just around the corner," said Chang-Díaz. "I see the young physicists, engineers and technicians in my lab tackle engineering problems for which the physics are not yet known – they must develop it as they go. This is what research is all about and I love every minute of it. To me this is the essence of NASA and I feel truly fortunate to be a part of it."

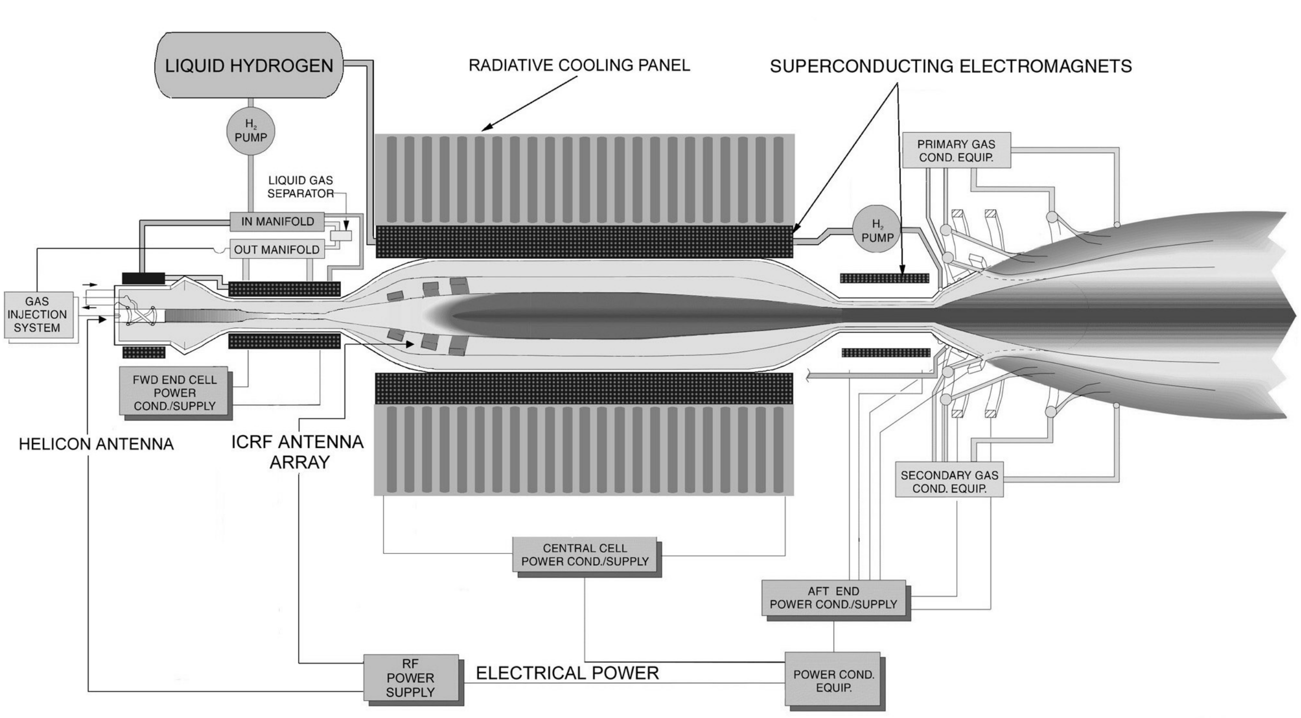
How it started

Chang-Díaz initiated VASIMR research in 1979 at the Charles Stark Draper Laboratory in Cambridge, Massachusetts. He was selected as a NASA astronaut in 1980, but continued VASIMR development at The MIT Plasma Fusion Center as a visiting scientist from JSC. Committed to the concept of alternative propulsion systems, Chang-Díaz founded the ASPL in December 1993 to carry out VASIMR research.

A local team of 20 scientists, engineers, technicians and students staff the laboratory. In addition, the ASPL brings together a bigger team of collaborators from government partner organizations as well as private industry and a half dozen universities. The ASPL also provides training for many students at the undergraduate and graduate levels.

"The students are a crucial part of this research," said Chang-Díaz. "They represent the next generation of space travelers, and they are the ones who will need to explore the alternatives that will enable us to pursue interplanetary travel and habitation."

The future looks very promising for VASIMR and plasma propulsion technology. In the meantime, Chang-Díaz is happy to see alternative technologies emerging. ■



Hydrogen, one of two gases that could be used to create the plasma, would be stored on external tanks and used to protect the crew from radiation in space.

VASIMR Benefits

VASIMR technology resolves many issues that hinder long-term space flight today.

- Power efficiency: Improved payload mass fraction;
- Faster interplanetary travel: Reduced travel time to Mars from six months to three;
- Physiological benefits: Reduced negative physical effects from long-term weightlessness and the psychological toll of confinement. Also, reduced radiation exposure when hydrogen propellant is stored in external tanks on the vehicle to shield the crew;
- Improved abort capability: VASIMR technology could be utilized to offer more expedient Earth-return maneuvers for human deep-space exploration or planetary habitation;
- Artificial gravity: During interplanetary travel, VASIMR would accelerate to the mid-point and then reverse itself for the remaining half of the journey. While the acceleration levels are still very low, they are nevertheless continuous. Future VASIMR rockets operating at high power levels could increase this effect considerably. The medical community is now evaluating these benefits in the context of human missions to Mars.
- A path to fusion rockets: In the near term, VASIMR propulsion is "driven" by solar arrays or an external fission reactor producing the required electrical power to heat and eject the plasma. In the long term, the plasma itself, if sufficiently hot and dense, could trigger its own thermonuclear fusion reaction, producing copious amounts of power internally. In this future embodiment, the VASIMR will become a fusion rocket, providing a breakthrough propulsion capability, which will change human space travel as we know it today. ■