TECHNOLOGY ALABAMA

spring 2006

Powering Tomorrow's Spacecraft

The In-space Transportation Office at Marshall Space Flight Center studies tomorrow's propulsion systems.

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The Future of Space Travel

MARSHALL SPACE FLIGHT CENTER IS AMONG SEVERAL ENTITIES THROUGHOUT THE NATION WORKING ON TOMORROW'S PROPULSION SYSTEM IN SPACE. WORKING AS A TEAM ON PROJECTS LIKE SOLAR SAILS AND AEROCAPTURE, THE IN-SPACE PROPULSION TECHNOLOGY PROJECT IS VALIDATING NASA'S GOAL OF MERGING ACADEMIA, PRIVATE INDUSTRY AND NASA CENTERS FOR MORE COST-EFFECTIVE INNOVATIONS.

By Russell Richey

DURING THE YEARS OF THE APOLLO program, testing day for the Saturn Vs created a giddy sense of anticipation among the engineers and scientists at Huntsville's Marshall Space Flight Center. The firing of the five monstrous F1 rockets, each producing more than 1.5 million pounds of thrust, rattled Huntsville for miles, stirring primal awe amongst scientist and local citizen alike.

Robert Dehaye, a retired NASA engineer still living in Huntsville, remembers those days vividly. "My laboratory was about a mile away from the test site and a buddy of mine worked in the test stand," Dehaye recalls. "We would call him up and he would say, 'yeah, we are going to have a firing today at eleven o'clock.' Those tests were really spectacular. All of the Space Center was shaking. It was amazing."

Flash forward 40 years and the tests that are creating a buzz through the ranks of NASA's best and brightest are happening without a sound in the world's largest vacuum chamber at Glenn Research Center's Plum Brook facility near Sandusky, Ohio.

At Plum Brook in the summer and fall of 2005, a series of successful experiments were conducted that represent the latest achievement in an effort to revolutionize spacecraft propulsion. Two solar sail propulsion systems went through their paces in deployment and altitude control exercises that validated technologies as amazing for their components' properties as they are for the ultimate simplicity of propulsion concept itself.

Solar sails tap a free and limitless resource, the photons generated by our Sun. According to NASA, this infinite power source eventually will be captured and harnessed by football field-sized solar sails, 40 to 100 times thinner than a sheet of writing paper and supported by a feather-light boom framework that will unfold to a size 100 times its pre-deployed dimensions.

Within 15 years, massive ghostlike kites could be roaming our solar system, gently powering through the vacuum of space using the Sun's continuous photon breeze. And there already is a queue of practical applications waiting for solar sail technology to power them.

Solar sentinels, strategically placed in hovering patterns aligned between Earth and the Sun, will track and warn us of destructive solar flares that can knock out terrestrial electrical power grids and fry unwary astronauts.

Solar sail spacecraft also will serve as solar polar imagers, positioned to allow scientific instruments unprecedented access to study the Sun's magnetic field and coronal mass ejections, while other solar sail applications include Earth "pole sitters" that float above the North and South Poles, enabling observations of Earth's climate and weather.

Eventually solar sails could power craft that deliver early warning of potential collisions between Earth and asteroids or comets.

And given that the potential achievement in velocity for solar sails almost is unlimited, spacecraft using this form of propulsion could make the recently launched nuclear-powered New Horizons probe, currently zooming its way to Pluto at a 36,000 miles per hour cruising speed, seem positively plodding by comparison.

"The velocity [of a solar sail spacecraft] would linearly increase with time, effectively unbounded until relativistic effects became significant," wrote Nalin Ratnayake of Arizona State's Solar Sail Research Group in a 2004 research paper. In common-man terms, this means that Einstein's theory of relativity, nature's ultimate speed limit, would eventually come into play to keep a solar sail spacecraft from accelerating forever.

Supporting Open Competition

As mind-blowing as concepts and potential applications of solar sails are, the technology is just one of a collection of propulsion systems currently being researched and developed by NASA, its industry and academic partners under the In-Space Propulsion Technology project.

The initiative is managed by NASA's Science Mission Directorate in Washington, D.C. and implemented by the In-Space Transportation Office, located at Marshall Space Flight Center.

In an August 2005 edition of *Forbes* magazine, an editorial penned by none other than Steve Forbes himself opined that: "If NASA had been in charge of developing the automobile, we'd still be riding horses."

While Forbes' cynical attitude may be sticky with regard to some of NASA's programs whose costs seem shockingly out of proportion to the benefits delivered, the driving principals guiding ISPT project are refreshingly egalitarian for the way that they mandate open competition for funding awards among NASA research centers, private enterprise and academia.

"All the technologies in our portfolio are there as a result of rigorous analysis of NASA science 'mission pull' and budget prioritization for maximum benefit to our customer, Science Mission Directorate," says Rae Ann Meyer, project manager of In-Space Propulsion Technology at Marshall Space Flight Center.

"Our [proposal] solicitations are typically directed at private industry, academia and NASA centers to seek out the best ideas and solutions for technology development," Meyer says. "In the minority of cases where it is smart to place the work exclusively within NASA, we have a set of strict criteria that must be met in order to demonstrate that open competition would be not be in the best interest of the customer."

Fostering Teamwork

The ISPT project was launched in late 2002 by a call from NASA for research proposals that would help drive development of new generations of in-space propulsion.

The technologies targeted for development included solar sails, aerocapture, tether propulsion, ion propulsion, advanced chemical propulsion and solar electric propulsion, with each method being required to deliver

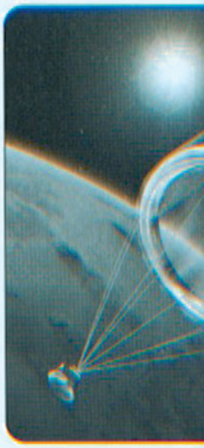
Other ISP Technologies

Aerocapture Technology

Aerocapture is the latest incarnation of a propulsion concept first used during the Apollo program era. It involves leveraging a planet's atmosphere through a flight maneuver akin to a controlled skid around the planet, which provides the propulsion necessary to direct and tease a spacecraft into a sustained high orbit without needing heavy, on-board fuel loads.

Ion Propulsion

Ion engine propulsion has been studied by NASA since the 1950s, but had to wait almost 50 years for practical missions application as the propellant for Deep Space 1, which successfully completed it's duties in December of 2001. Ion engines take xenon gas and uses magnetic fields and cathodes to pry away an electron from the xenon molecules. The ionized gas shoots out of the spacecraft in a directed jet, creating thrust that propels the craft forward. Ion engines have 10 times the efficiency of on-board chemical propulsion systems.



Solar Electric Propulsion

Solar electric propulsion systems convert solar radiation into electric power, which is used to accelerate an on-board propellant. There are three processes through which the electrical energy is harnessed: electrostatic, where charged propellant particles are forced through reduced mission costs related to fuel mass, increased scientific payload potential and shortened travel times.

A panel of independent experts evaluates all research proposals, a competitive process shorn of favoritism to technologies or contractors.

Amazingly, the cost so far of the ISPT program has rung in at under $25 million, a pittance compared to the annual multi-billion dollar budgets of other projects.

The ISPT project also is innovative for its strategic collaborative teamwork models and knowledge-sharing frameworks, with NASA centers, academic institutions and private contractors all teaming to achieve the goals and objectives of the various propulsion technology initiatives.

Private contractors L'Garde Inc. of Tustin, Calf. and ATK Space Systems of Goleta, Calf. developed the two solar sails tested last year at Glenn Research Center. Huntsville-based SRS Technologies is producing an exotic "aluminized, temperature-resistant material" for structural components, a material invented by NASA's Langley Research Center in Hampton, Va., and the Jet Propulsion Laboratory in Pasadena, Calf. is providing leadership in the in-space solar sail charging experiments.

Solar sail collaborators from academia include Arizona State University, where research is being conducted on flight control systems that will steer and orient a solar sail spacecraft, and the University of Alabama at Huntsville, which is helping with the charging analysis work.

The unique team-base approach to leveraging cooperative synergies already is winning praise as a leading example of the new "One NASA" concept in action.

In November of 2005, the ISP team was awarded the One NASA Peer Individual/Team Award, a citation given for the consolidation of talent and expertise among the agency's centers and partners working on the sôlar sails project.

Key to the success of the ISP team's collaborative efforts are continuous knowledge exchange dialogues among team members, monthly issues and risks reviews for each ISP area, and two major annual conferences, the AIAA Joint Propulsion Conference and the JANNAF Propulsion Meeting, where scientists collect to deliver technical papers, share ideas and explore innovation.

Meyer explains, "At these meetings, we get the benefit of interaction across the respective communities, which promotes problem identification and solving, and exposure to persons who have not been involved with us, but who may be able to make a contribution."

These meetings not only foster open exchange of knowledge and create a spirit of positive cooperation, but also have been the catalyst for novel contributions from unexpected sources.

"We participated in a materials conference that was attended by people from many areas of enterprise, not just aerospace," Meyer recalls. "A paper was presented describing the challenges that needed to be met in creating a material for advanced solar sails. A person from the audience came forward who manufactured a material that was used by makers of department store mannequins that had the very characteristics described and that material is presently a candidate for future generation sails."

In a way, the ISPT project exemplifies what really fuels innovation: the fusion of imagination and creative drive spark, two elements that NASA has been criticized for lacking over the years.

"I first went to work at Marshall, it was extremely creative back then, and it wasn't like a government agency at all," Dehaye remembers. "It was just fun to work for NASA and for them to get that type of feel back would be wonderful."

If the current efforts and achievements of the ISPT project are any indicator, perhaps NASA already has.

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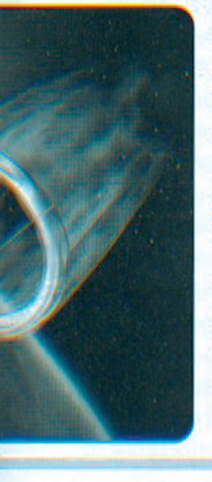
an electric field; electromagnetic, which uses a current to create magnetic field that accelerates the propellant; and electrothermal, where the propellant is accelerated by heating it electrically and directing it through a nozzle. Solar electric propulsion technologies can eliminate the dependence on successfully hitting the tight launch windows that come with using planet-gravity assisted maneuvers to accelerate spacecraft.



Momentum-Exchange Electrodynamic Reboot (MXER) Tether

Momentum-exchange tether propulsion will literally use a space-based 60 to 90-mile-long sling made of advanced materials to whip spacecraft from low-Earth into high-Earth orbits or into the reaches of deep space. Payloads like satellites could then be shot into low-earth orbit, rendezvous with spinning tether facilities and be whipped out into geosynchronous transfer orbit, eliminating the need for upper-stage booster rockets. NASA scientists believe tether technologies could become an "economical gateway to space."

Advanced Chemical Propulsion

While chemical propulsion is the first and still tried-and-true workhorse method of delivering payloads into space, NASA scientists are continuing to refine and innovate its possibilities. One way to improve chemical propellants is to use additives, such as gelling agents, to allow for more compact storage of the fuel. Another focus of advanced chemical propulsion research is in cryogenic systems and propellants, cold storage solutions that could allow NASA to more efficiently deliver probes to the outer planets of our solar system and beyond. In tandem with chemical propellant innovation is the need to improve hardware components and systems in order to handle the new properties and performance demands of the next generation of these chemical fuels.

— Russell Richey