NASA Facts

National Aeronautics and
Space Administration

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Huntsville, Alabama 35812

Solar Sail Propulsion

Traditionally, solar exploration missions have been limited by the performance margins of state-of-the-art chemical rocket engines and by the amount of fuel a spacecraft must carry to travel in space—up to 25 percent of the launch weight of typical planetary-exploration spacecraft. Now, NASA researchers are developing a key in-space propulsion technology (fig. 1) that—for some applications—could replace conventional chemical fuels with an inexhaustible natural resource: sunlight.

Solar sail propulsion is now being developed by NASA scientists and their partners in industry and academia, led by NASA's In-Space Propulsion Technology Office at Marshall Space Flight Center in Huntsville, Ala. The Center implements the In-Space Propulsion Technology Program on behalf of NASA's Science Mission Directorate in Washington. NASA fuels discoveries that make the world smarter, healthier and safer.

Using the Sun's energy as a way to travel through space could give spacecraft more mobility and versatility during flight—thus opening up new regions of the Solar System for exploration and science.

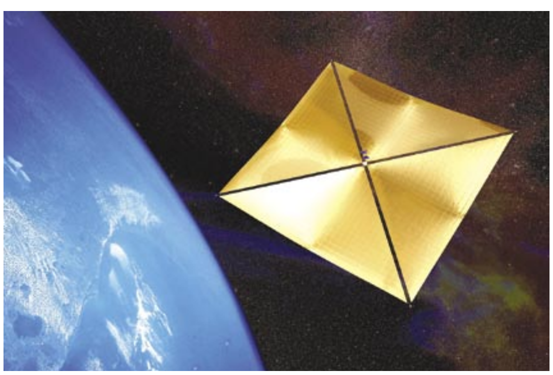

Figure 1: Solar Sail Propulsion concept in Earth Orbit.

Solar Sail History

The idea of "sailing" through space has been around for years. NASA considered the use of solar sails in the 1970s as a potential propulsion system for performing a rendezvous with Comet Halley during its 1986 flyby of Earth. Lightweight technologies such as "sails" were not mature enough at that time and the mission was deemed unfeasible. However, as more and more advances in design and construction of the large solar sails and their hardware systems were made in the 1980s and 1990s, the viability of the technology increased.

Solar sail propulsion uses sunlight to propel vehicles through space, much the way wind pushes sailboats across water. The technology uses solar photons—sunlight—which are reflected off giant, mirror-like sails made of lightweight, reflective material 40 to 100 times thinner than a piece of writing paper. The continuous photonic pressure provides enough thrust to perform maneuvers, such as hovering at a fixed point in space and rotating the space vehicle's plane of orbit, which would require too much propellant for conventional rocket systems. Because the Sun supplies the necessary propulsive energy, solar sails also require no onboard propellant, thus reducing payload mass.

Solar Sail Design

The sail itself would vary in size from tens of meters up to 1000 meters in diameter, depending on its mission destination, and typically would be shaped like a square. It would be compactly stored—to about the size of a suitcase—and stowed for launch. Once deployed, the sails would be supported by ultra-lightweight trusses.

Solar sails are composed of flat, smooth material covered with a reflective coating and supported by lightweight structures attached to a central hub. Near-term sails likely will use aluminized Mylar—a strong, thin polyester film—or CP-1, a space-rated insulating material. Both are proven materials previously flown in space. More robust sails might use a meshwork of interlocking carbon fibers.

There are three basic types of near-term solar sail designs: three-axis stabilized square sails, heliogyro sails and spinning disc sails. Heliogyro and spinning disc sails are similar in that both spin as they travel in space; however, their structural designs differ.

Heliogyro sails (fig. 2) are composed of several vanes, extending directly from a central hub, that "roll out" because of the spinning motion of the craft. Circular in shape, spinning disc sails (fig. 3) are connected to a structure composed of interlocking masts and booms which surround and connect to a craft.

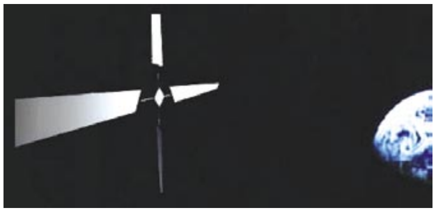

Figure 2: Concept design of heliogyro solar sail system.

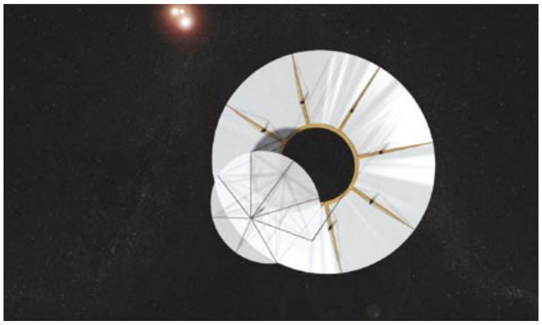

Figure 3: Concept design of spinning disc solar sail system.

NASA is concentrating its development effort on the three-axis stabilized, square sail (fig.4). This sail looks much like a kite and uses a rigid structure to extend and suspend the sail material in space to catch sunlight. Four booms extend from a central hub that houses the four sail quadrants during launch.

These booms are made of fiber-reinforced composite shell, much like an inflatable tube, or graphite rods assembled in a truss—a structural frame that provides support—which are lightweight yet stiff and weigh less than an ounce per foot. The sail orientation and resulting thrust vector—the direction in which the force is applied—is controlled by imposing a torque, a twisting motion or rotation, on the sail. This is done either by using control vanes—miniature sails—or by offsetting the center of the structure's mass from the center of solar pressure—much like the effect of pushing on a revolving door.

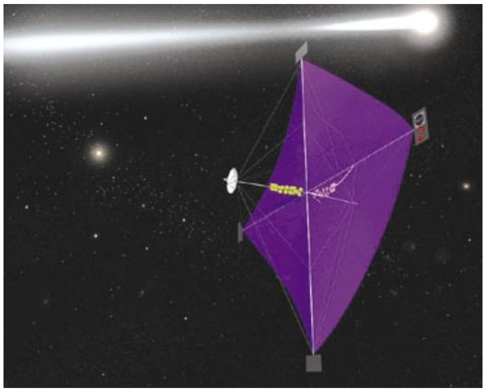

Figure 4: Concept design of 3-axis stabilized square solar sail system.

Two teams have been selected by NASA to lead hardware development activities that will culminate in ground demonstrations of key solar sail technology systems. L'Garde Inc., of Tustin, Calif., is developing a solar sail system that employs inflatable booms that are flexible at ambient temperatures but "rigidize" at temperatures below minus 35 degrees Celsius. Able Engineering Company, of Goleta, Calif., is developing a system based on the company's "CoilABLE Booms," which uncoil in space, much the way a screw is rotated to remove it from an object. This boom system has flown on several missions, including the Mars Pathfinder, launched in December 1996, and the Mars Polar Lander, which launched in January 1999.

Both hardware development activities produced 10-meter subscale solar sails that were tested under thermal vacuum conditions in 2004. The demonstration of a 20-meter subscale solar sail system at NASA's Glenn Research Center's Plum Brook facility near Sandusky, Ohio, will follow in early 2005.

Solar Sail Missions

Solar sail propulsion is a leading candidate for missions that require a space vehicle to complete a large variety of maneuvers, such as changing orbital elements or orientation, hovering at a fixed point, or for missions that require constant vehicle thrust to achieve science objectives. These propulsion technology systems eventually could lead to missions to study the Sun and its heliosphere—the magnetized bubble of plasma around the Sun—that are impossible using today's technology.

Solar sail research is part of NASA's In-Space Propulsion Technology Program, which is managed by the Science Mission Directorate in Washington and implemented by the Marshall Space Flight Center in Huntsville. The program's objective is to develop in-space propulsion technologies that can benefit near and mid-term NASA space science missions by significantly reducing cost, mass and travel times.

For more information about solar sail research, visit:
http://www.inspacepropulsion.com
http://www.nasa.gov

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