Interplanetary travel

A puff of wind for the solar sail?

from L.D. Friedman

ALTHOUGH out of favour with the space agencies, the idea of solar sailers coursing through the Solar System is being kept alive by enthusiasts on both sides of the Atlantic Ocean. The World Space Foundation, a non-profit public subscription space group in the US, is building a prototype sailing vehicle in preparation for a Space Shuttle or Ariane test, tentatively scheduled for 1986. A 260 m² sail has been successfully fabricated, packaged and deployed in a ground test.

In France a similar group of space enthusiasts has challenged the World to a solar sailing race to the Moon. The engineers at Union Pour la Promotion de la Propulsion Photonique (UPPP) have designed and built a scale model of a solar sail for their entry in the proposed race. They hope to obtain a ride on Ariane. Like the members of World Space Foundation, many of the volunteers working with UPPP are professional engineers and scientists with industry and space agencies. The president of World Space Foundation, Robert Staehle, is an engineer at NASA's Jet Propulsion Laboratory. Anne Marie Mainguy, new president of UPPP, is with ONERA.

At last October's meeting of the International Astronautical Federation, a third group from Prague also put forward plans. They are doing theoretical studies and building model sails to study dynamics of the vehicle.

Interest in the solar sail has remained extraordinary ever since NASA rejected as too risky the idea of using a sailing vehicle to rendezvous with Comet Halley (current planned missions to the Comet by Europe, Japan and the USSR will all fly-by at speeds of approximately 70 km s⁻¹ instead of being able to rendezvous, that is, match speed and position). The Jet Propulsion Laboratory studied two sail designs: the Heliogyro, a spinning vehicle which derived its structural rigidity and control from helicopter-like blades; and a square sail rigged like the sails of an ocean ship with spars, stays, winches and vanes for control and structure. The Heliogyro design was the finalist in that study although it defied intuition at the time. The present groups, working their smaller plans, now are using square sail designs.

Although the JPL study concluded that sailing was feasible, and perhaps advantageous for operations in the inner Solar System, the research work never found a home in NASA and was dropped. Study of the basic technology of thin films, materials, control of large vehicles and

structural dynamics has continued, however. The sail was a victim in part of bureaucratic scepticism and inertia, but more so of the decline in planetary exploration. Not only it, but also the electrical propulsion schemes of ion drive and nuclear drive were dropped from NASA plans. With the pace of exploration of the Solar System cut from one dozen missions per decade to one or two, there is simply no near-term need for low thrust propulsion — at least not until basic reconnaissance and exploration of the Solar System objects are complete.

But ideas such as a race to the Moon, and volunteers joining to build a Shuttle test vehicle and then finding financing to go to an asteroid, and students in a non-space-faring nation building and researching a new vehicle design, keep the idea of the sail alive. Operation in near-Earth orbit, as would be required in a Moon race, is not the best way of using the sail. It must be continually manoeuvred as it goes around the Earth in a lazy spiral to face (approximately) the Sun. Most sail enthusiasts look to the applications of the vehicle as an interplanetary shuttle. In this capacity it offers re-usability, no fuel consumption, efficiency and large mass cargo capability.

The sail is a low-thrust vehicle generating only about 10⁻⁴g acceleration (10⁻³ m s⁻²). That's why a slow spiral is necessary in

Earth orbit unless there's a large chemical rocket push. On interplanetary trajectories the small acceleration gradually builds up a high velocity. Sunlight pressure is the basic force, applying about 9 Nt km⁻² at the Earth's distance. Thus, a large (say 0.25 km²) reflective sail can have an acceleration of about 9 mm s⁻² divided by the mass per unit area of the sail ('load'). The JPL-designed sail vehicle had a total load of 5 g m⁻² (with the sail itself being 1.2 g m⁻²). Future designs, such as those developed by Eric Drexler at Massachusetts Institute of Technology, involve manufacturing the sail in orbit. This might reduce the load by a factor of three to five.

Whereas an ocean sailer operates at the interface of the wind and water, a space sailer derives its steerability by operating at the 'interface' of sunlight and orbital velocity. As the accompanying diagram shows, the sail can be made to spiral inwards or outwards in the Solar System by either adding or subtracting orbital velocity.

Managers in the space community are still sceptical about the sail's future. Both the World Space Foundation and UPPP have had to struggle for support and they have no assurance of completion of their efforts. Unlike governments and traditional private industry, however, they can work with uncertain funding, sequential grants, volunteers and donations until such time as they are ready for launch. Then, they hope that popular interest and the opportunity for realization of a true interplanetary cruise vehicle will be so strong that the naysayers will be suppressed in favour of the dreamers. □

A solar sail is a mirror that uses sunlight to obtain a propulsive thrust. As each photon bounces off the sail, the reversal of its momentum shows up as a reaction force perpendicular to the sail. To go inwards towards the Sun, the operator sets the sail to reflect sunlight along the sail's velocity vector (direction of motion) in its orbit around the Sun. The thrust is then opposed to the motion around the Sun and the sail slows down. Solar gravity then pulls the spacecraft inwards and the sail spirals in towards the Sun. The process is reversed to sail outwards to Mars, the asteroids and the outer planets. It is theoretically possible to build a sail so light that it would 'feel' no gravity from the Sun and go off in a straight line away from the Solar System.

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