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Solar winds to propel interplanetary sailing

Interplanetary exploration may call for the Columbus and Vasco da Gama spirit. It may also use similar sailors' technology, says S.Ananthanarayanan.

An important thing in all flight is to keep down the weight of the fuel needed for propulsion. The first flying machines used petrol that burned in air. When they needed to go higher, the engine changed to the turbo-jet, which can work in thin air.

Rocket economics

But when we go even higher, where there is scarce or no atmosphere, we have to rely on rocket propulsion, where the oxygen is carried along with the fuel. The simple rocket uses gunpowder, which is sulphur, with potassium chlorate, which is rich in oxygen. These oxygen-rich substances are heavier than fuel and make rockets unviable after a point.

The economics of space travel is that for an object to be placed in orbit, the load of fuel and its container makes up 95% of the take-off load. And most of this fuel is burnt to lift the fuel, not the payload. It is only when most of this 95% load has been burnt or jettisoned that the rocket is able to really get going. And again, for the long transit within space, more fuel needs to be carried, much of it, again, to propel fuel.

Wind propulsion

We certainly need to think of a way to pick up the fuel, or oxygen, en route, or use something out there in empty space. A solution in sight is to use the light from the sun, like the wind, to propel spacecraft.

Wind propels a sailboat because air has mass and when it is in motion it has momentum. When the wind strikes the sails, the energy in the wind is shared by both boat and the wind. The wind slows down, while the boat gets the better of the bargain. There is no wind out there in space, but there is certainly plenty of starlight! Now light has energy and Einstein's famous '$E=mc^2$' relation implies that photons have an effective mass too. Light thus has momentum and, like the wind, it should push along a spacecraft if there were a ‘sail’ to catch it! But the energy of a particle of light, or E in the equation, is a low figure and ‘c’, the speed of light, on the other side of the equation, is so high, that m, the mass of sunlight works out to be exceedingly low, and the ‘push’ is extremely feeble. A square meter of perfectly reflecting ‘solar sail’, in fact, would feel the pressure of only about 4 thousandths of the weight of a paperclip!

But given a large sail, even this tiny pressure could propel a craft once it is already in orbit and ready to start its voyage. When the craft gets too far from the sun, we could use the nearest starlight, swinging the sail around, like a real sailor. During flights lasting years, even this ‘lightweight’ pressure could build up tremendous speeds. Starlight sails could then be the way at least for advance shipment of materials and equipment!

How large a sail?

Still, thousandths of the weight of a paperclip is pretty small and the sails do need to be really large - thousands of square meters in area, the size of a football field, or more. And then, the sails themselves should not get too unwieldy!

A material of choice is a polymer-based film coated with aluminum for reflectivity. The search is on for a material that is strong enough to unfurl and yet would disintegrate once in place. This would leave just the thin aluminum film, which could bear that lightest ‘wind’ and propel the craft in the stillness of space!

A sail a kilometer square is a million square metres. The force due to light is then the weight of a million of those thousandths of a paperclip – maybe half a kilogram. If the load is 20 tonnes, the ratio is 1/40,000. Under gravity, things speed up by 10 metres a second each second. So our load of 20 tonnes would reach 10 metres a second in 40,000 seconds, or in some 11 hours. In 110 hours this would be 100 metres a second. In 1100 hours, or 45 days, it would be at a kilometer a second! We can imagine that in some years, the load would make good speed!

Another problem then would be to slow down for the landing. The only brake force, again, is light pressure. So, for the last half of the journey, the load would have to point its sails to stars on the other side!

But there is saving grace. Would it be necessary to roll up the sails on reaching the other end, for use in the return journey? In practice, astronauts would travel by faster, powered spacecraft and solar propulsion would be for supplies and equipment. As these would not need to be brought back, there would not be a return trip for the sails.