Missions of Gravity

Image Credit: NASA

Fly-by photo 1 Gravity assist manoeuvers are a great opportunity to take spectacular images. New Horizons took this evocative shot of Europa rising over Jupiter.

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In the last issue of Astronotes I described how interplanetary spacecraft travel in slow but energy-efficient transfer orbits to their destinations. The 'classic' trajectory of this type is the Hohmann orbit and I gave journey times for the planets of the Solar System for spacecraft following Hohmann orbits. I think that I should clarify one point, Hohmann orbits are those which allow you to reach a planet using the lowest possible energy to accelerate the craft, but there are an infinite number of possible transfer orbits. If you are willing to spend more energy by burning more fuel, it is possible to use a transfer orbit which allows a shorter journey time and a wider choice of launch windows. For example, in 1969, thanks to their high-enery trajectories, Mariner 6 and 7 reached Mars in five months rather than the nine months you would expect if they had used a Hohmann orbit.

Reaching the outer planets is always a slow process, but early in the Space Age we learned to exploit Nature to shave years off the journeys. This is the principle of gravitational assists (sometimes called slingshot manoeuvres). Here is a good, recent example of a gravitational assist in action.

The probe New Horizons was launched in 2006 and, thanks to a mighty Atlas V launch vehicle, was the fastest moving spacecraft to leave Earth yet. When its rocket motor shut down, New Horizons was travelling at 16.21 km/s (58 000km/h or 36 000mph). Thanks to this impressive speed, it passed the orbit of the Moon in nine hours. However the probe did not travel directly to its final destination- Pluto and its family of moons. Instead New Horizons arced across the Solar System towards Jupiter. As it neared the giant planet, New Horizons began to speed up as Jupiter's gravitational influence increased, at the same time its course began to change as Jupiter pulled the probe towards it. Seen from above, the probe's path would have developed a distinct kink, as Jupiter eased it into a new trajectory. On 28 February this year, the tiny probe made its closest approach, about 2 million kilometres from Jupiter. It then continued on its way, travelling 4 km/s faster than before, at a stroke taking

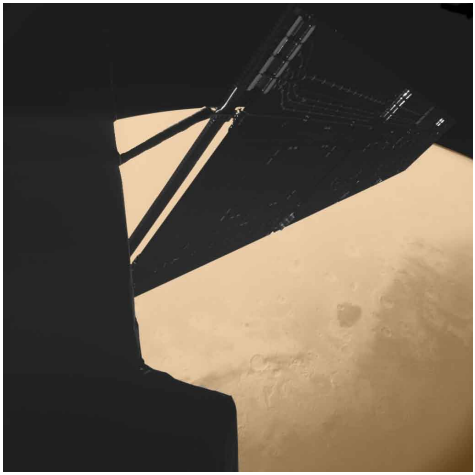

Image Credit: CIVA / Philae / ESA Rosetta

Fly-by photo 2 European comet probe Rosetta photographed Mars as it made its 2007 fly-by..

four years off its journey time to Pluto.

This sounds outrageous. Where did this increase in speed come from? The mathematics of the encounter show that energy and momentum were conserved throughout. The probe's gain in speed was essentially stolen from Jupiter. As a result of the encounter New Horizons sped up by a significant amount, but Jupiter was slowed down in its orbit around the Sun by a small amount. Thanks to New Horizons, the length of Jupiter's year has slightly increased, but not by much. The scale of Jupiter's speed loss is in proportion to the size difference between the giant planet and the spacecraft, so Jupiter was slowed by about a million trillionth of a millimetre per second.

Such gravity assist manoeuvres are common place now, there are several scheduled this year. Apart from New Horizons at Jupiter, ESA's Rosetta flew by Mars on 25 February to send it towards comet 67P/Churyumov-Gerasimenko and MESSENGER will fly past Venus on 6 June. MESSENGER's gravity assists are interesting as they are necessary to give the probe enough velocity to enter orbit around Mercury.

The classic (and most fortuitous) use of gravity assists was probably when Voyager 2 used three gravity assists (at Jupiter, Saturn and Uranus) to facilitate its epic tour of the outer planets. It was fortuitous as the planets are rarely neatly lined up to permit this. It is worth noting that the Voyager project was a cut-down version of a much more ambitious scheme, Project Grand Tour, which was rejected for financial reasons when NASA's bugdet was cut in the early 1970s. The Grand Tour project would have used a series of gravity assists, thanks to a once in 176 years planetary alignment, to send a probe to Jupiter, Saturn, Uranus, Neptune and Pluto!