Slow lane to the planets

By Colin Johnston, Science Communicator

Anyone interested in space exploration will know that travelling to the planets is a slow process. Years can pass between the spectacular launch of a rocket and a space probe's visit to the destination planet. The amazing data and images returned make it worth the wait but why do spacecraft take so long to get to other worlds? In fifty years of space travel the speeds do not seem to have improved an iota.

We all know that each planet is constantly moving around the Sun in its orbit, a fixed, almost circular path with the Sun at the centre. As observed by Kepler, and explained by Newton, the Sun's gravitation means that planets in orbits closer to the Sun move faster than those further out. The distances between the worlds are enormous, so large in fact that, it is best to measure them not in kilometres but in AU (Astronomical Units, 1 AU=150 million km, roughly).

Ideally, to get to, say, Mars our spacecraft would point its nose towards the planet and run its engine continuously, heading straight to its destination. Half way through the journey it would have to start to decelerate, shedding all the speed it had gained and coming to a halt at the planet. Travelling in a near straight line, this flight would be very fast, but it would not only be extremely energy inefficient, it will be impossible for the foreseeable future. There will be simply no propulsion system capable of this kind of trajectory for decades to come, even the proposed Project Orion nuclear blast spacedrive (See Astronotes December 2006) could not achieve this. Instead, after being hefted into space by a launch vehicle (i.e. a rocket) such as an Ariane 5, Atlas V or Soyuz-Fregat, most spacecraft run their onboard rocket motors long enough to build up sufficient speed to insert themselves into a very elliptical orbit around the Sun. This orbit is carefully chosen to pass nearby their target planet. The vehicle spends months to years coasting through space in a lazy arc towards its target. The path is slow but steady and it is sure to get there in the end. Such trajectories are called Hohmann transfer orbits after the German engineer Walter Hohmann (1880-1945) who discovered the concept in 1916 (and who later refused on principle to work on the Nazi rocket projects, a noble act which saw sadly few imitators). Hohmann orbits are the easiest way to reach other worlds.

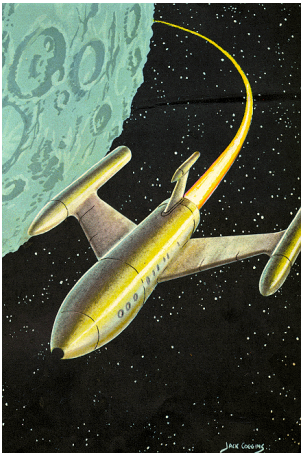

Image Credit: www.dreamsofspace.com

Between planets A 1950s spaceship concept from artist Jack Coggins. Sadly we cannot yet speed through the Solar System like this.

> "To arrive at empty space would be an embarrassment"

In practice, spacecraft never complete a whole Hohmann orbit as it would take them sailing past the planet only to loop back and return to the original starting point. Instead, as the spacecraft nears its destination, a push from its rocket motor slows it down enough for it to be caught by the gravity of its target planet. From then on it may achieve a stable orbit around the planet or land on the surface according to the plans of the people who sent it. As you can see, apart from occasional course corrections during the cruise

phase, the probe's motors only fire at the beginning and end of the journey.

If you feel like planning a space mission, here are the travel times from Earth to the planets and dwarf planets. Note that the transit time from Earth to Mercury is less than the transit time to Venus despite being a longer distance - remember orbital speeds are greater closer to the Sun!

Average Distances from the Sun in AU

Mercury	0.4
Venus	0.7
Earth	1.0 (by definition!)
Mars	1.5
Ceres	2.8
Jupiter	5.2
Saturn	9.5
Uranus	19.6
Neptune	30.0
Pluto	39.5
Eris	67.7

There is of course a slight additional complication. Nothing in space is standing still. The planets are continually moving in their orbits. This means that the timing of the launch must be extremely precise so that when the spacecraft reaches the other side of the Hohmann transfer orbit the target planet is there to meet it. To make an arduous journey through millions of kilometres only to arrive at empty space would be an embarrassment! In practice there are only certain periods when it is feasible to launch from Earth to reach another planet by transfer orbit. It is possible to calculate tables of possible departure times for each planet. For example, opportunities to fly to Mars occur only every 780 days. These periods are called launch windows, and they form a kind of timetable for launching missions to other planets. A launch window lasts only a comparatively short time and if you miss it you may have a long wait!

In fifty years of spaceflight, engineers have become accomplished at planning missions to elegantly send craft from world to world with minimum expenditure of energy. Hohmann transfer orbits are the sure and steady roads to the planets. However they are a very slow way to

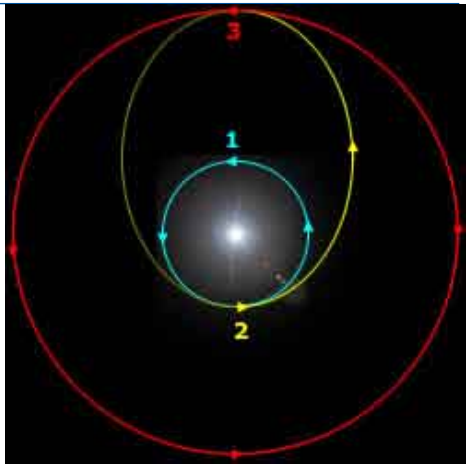

Image Credit: Flandmann via Wikimedia

Hohmann transfer orbit A spacecraft leaves an inner planet (orbit 1) and travels along a transfer orbit (2) to an outer planet (orbit 3). Note that unless it brakes at its destination the craft will keep on going until it returns to its starting point.

reach the most distant worlds. A Hohmann trajectory from Earth to Mars would take about nine months, but from Earth to Saturn would take more than six years. The equivalent time to Pluto is more than forty-five years, more than half a typical human life span. So how is NASA's New Horizons probe (launched 2006) going to reach Pluto on schedule in 2015? The key to shorter space journey times is to exploit the gravity of the planets for a free extra boost. We will take a look at this very clever application of Isaac Newton's Laws in another Astronotes.

Typical Hohmann orbit journey times (departing from Earth)

Mercury	3.5 months
Venus	4.8 months
Mars	8.5 months
Ceres	1 year 3.5 months
Jupiter	2 years 8.8 months
Saturn	6 years 1 month
Uranus	16 years 1 month
Neptune	31 years 4 months
Pluto	46 years
Eris	100 years!