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WHAT DOES IT TAKE TO PUT A MAN ON MARS?

A Lecture by

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What does it take to put a man on Mars

At the height of the cold war in 1961, John F Kennedy, shocked the world by announcing the USA's intention to put a man on the Moon by the end of the decade. This was an enormously ambitious plan considering human space travel was only a matter of a couple of years old. The Apollo programme, despite its set backs, ultimately succeeded in its goal in July 1969. At times it cost the American taxpayer as much as 7% of the country's GNP. Only a defence motivated or perhaps a social welfare activity could ever expect to command such expenditure.

The first problem then that has to be overcome in sending a person to Mars is the sheer cost. It is difficult to estimate what the overall financial bill might be but an indication of scale can be arrived at by comparisons with other parts of the space programme. For a start, UK's Beagle 2 lander at £25M over 5 years shows the relatively minor cost of putting a very small instrument package on Mars. Beagle 2 is only a component of ESA's 2003 Mars Express mission which has launch, orbiter platform and operations costs of £100M. NASA's much larger Mars Surveyor programme, which allows two launches, an orbiter and lander in each case, to our nearest planetary neighbour at every opportunity (two years apart) for the next ten years; Surveyor's budget requirement is for *ca* £200M/year. The US government's involvement in the International Space Station (ISS) (many other countries but not Britain are contributing) is probably at least an order of magnitude greater than their Mars effort per annum. NASA's existing Mars programme, and elements of the space station, are vital prerequisites for putting anyone on the red planet so it is easy to see so far we have hardly made any inroads into the eventual bill. Without the motivation of demonstrating military supremacy, it becomes fairly obvious that the only way a manned Mars landing will ever be achieved is by international finance and a will amongst the participating countries to show that, given an endeavour of sufficient magnitude and scale, they can cooperate.

The ISS will play a major part in manned exploration. The simplest reason being that at the present time we do not know about the physiological problems created by long periods of weightlessness. Only by continual and methodical investigation will all the medical implications be evaluated.

Without developing new methods of propulsion there are two routes to Mars assuming that in the first instance a manned voyage of discovery would exploit one conjunction of the planets to fly the outward journey and the next to fly home. The minimum journey time would be at least six months and thus of a duration longer than the longest tour of duty ever undertaken by a Mir astronaut; what is more, whatever happens, a man going to Mars will have to double up his exposure.

It is not absolutely clear yet which mission scenario is most hazardous for the would be astronauts. A minimum time trajectory would almost certainly be the chosen route for the return. Thus martian astronauts could either spend 150-180 days in space on the way to Mars and 500 plus days on the planet or vice versa. The planet is not the safest place to be, even if it does have 40% of Earth's gravity given the possible radiation / toxic environment, climate, dust storms etc, none of which we currently know very much about. Hence there is a continuous need for robotic missions prior to embarking on a manned programme.

With the above in mind, it is easy to understand the rationale in NASA's grand plan for Mars exploration. The Surveyor programme is one which encompasses scientific exploration but also has to address technological, engineering and resource implications. The medium term goal of NASA's activities is to return samples of Mars to Earth for investigation. They have already been joined in this venture by the French and Italian agencies, CNES and ASI. The former are donating an Ariane V as a launch vehicle and are undertaking the developments for rendez-vous activities in Mars orbit; the latter are heavily involved in a variety of telecommunication initiatives. The European Space Agency also wishes to play in part but at the present time its contribution is confined to providing Mars Express as a relay satellite. Britain has no officially defined role except via its ESA subscription; Beagle 2 potentially could be valuable to the NASA programme to counter a growing lobby which would try to prevent return of martian samples to Earth without a prolonged quarantine in-orbit. Beagle 2 would address life questions concerning Mars which would allow assessment of the hazard of back contamination due to introduction of an alien biology.

The methodology for sample return almost exactly mirrors the procedures which would be required for manned missions. The problems of course are related to the resources which are required. To return samples in 2008, the programme will commence in 2003 when a robotic roving vehicle will be dispatched to the martian surface to collect a series of specimens (a total of perhaps 200 grams). A variety of rocks and soil locations will be sampled and cached in a module which can be stowed into a Mars Ascent Vehicle (MAV) and lifted off into Mars orbit. Until we know more about the Mars environment, it is deemed too risky from a mechanical standpoint to wait for more than a couple of months on the surface.

Once the acquired samples are in orbit, they will have to wait for the requisite 500 days until another launch vehicle which sets out in 2005 arrives to rendezvous and collect the MAV which it locates by a beacon. After a transfer procedure there is a further wait until the next Mars Earth conjunction in 2007 when the samples will set out on a return trajectory to arrive at Earth in 2008. One might ask why not take the system to track down the MAV and undertake the return voyage in 2005 to arrive back in 2006. The answer is that the appropriate piece of space hardware is yet to be developed. An advantage of using the 2005 launch however is that the more powerful Ariane V is available, so too is the Mars Express orbiter to act as a communication relay. Therefore the 2005 opportunity will take a second lander and roving vehicle as well as another MAV so that in fact two sets of samples from different locations can be gathered up for return. The procedure is convoluted but as can be gathered it makes best use of what is available and shows how international collaboration can be used to defray enormous costs.

In the above scenario all the rendez-vous type activities take place in powered flight in orbit. This is because such procedures are much more easily controlled. So far the landing accuracy for vehicles going to Mars would be tens of kilometres; it might not seem much but traversing over unknown terrain for remote controlled vehicles is enormously difficulty and very hazardous.

The kinds of procedures being envisaged for sample return are almost exactly the same for manned landings. Multiple launches and voyages have to be the order of the day. However to fly across space the enormous amount of paraphernalia needed for manned expeditions needs space launchers having a lift capability of at least twenty times that of an Ariane V. The Ariane V to be employed in 2005 will despatch 3.3 tonnes en route for Mars. Space agencies are now thinking about 80 tonnes capacity rockets but for the moment such vehicles constitute only a dream. Even considering the mammoth capabilities of being discussed, initially at least three payloads would need to be sent out to cope with the logistics of manned missions. At the first launch window an Earth Return Vehicle (ERV)/ Earth Re-entry Capsule would be sent to a Mars parking orbit. At the same time, a Mars Ascent Vehicle suitable for men and a Habitation Facility would need to be conveyed on separate vehicles, and deployed to the planet's surface to create the first martian manned base. Only when all three items were safely in place would a team of astronauts (six would be a minimum) and their supplies be sent at the next window of opportunity. A second MAV would accompany them to land at the same site as the first and a second ERV to go into orbit. These two items would be launched as back-up solutions for emergencies. The astronauts would sojourn on the surface for how ever long the mission duration required, before returning at the next planetary conjunction. There probably would be a preference for having the astronauts on the martian surface for the longest period appropriate because the physiological problems would be minimised but, perhaps even more important, the psychological difficulties associated with having little to do whilst in space would be alleviated. There are plenty of experimental/exploration tasks which would occupy the astronauts on the surface of Mars so boredom would not be an issue.

The problem of bringing supplies for the astronauts would be immense, not just rations but the fundamentals of water, oxygen and fuel for the return journey. This major headache explains why NASA are undertaking some of the investigations they currently have underway apparently at the expense of science. For example there is an idea already being considered for a chemical resources plant which would provide the three essential ingredients. It relies on an abundance of carbon dioxide in the martian atmosphere and the transport of hydrogen from Earth to start up the project. Three simple chemical reactions are necessary:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

$$2H_2O \rightarrow 2H_2 + O_2$$

$$2O_2 + CH_4 \rightarrow CO_2 + 2H_2O$$

According to these equations methane as a rocket fuel, water and oxygen for life support can be created in situ; hydrogen gets recycled. It is assumed that power is provided by solar cells. The resources plant could be even more simple if martian rocks turn out to have an indigenous component of bound mineralogical water. This is not inconceivable since we know martian meteorites have water in them, which came with the samples rather than being adsorbed on Earth. To make thermally processing martian materials a power viable option, there needs to be perhaps more than 0.5wt% water in martian surface rocks and soils.

With so much in the way of infrastructure to establish, it is easy to see why a single permanent Mars base would be the order of the day. Other methods of transportation to explore the surface of Mars would be considered the best option for visiting potentially interesting surface locations. One possibility is to go ballooning but NASA have already indicated there might be a martian aeroplane on their 2003 launch opportunity. They have even named the day it would fly, December 16th, the hundredth anniversary of the Wright brothers taking to the air.

Another aspect of the mission scenario is that any astronauts returning from Mars would have to come in with a direct atmospheric entry trajectory (the same applies to the samples which could be brought back in 2008). It is very easy for people to believe that Mars return vehicles could be slowed down and docking manoeuvres undertaken with ISS. Slowing down means fuel, fuel means tanks and motors and everything means mass and power, the commodities in shortest supply in space missions because everything has ultimately to be lifted up from Earth. In respect of return vehicles, it is much better to make use of what is available for free, this means atmospheric re-entry capsules with a heat shield for slowing down and martian orbiters employing the solar panels for aerobraking. All these tricks are necessary to save consumables which ultimately means money. Incidentally, mass is in such short supply on the 2008 return opportunity that it is envisaged that the sample return container will be hard landed (without retrorockets or parachutes). The risks in this plan are a major cause for concern to the Planetary Protection lobby, especially since re-entry after a Mars to Earth interplanetary flight involves speeds about twice those which the Apollo astronauts experienced after travelling from the Moon.

When are we going to have a manned landing on Mars? This is one of the questions most frequently addressed to the Beagle 2 team. Despite the difficulties outlined above which involve many technological firsts, not to mention cost, people still believe it is something which is just around the corner. The most adventurous of NASA time lines progresses as shown in the accompanying figures. It requires what NASA calls a go/no go decision in 2001 and would envisage a team of astronauts triumphantly emerging from its re-entry capsule in 2012, forty years after man last set foot on the Moon. Maybe this time they will get the quote correct: "That's one small step for a man (woman), but a giant leap for mankind". A much more realistic scenario would have everything taking about a factor of two longer than so optimistically anticipated so 2025 might be a far better bet.

Further Reading

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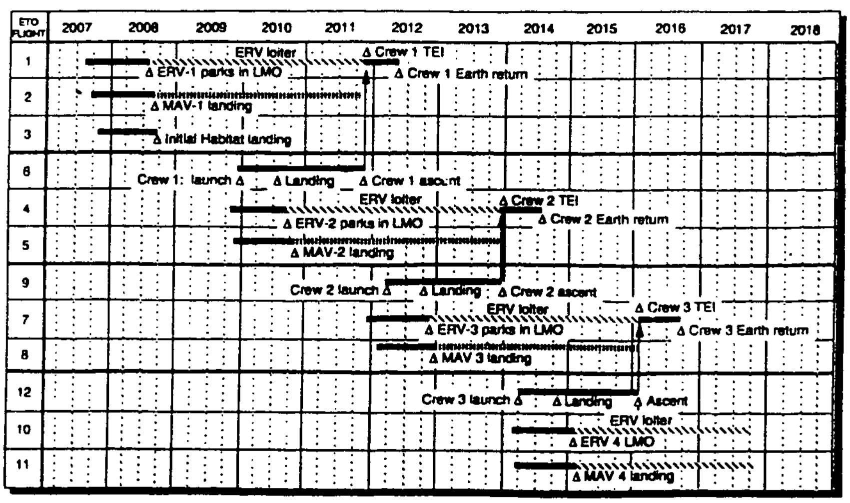

ERV: Earth Return Vehicle
MAV: Mars Ascent Vehicle
TEI: Trans Earth Injection
LMO: Low Mars Orbit