
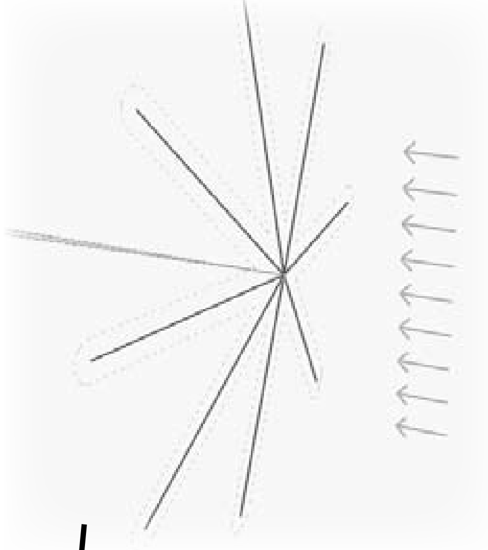

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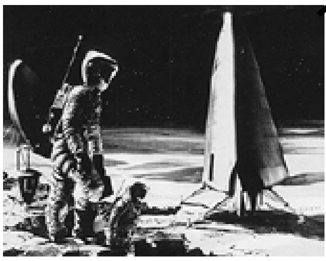


Suomen avaruustutkimusseura ry – Sällskapet för astronautisk forskning i Finland rf on 1959 perustettu yhdistys, jonka tarkoituksena on harjoittaa avaruusalan kokeilu-, harrastus-, tutkimus- ja tiedotustoimintaa sekä toimia avaruustutkimuksesta kiinnostuneiden henkilöiden yhdyssiteenä. Seura on Suomen äänivaltainen edustaja Kansainvälisessä astronautiikkaliitossa (IAF; International Astronautical Federation). Suomen avaruustutkimusseura julkaisee Avaruusluotain-lehteä ja ylläpitää kirjastoa, josta voi lainata alan kirjallisuutta, kuva- ja videomateriaalia. Seura järjestää avaruusaiheisia näyttelyitä ja tapahtumia sekä ylläpitää aihepiiriin liittyvää harrastustoimintaa.

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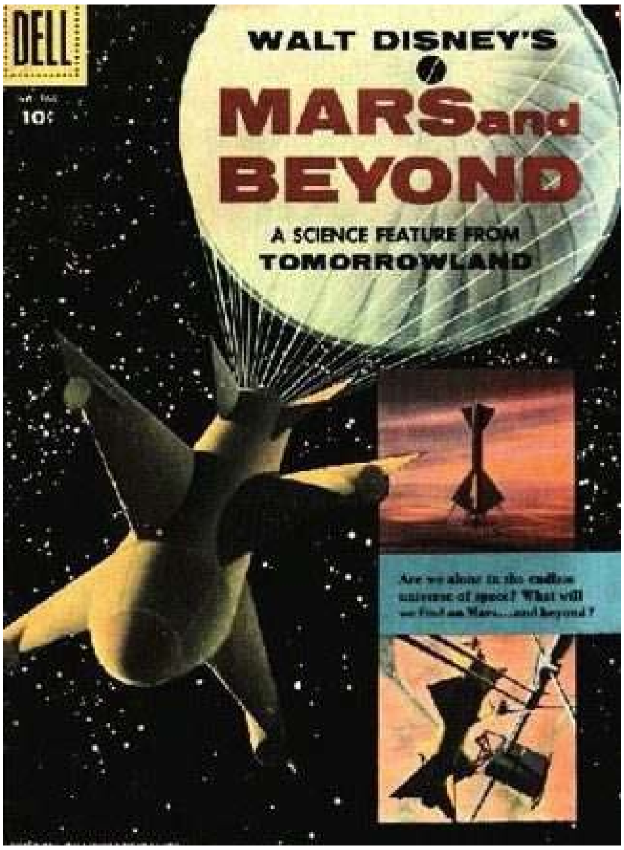
Nimellä tai nimimerkillä kirjoitetuissa artikkeleissa esitetyt mielipiteet ovat kirjoittajien henkilökohtaisia käsityksiä, eivätkä välttämättä vastaa seuran tai lehden virallista kantaa.

Edellisessä Avaruusluotaimen numerossa näimme viimeisen osan ruotsinkielisestä kuulentoja käsittelevästä jatkosarjasta. Nyt alkaa miehitettyjä Mars-lentoja koskettava englanninkielinen jatkosarja. Sarjan kirjoittaja, tohtori Mark Paton, työskenteli viime vuoden Ilmatieteen laitoksella Avaruus ja Yläilmakehä osastolla Mars-tutkimuksen parissa ja on nyt palannut takaisin Englantiin. **Miellyttävää Marsin matkaa!**

Piloted Mars Lander
by Mark Paton

INTRODUCTION

Landing humans on Mars will be an expensive, technologically difficult, risky and drawn out affair. According to the NASA Roadmap Team it will take 25 years to develop human scale demonstration missions. When eventually the crewed space ship departs, the inward and outward leg of the journey to Mars will still take six months apiece; with a one and a half year stop over on Mars. At Mars the piloted (i.e. with humans aboard) Lander will descend to the surface using an ugly amalgamation of technologies. It will be a scary nail biting experience, taking only a few minutes to transform the Lander from a aerodynamic hypersonic entry vehicle to a rocket powered, legged Lander. The Martian base will probably be manned for a year and a half before Mars and Earth are aligned so they can return to Earth. In the meantime the crew have, what appears to be, an infinite and desolate desert for company. To keep down the mass launched from Earth and the associated cost, they'll live off the land, making their own rocket fuel for the return flight back to Earth. Still the total expense will most likely be well over 10 billion US dollars even with every cost cutting trick applied to the mission. How can people understand and support such a seemingly expensive and pointless adventure? One way to educate people about the complexities of human space travel, and its excitement, is to use the increasing power of computers, software and the internet.



A Mars Lander. This design was featured in Walt Disney's TV feature Mars and Beyond. The rocket entered the atmosphere nose first and used the parachute for braking. The final part of the descent used a rocket engine. Image credit: Walt Disney

A few intrepid space explorers have taken up the challenge and implemented various human mars mission add-ons in a popular, free space flight simulator called Orbiter, developed by Dr. Martin Schweiger at University College London. It has a good Newtonian physics engine and a good graphics engine, with close to photo realistic renderings in some cases. It has proved to be an effective tool in communicating the technical complexities of a human Mars mission, with two virtual mission projects presented at the Mars Society Conference in August 2006. One of these presentations was by *Bruce Irving* with a paper called "Virtual Prototyping of a Human Mission to Mars".

Things are evolving and now Orbiter is being used by Bruce, a recently created JPL Solar System Ambassador as part of his mission to communicate the complexities of space exploration to the general public. A contributor to the virtual prototyping (VP) paper, Andrew McSorley has also moved on and is busy prototyping and iterating NASA's DRM 3.0 in Orbiter with participation of the Orbiter community. Even Dr. Robert Zubrin took time out to sit down with MSC presenters and Orbiteers Seth Hollingsead and Cyrus Phillips to watch his mission Mars Direct flying in the virtual world! Mark Paton also contributed to Bruce's paper building the model of the piloted Mars Lander described in this article and designing its Entry, Descent and Landing trajectory.

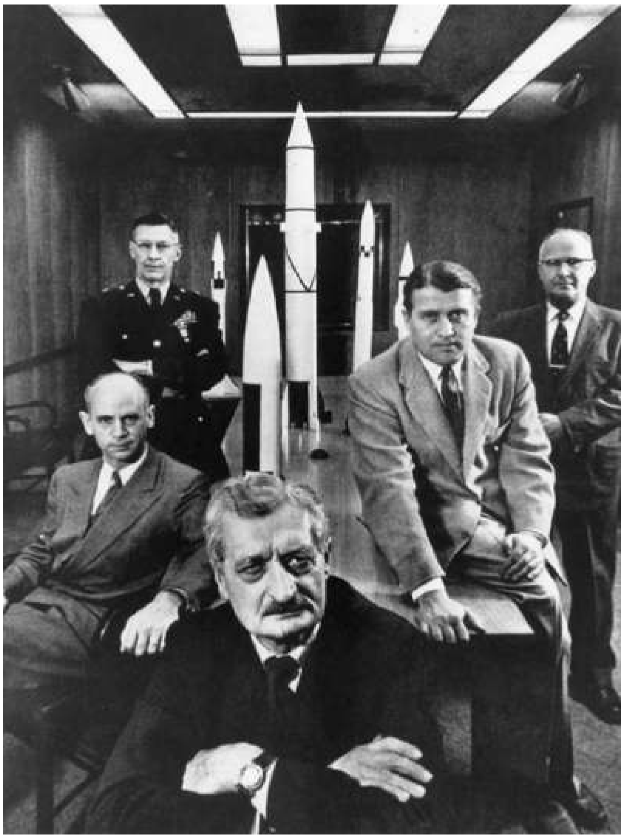
1. A HISTORY OF PILOTED MARS LANDERS

This section describes past and present mission plans beginning in the nineteen-fifties and finishing with some recent initiatives. Many human Mars missions have been studied but those only with details of Mars Landers are included in this section. Mars Landers have evolved over time, as more has been learnt about the atmosphere of Mars and new technologies have become available. The mission objective has changed from (mostly) a simple excursion to the surface, like with the Apollo LEMs on the Moon, to full scale exploration of the surface complete with a base able to sustain the crew for up to one and a half years and pressurised rovers to travel large distances. The political environment and the money available for space exploration has also had a significant effect on our plans to send humans to Mars. Consequently this makes for an altogether different kind of Lander (although there are superficial similarities) than that proposed in the early days of the space race.

1.1 THINKING BIG

One of the first serious attempts to plan a human mission to Mars was developed by Wernher von Braun. He published Das Marsprojekt in 1952. In his plan a flotilla of ten 4000 mT ships would be constructed in Earth orbit using 950 winged ferry flights. They would then journey to Mars with a 70 member crew. Three of the ships would each carry a glider for Landing on Mars. Each glider had a mass of 177 mT and large swept wings.

The huge surface area would allow an extended glide path reaching half way around the planet. The maximum g force from entry into the atmosphere would be 0.12 g and the maximum temperature would be 649 K. One of these Landers would land on a smooth surface at the pole on skids. The crew would then trek to somewhere around the equator and build a runway to allow the remaining wheeled gliders to land on Mars. Von Braun based the design of his Landers on a model of the Mars atmosphere with a surface pressure ten times higher than that measured by robotic Landers (i.e. by Viking etc). The Martian atmosphere is very thin and consequently the landing speed for these gliders would be very high. It would be like trying to land the Space Shuttle on a runway at 40 km altitude on Earth. In Braun's architecture the gliders would then be stood on their tails for launch back into orbit after a 400 day stay on Mars. Total time for the mission would be about 3 years.



Rocket men. In the foreground is Hermann Oberth an influential rocket pioneer. On the right is Wernher Von Braun and on the left is Ernst Stuhlinger. At the back, in military uniform, is General Holger Toftoy who was responsible for rounding up German rocket experts and at the back in the suit is Eberhard Rees Deputy Director of the Development Operations Division at the Army Ballistic Missile Agency. Image credit: NASA A Mars Lander.

Between 1953 and 1959 the US Army Ballistic Missile Agency studied a mission concept using electric propulsion to send humans to Mars. Ernst Stuhlinger lead the investigation and published his first paper on the subject in 1954. Stuhlinger, like von Braun and other rocket experts, had been rounded in Germany at the end of World War II, see figure of Rocket men.

The 1962 version of the mission involved the use of five ships, each being 150 m long, 360 mT in mass and with a crew of three. To get to Mars a nuclear reactor would drive electric-propulsion thrusters. It would take 56 days to spiral out of Earth orbit then a 146 day Earth to Mars journey and then 21 days to spiral down to Mars. Artificial gravity at one tenth of Earth's would be generated by spinning the ship. The ship also included a 50 mT radiation shelter. Three of the five ships each carried a 70 mT Lander. Two of the Landers carried cargo, one being a backup incase the first failed. The other carried the crew to the surface. First a cargo Lander landed followed by the crewed Lander for a 29 day stay on the surface. The 1957 version of Stuhlinger's mission was portrayed by Disney in their TV show Walt Disney's Wonderful World of Color in an episode called Mars & Beyond (See figure A Mars Lander). Here a Mars Lander was used that entered the Martian atmosphere nose first. A parachute was used to brake its fall followed by a rocket powered descent. The vehicle had short stubby fins to land on. The Lander is reminiscent of recent rocket shaped Lander designs such as the Case for Mars II study in 1984 or more recently NASAs Design Reference Mission 3.0 from 1997. However the DRM 3.0 biconic designs are based on nuclear weapon delivery systems probably not around or in a very early stage of development in the 1950s.

Jackson and Hammock of the Manned Spacecraft Center (now the Johnson Space Center) presented a Mars mission study in 1963. Their mission comprised of two ships one of which was crewed and housed a piloted Mars Excursion Module (MEM). The other ship was an unmanned Earth Return Vehicle (ERV). The ERV would be launched 50-100 days before the crewed ship and take 200 days to reach Mars. The crewed ship would travel using a faster trajectory taking only 120 days to reach Mars. This meant they would overtake the ERV and land on Mars in the MEM, spending 10 to 40 days on the surface.

Then as the ERV flies by Mars the crew launch in the ascent stage of their MEM and catch up with the flyby ERV. They would then enter Earth's atmosphere in an Apollo type command module.

Aeronutronic studied a MEM design for the Center's mission. Their design utilised a lifting body to minimise the amount of propellant required and reduce the mass. The vehicle was nine metres long with a mass of 30 mT. The maximum temperature during entry would be about 2000 K. At Mach 1.5 between an altitude of 23 and 30 km a parachute would be deployed from the nose. The MEM would land tail down with enough fuel for 60 s hover time if necessary. The landing site was chosen to be Cercopia near the Martian North Pole as it had been theorised that organism may follow the retreating ice cap. The MEM would have windows enabling the crew to look out and evaluate local hazards including unfriendly life forms! The MEM had two stages with the upper stage used for leaving the surface after a stay of 10-40 days. For their studies Aeronutronic used a model Mars atmosphere which was composed of 98.1% nitrogen and 1.9% carbon-dioxide at a pressure ten times less than on Earth, or at the same pressure on Earth at an altitude of 20 km. Their craft design would not work on Mars as designed. However lifting bodies have been proposed for use on Mars by Energia, NASA and others in more recent times for their low g levels and accurate targeting capability.

Mark Paton

The Planetary and Space Sciences Research Institute, The Open University

Avaruus 2007 Space Exhibition

Avaruus 2007 is a interesting space exhibition that will celebrate 50 years of spaceflight and 20 years of Finnish space activities with a view to the tourist flights to space and exploration missions in the future. The exhibition will take place at the special exhibitions hall of the Finnish Aviation Museum November 11, 2007 – February 29, 2008 and it will be direct continuation to Avaruus 2001 and Avaruus 2003 exhibitions.

The opening weekend (November 10 – 11, 2007) will spread the expo to the Helsinki city centre: the most waited presentations will be given at the big lecture hall of the University of Helsinki, just aside of the Senate square, the most central part of Helsinki. There will be activities at the museum during the weekend and the national amateur astronomy meeting Star Days will be also on the premises at the same time. All opening weekend activities will be free for the grand public.

During the four-month-exhibition, there will be approximately every second weekend lectures and special programme at the museum about the specific areas from historical reviews and technical presentations to kid's space weekend and flying the model rockets.

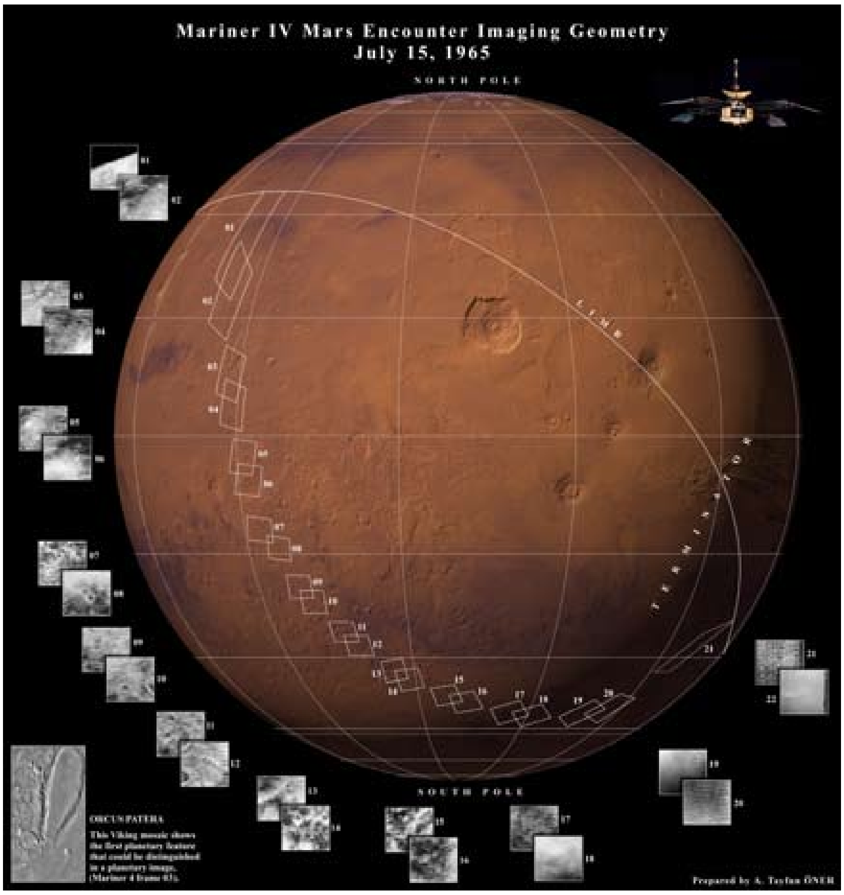
The exhibition will feature the highlights of the European space activity today: spacecraft models, interactive videos, panels and astronaut Christer Fuglesang as special guest during the opening weekend. As the Finns are practical people, the ESA part will have heavy weigh in Galileo and satellite navigation as well as GMES initiative with many Earth observation applications. On the scientific side coming small missions and bigger astronomy missions Planck and Herschel will be presented with up-to-date information from Mars, Venus and Titan. Visitors can also try flying a simulator modified for flying in thin atmosphere of the Mars.

The National Aviation Museum is located near the Helsinki-Vantaa Airport, only 20 minutes from the Helsinki city center. The museum is easily accessible with car, public transport and - of course - by plane.

Piloted Mars Landers
part II: **Rise of the Robots**

series by Mark Paton

In the 1950s and early 1960s interplanetary robotic missions were struggling to demonstrate their use with numerous failures and poor images. However in 1965 Mariner 4 reached Mars and took a swath of images of the surface (about 1 %), running from north to south and east to west, as it flew by. A large number of these images showed a heavily cratered landscape bearing a striking resemblance to our Moon. We now know that this is not representative of Mars. For example the northern hemisphere landscapes are younger and so have fewer craters than the southern hemisphere. Mariner 4 was also used to make radio-occultation measurements of the Martian atmosphere, revealing it to be about a hundred times less dense as Earth. Mariner 4 also helped determine that most of the Martian atmosphere must be carbon dioxide, not nitrogen as previously thought.

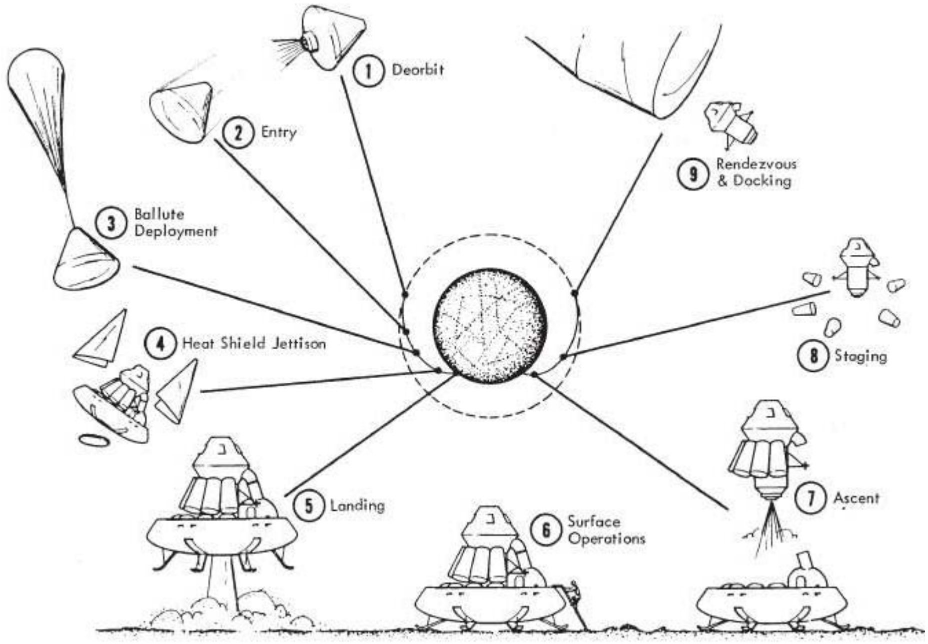


Mariner 4 imaging of Mars. Image credit: NASA

For future Landers this meant that more propellant would be needed for the descent and lifting bodies would be of reduced use, so landing Von Braun gliders would be out of the question. The Mariner 4 results dispelled the idea that intelligent life may exist on Mars, as the heavily cratered landscape and thin atmosphere, suggested that Mars must be very inhospitable.

One of the last big NASA studies for a while was done by Boeing in 1968 and incorporated the Mariner 4 findings. Their piloted Mars spacecraft was 33 m long with a mass of 140.5 MT. There was also a 144 m long propulsion section weighing 1000-2000 MT that included an 837 kN NERVA engine. A 33 MT Mars Excursion Module (MEM) would be used to descend and support two people on the surface for four days. Alternatively a 54.5 MT MEM could support four people for 30 days. The MEM had two stages, one for descent and one for ascent. The vehicle looked like the Apollo CM with a conical body and spherical shaped heat shield. The crew would experience seven Earth gravities during landing. We now know from long stays in microgravity aboard MIR and ISS that the maximum g deconditioned crews can experience is between three and five Earth gravities.

Between 1966 and 1968 a series of unmanned Mars probes was planned as a precursor to humans on Mars in the 1980s. This was known as the Voyager Mars Program. The program was to use hardware developed during the Apollo program such as the Saturn V to launch a pair of probes at the same time. The probes were to consist of a Mariner 9 type Orbiter with a Lander based on the lunar surveyor probe but fitted with a heat shield and parachutes. In 1968 a cut-price version of the Voyager probes was announced as the Viking program which included a biology experiment to look for life.



Mars Lander. North American Rockwell's design for a Mars Lander incorporating the findings of Mariner 4. Image credit: Boeing Company

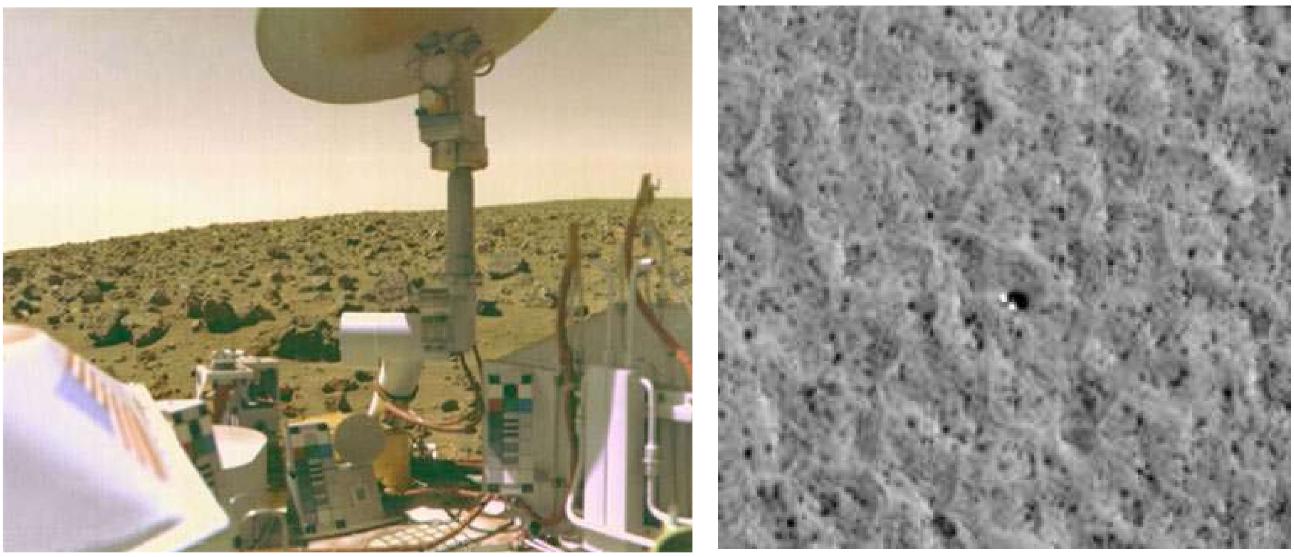
In 1976 Viking landed on Mars and did not find any conclusive evidence for life which was not good for Mars exploration support. However Viking did find silicon, calcium, chlorine, iron and titanium, demonstrating Mars was resource rich. Studies into In-Situ Resource Utilisation (ISRU) were published after the Viking landings. One idea was to split water to produce hydrogen and oxygen. It was decided that this needs heavy cooling equipment. Liquid methane / oxygen production was decided to be an interesting compromise. First water is used to produce oxygen and then hydrogen is reacted with carbon-dioxide to produce methane. The Viking results generated a surge of interest amongst scientists, engineers and in sending humans to Mars. In 1978 the first paper was published exploring the life-support possibilities for humans on Mars. It was called the "The Viking Results-The Case for Man on Mars".

THE CASE FOR MARS

In 1981 the first Case for Mars conference took place, named after the paper mentioned at the end of the last section. This conference was a public forum for Mars enthusiasts to meet and discuss how to explore Mars. In the 1984 conference plans for a permanent Mars base were developed and presented. The plan included cyclers, ISRU and aerobraking to reduce the mass and optimise reusability. Cyclers are large spacecraft that transfer the crew to and from Mars. They would be in a resonant orbit with Mars and Earth so they could return to Earth carrying only a small amount of onboard propellant.

The crew would use smaller shuttle crafts, assembled or refurbished in Earth orbit, to chase and catch up with a cycler. Three shuttles, with a total of 15 crew members would dock with the cycler in a pin wheel configuration. The whole assembly would be spun-up to generate artificial gravity at one third that on Earth. The shuttles would have a reusable heat shield serving as Mars Landers, Mars Ascent Vehicles and Earth Return Vehicles (together with a cylcer on its inward leg). The shuttle crafts derived from nuclear weapon delivery systems could be accurately steered at hypersonic velocities. The Landers were biconic in shape, 20 m long and had a mass of 28 MT.

On arrival at Mars the shuttles separated from the cycler and aerobrake into orbit around Mars. Once regrouped and the position of the base established the shuttles landed with their nose point upwards (i.e. base down), using parachutes and rockets. The cycler would pass Mars and return to Earth, picking up the previous base inhabitants. After a two year stay



Viking on Mars. The left image is a self portrait of Viking on the surface of Mars in the 1970s and the image on the right is an image of Viking taken from orbit in 2006 by MRO. Image credit: NASA

The Case for Mars II mission Landers. From left to right, Aaerobraking, landing, setting up base and the finished base. Image credit: Carter Emmart

the crew from the base would blast off the Martian surface using the shuttles, refuelled using ISRU. They would hook up with the passing cycler, while the new crew waited in orbit.

END OF THE SPACE RACE

Sally Ride charged with planning a new course for NASA after the space shuttle disaster published a report with four sets of initiatives. Among these was included an initiative to land humans on Mars. The mission design was begun in 1987 by SAIC. Their mission was based on a study by students at the University of Texas for the report. Orbital Transfer Vehicles (OTVs) would be used to push the automated one-way cargo vehicle that included a Mars lander to Mars. The 19.4 MT sprint vehicle would include the crews living quarters and the ERV mounted behind a 24.4 m diameter aerobrake for aerocapture. It would be boosted onto Mars by OTVs. Once the sprint vehicle docked with the cargo vehicle in Mars orbit three astronauts could access the Lander and descend to the Martian surface for a 10 to 20 day stay. A crew of three would remain in orbit. The cargo vehicle would be used to refuel the crewed vehicle (with ERV). The returning crewed vehicle would aerobrake into orbit around Earth and be refurbished for reuse. In 1987 Martin Marietta was chosen to lead the study (with SAIC assisting) successfully retaining its contract and producing reports for NASA until 1990.

In 1988 the Soviets sent two 6.5 ton spacecraft towards Mars, the largest spacecraft ever sent to the Red planet. The probes were called Phobos 1 and Phobos 2 after one of the two small moons of Mars, which was also a target for investigation. Also around this time Energia heavy launch vehicle, capable of putting 80-100 MT into LEO, about the same as the US Saturn V was used to launch the Soviet space shuttle. Soviets were also busy publishing a detailed human Mars mission using their heavy lift Energia rockets. As if to compliment these accomplishments and studies Titov and Manarov completed a year aboard the Mir space station, long enough for a round trip to Mars. It seemed the Soviet Union (with their impressive array of space hardware and experience) was on its way to sending humans to Mars. However, the economic reality was very different and it would not be too many years before the Soviet Union was no more.

Mars Desert research station in Utah, USA is build to simulate Zubrin's Mars Direct scheme. Picture taken by Crew 8.

The counter the Soviet's apparent mastery of space the Space Exploration Initiative (SEI) was started in 1989 by the Bush administration in the US. The SEI proved to be a failure in terms of producing hardware but generated some good ideas. The 90 day study proposed space station freedom with fueling facilities and hangers, base on the moon and then Mars, with heavy dependence on ISRU at moon and Phobos, four different, detailed, architectures are proposed. Also in 1990 Martin Marietta, sponsored by NASA to produce SEI concepts put forward the Mars Direct mission. This mission used a clever synthesis of ISRU, aerobraking and artificial gravity. A 40 MT cargo Lander including heat shield, descent stage, ERV, ISRU, 5.7 MT Hydrogen and a 100 kW nuclear reactor would be launched DIRECTLY to Mars without assembly or refuelling. An automated rover would then be used to deploy a nuclear powered reactor once on the surface of Mars. A 38 MT piloted craft would then be launched (and another ERV for back-up and following crew) after the fuel for the ERV had been produced. A small ERV was thought to be a possible weak link. Mars Direct required a hypothetical Ares heavy launch vehicle (240 MT) derived from shuttle technology (now being planned by NASA). The mission was presented by Robert Zubrin, its leading author and a Martin Marietta engineer, at the Case for Mar IV conference in 1990.

Continues in the next issue of the Spaceprobe!

Piloted Mars Lander

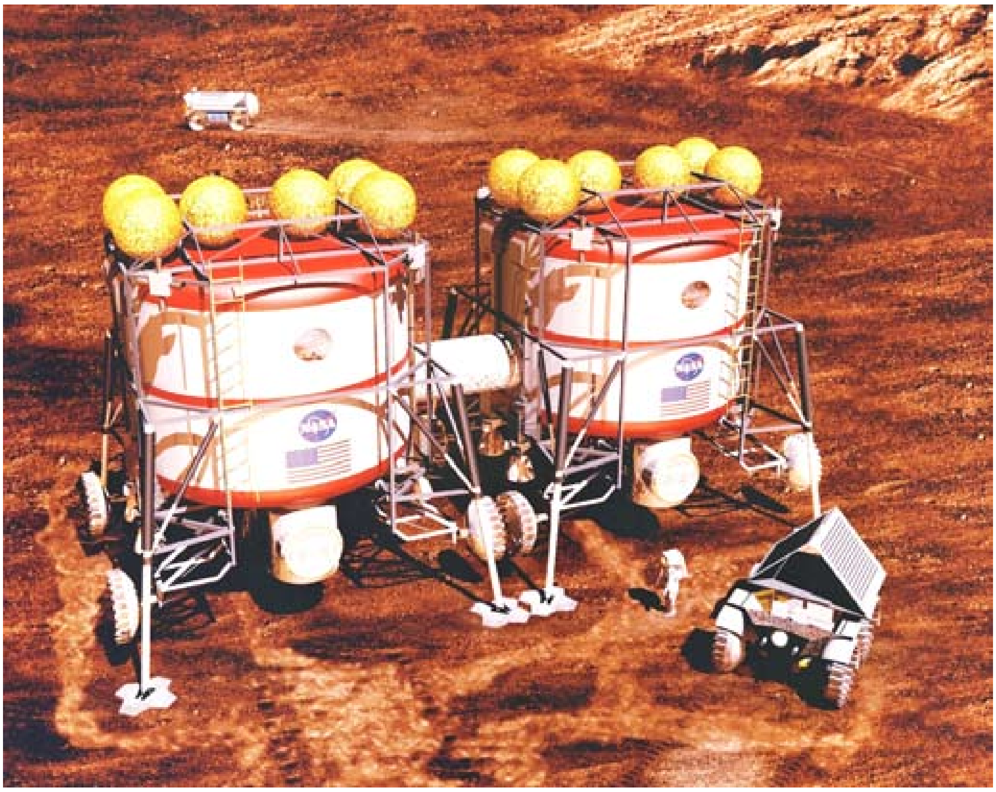
part III: Reference Missions

a Question of Mass?

series by Mark Paton

A QUESTION OF MASS?

Reference Missions (such as Mars Direct, NASAs DRMs, Mars Society reference mission etc) are used to further develop and explore mission architectures that can take humans to Mars, land them and return them to Earth. They are not intended to be complete. Quoting the introduction to DRM 3.0, "First, it is used to form a template by which subsequent exploration strategies may be evaluated for consideration as alternative or complementary approaches to the human exploration of Mars. Second the Reference Mission is intended to stimulate additional thought and development in the exploration community and beyond."



Remote surface exploration in regions around the habitat complex is accomplished by using pressurized

A response to Mars Direct was developed by the Mars Exploration Study Team in 1993. The mission architecture included a cargo Lander (MAV, ISRU, propellant factory and hydrogen and 40 tons of cargo including pressurised rover), empty habitat Lander and ERV Orbiter each being 60 to 70 mT each. These would be sent to Mars before a crewed habitat Lander is sent. This was to allow time for the production of fuel and consumables ready for the crew's arrival. The crewed habitat Lander can be docked with the backup second habitat on the surface using wheels to move it. The mission design included a departure from Mars Direct in that a large ERV Orbiter was included for a more comfortable return journey. Mars Direct used an ERV launched directly from the surface of Mars after using ISRU to produce its fuel. Due to mass constraints this allowed only a small living space for the returning crew. With NASA DRM 1.0 the crew blasted of the surface in a small MAV which then docked with the large ERV in orbit.

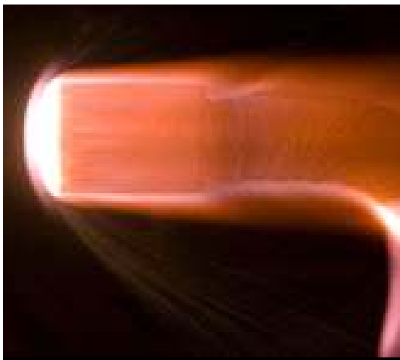
The subsequent NASA DRM 3.0 study has reduced the mass launched towards Mars. It became clear that a 200 mT HLLV launcher, required for DRM 1.0 would be very expensive to develop. Instead a more realistic 80 mT HLLV was envisaged for the DRM 3.0 (1997) study. Also the initial uncrewed habitat Lander was dropped for DRM 3.0. The Lander technology was revised to include biconic shaped Landers. These types of vehicles, based on nuclear warhead technology, have good targeting ability and the capability to manage g load due to their relative high lift to drag ratio. On the surface an inflatable habitat is used to augment the living volume available to the crew.

Mass considerations are important for a Mars mission when using available launcher technologies. Reference missions particularly try to reduce the fuel carried into orbit and beyond. To do this their architectures utilise immature / untested technologies (e.g. nuclear rockets, in-situ resource utilisation) to make a mission possible. The following 'tricks' are used:

- High specific impulse (a measure of efficiency) propulsion such as nuclear orelectric propulsion.

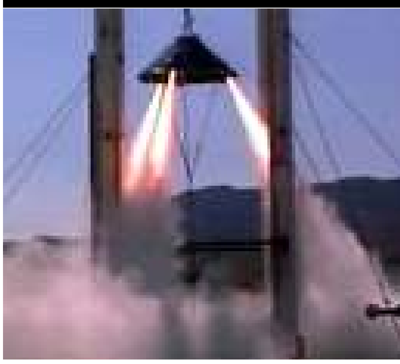
Aerobraking in Mars atmosphere for landing. The presence of the Martian atmosphere is essential for helping minimise the fuel taken up for a trip all the way to the Martian surface. Over ninety percent of the energy can be achieved by simply ploughing into the atmosphere with a heat shield. The remaining energy can be removed using parachutes and rocket engines. However for human scale Landers untested large aerobrakes (15 m diameter heat shield, 30 m diameter parachutes) are required.

- Aerocapture into Mars orbit. Used successfully on robotic probes for tweaking their orbit but not for insertion into orbit around Mars. Human mission may need two shields, a heavy one for aerocapture and a lighter one for thew descent. A mass penalty may come from the packaging of nested heat shields.
- In-situ resource utilisation (ISRU) on the surface of Mars to make fuel for the return flight to Earth. Sending a precursor robotic mission, with a tank of hydrogen and a power source, to break down atmospheric carbon dioxide to created methane, oxygen and water.
- Aerocapture into orbit around Earth. High approach speeds to Earth requires a heavy heat shield. Also an efficient lifting body is required to keep the g loads off a possibly deconditioned crew.
- Of course these undeveloped or untried technologies could be side stepped by using HLLVs capable of lifting >200 mT. Landing humans on Mars is inherently complicated as it is impractical to launch a single spacecraft that can transport a crew from the surface of the Earth to the surface of Mars and back again. Even the Apollo moon landings required two spacecraft, the Command and Service Module (CSM), to transport the crew into orbit around the moon and the Lunar Excursion Module (LEM) to get humans onto the lunar surface. Both Apollo spacecraft were launched on a single heavy lift launch vehicle (HLLV) the now discontinued Saturn V. To land on the more distant Martian surface and return to Earth requires two or three spacecraft, launched individually on HLLVs. Therefore a new HLLV capability will have to be developed.



Entry into the atmosphere at high speed produces very high temperatures reaching a maximum at an altitude of about 30 km. A heat shield is required to protect the spacecraft (situated behind the shield) from the hot plasma. The picture on the left shows a test.

Once the entry phase is over a parachute is deployed at supersonic speeds to slow down the Lander and pull it off the heat shield. This then exposes a terminal descent system such as rockets or airbags. On the right shows a test of the MER parachute.



On the left is a test of the retro rocket for the MER rovers. The retros slow the Lander to zero velocity just above the surface. The rover is then dropped to the surface, cocooned in airbags which deflate once bouncing has ceased.

Entry, descent and landing technologies for a robotic mission (<1mT). Images: NASA

It has been shown in DRM studies that about five times the mass landed on Mars has to be placed in LEO first. Since >30 mT of payload will need to be landed on the surface DRMs typically invoke launchers capable of launching 100 to 150 mT into low Earth orbit (for comparison the Saturn V could launch 100 tons into LEO). These high lift launchers can only be built through a national organisation like NASA due to the high cost (10 billion US dollars).

Alternatively smaller Medium Lift Launch Vehicles (MLLV) are being developed by private companies or those already in existence with NASA could be used to launch a modular design that is assembled in Earth orbit. This may then be cheaper especially if commercially development of space (e.g. tourism) drives the cost of launchers down or through increased efficiency (small team).

Launchers both expendable and reusable are being developed by private companies and may one day take us into orbit and beyond, perhaps taking human to Mars for the first time. Due to the expensive development cost these rocket launchers are being built by a handful of billionaires, who have already made their money elsewhere. Possibly the first private company that will begin launching payloads up to 570 kg into orbit will be SpaceX, founded by Elon Musk. They have already flown their falcon 1 vehicle in March 2006 carrying a satellite but the engine failed 26 s after launch. However the payload was thrown free when the rocket impacted the ocean on its side and was recovered with some damage. A second attempt to launch the falcon 1 will take place in 2007. SpaceX also have plans for a MLLV launcher the falcon 9 S9 that could boost 25 mT into LEO.

Another billionaire who is developing rockets is the owner of Amazon.com. His program is to develop a reusable rocket. The great thing about development of reusable rockets is that the design can be iterated with the same rocket! This is assuming the rocket isn't lost in an accident like the DC-X being developed by NASA and McDonald Douglas in the 1990s. However it demonstrated a turnaround time of 26 hours before being destroyed.

Space X Falcon 1

The Japanese have had a fruitful research project iteratively developing a reusable test vehicle from 1999 to 2003. In a book called "The Rocket Company" by Steinen he writes about the development of a reusable rocket in great detail projecting into the future when these rockets take human to Mars. He has a patented design of a unique design and trajectory for a reusable rocket that can, in principle, be operated under conditions as airlines do today.

The details of (Entry Descent and Landing) EDL technology in DRMs are often vague. This is a challenging part of the mission to design in terms of how to do it. We basically know how to return a crew back to the Earth's surface utilising its thick atmosphere. It was done as part as the Apollo mission to the Moon using a heat shield and three large parachutes to set it down in the Atlantic ocean at a leisurely 9 m s^{-1}. A vehicle returning from interplanetary space will be travelling faster so a new type of vehicle may have to be used based on a more aerodynamic design to give greater lift and reduce the g levels experienced by the crew. If the spacecraft is particularly large (it may be to house a crew of 4 to 6 for 6 months) then it may not even descend to the surface but remain in Earth orbit after using the atmosphere as a brake and dock with a space station.

We also know how to land humans on an airless body like the Moon, as with the LEM, which put about 10 mT on the surface of the Moon. However we do not know how to land humans on Mars, which has a thin atmosphere, unlike the Earth or the Moon. It is a technological problem, especially as the payload masses involved are so much higher than past robotic missions.

Aerobraking technologies used by past robotic missions to Mars, like the parachutes for Viking, cannot simply be scaled up. Mass for a solid object will increase approximately as the cube and surface area will increase as the square of a single dimension like radius or length. For a spacecraft there is a similar scaling up in the mass to surface area ratio as you increase the volume. Parachutes for a manned mission to Mars would have to be larger than previous parachutes used on Mars and deployed at higher speeds, possibly creating stability problems and increasing deployment time. In Reference Missions the authors often make estimates for parachute, heat shield and rocket fuel massed to land their habitats of excursion vehicles on the surface based on a scaled up version of the traditional heat shield, parachute and powered descent EDL system. However there are several consequences of this scaling approach that need to be examined. For a human payload g levels need to be constrained (effecting heat shield and parachute sizing) and inflation time of larger parachutes may incur a time penalty during the descent. Also pinpoint targeting (necessary for delivery of the crew next to a cargo Lander) needs to be developed (possibly requiring a large amount of propellant). These should be important considerations for Reference Missions as they control the amount of mass that has to be launched towards Mars (and landed on Mars).

Continues in the next Spaceprobe!