Piloted Mars Landers

Part VII: Aerocapture vehicle design

Series by Dr. Mark Paton

3.5 AEROCAPTURE VEHICLE DESIGN

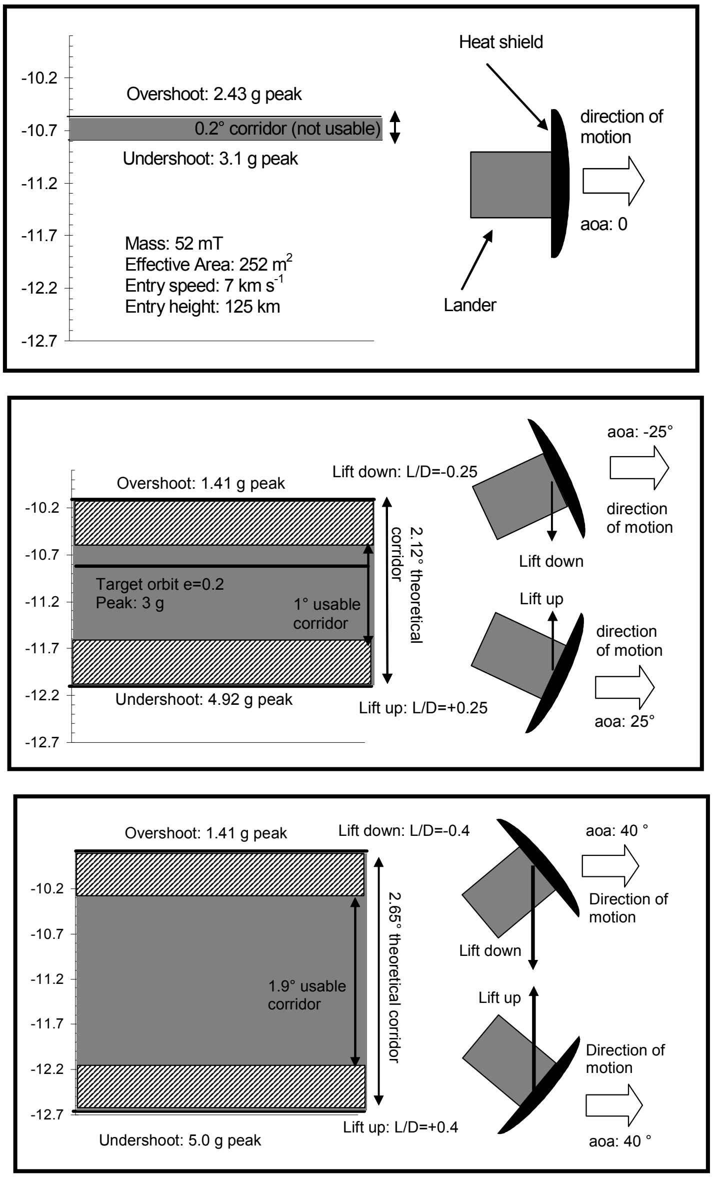
The mission architecture as described in Bonin (2006) requires the use of aerocapture to decelerate the Mars Transfer and Surface Vehicle (MTSV) into orbit around Mars before descending to the surface. To investigate the g level loading on the astronauts and determine the vehicle type (blunt or slender body) during this phase a computer model of the habitat module with aeroshell was developed by the author in FORTRAN called aerobrake2D. A validation was made by comparing the results with those in Orbiter Space Flight Simulator (OSFS) using the same model of the MTSV. It was found that neglecting the rotation of the Martian atmosphere in aerobrake2D gave a 10 % difference in the semi-major axis of the capture orbit compared to OSFS. When the rotation of the atmosphere was included the difference in the semi-major axis predicted by aerobrake2D and that in OSFS went down to 0.2%. This was deemed to be acceptable for setting up test scenarios in OSFS and experiment with the aerodynamic model.

The Martian atmosphere, like the Earth, can be split into distinct isothermal or adiabatic sections. Within these levels the temperature will either increase or decrease with altitude (adiabatic) or it will remain constant (isothermal), effecting the thickness (or density) with height. In OSFS five levels are modeled based on the real Martian atmosphere. In OSFS the atmosphere cuts to vacuum at 100 km. For an entry vehicle with a high enough ballistic coefficients, such as the MTSV, this has little effect as significant hypersonic decelerations start between 60 and 70 km.

A spacecraft approaching Mars on a hyperbolic trajectory has to reduce its velocity enough so it enters into an orbit. With aerocapture this is done by passing through the atmosphere and using drag forces for deceleration. For crewed missions the deceleration must be kept below a certain level. A crew that has been in reduced gravity will suffer from muscle wastage, including the heart. For a deconditioned crew the maximum is between 3 and 5 g. Therefore it is important to fly the spacecraft along a path that minimizes the forces on the crew. The forces experienced by the crew will depend on the entry angle, the entry speed (which depends on the approach speed to Mars and the gravity of Mars), the desired target orbit (with a small eccentricity for large payload advantage of an all propulsive capture) and on the aerodynamic properties of the vehicle (specifically the lift over drag ratio).

To determine if a low lift blunt body type of vehicle could be used for aerocapture the dependence of corridor width on L/D was calculated. These calculations also determined if the decelerations during aerocapture would be low enough for a human crew. The vehicle used was an Apollo type blunt body heat shield with an L/D that depends on the angle of attack with the on coming flow. The mass was 52 mT and the effective area was 242 m^2 (CD=1.242 and diameter=15.75 m). Three values of L/D were used. These were L/D=0 at an angle of attack of 0°, L/D=0.25 at an angle of attack of 25° and L/D=0.4 at an angle of attack of 40°.

This entry corridor width was determined using a simulation program



Entry corridors. Entry corridors were generated by flying a simulation of a blunt-body MTSV with different L/D values. The target orbit can be achieved with certainty if the L/D is bigger than 0.25.

MTSV model properties in OSFS. The total mass means empty mass plus fuel mass. The centre of mass is measured from the origin of the axis of the heat shield. The centre of drag of the heat shield has been moved back by 10 m to increase stability.

Component	Total mass / kg	Centre of mass along z axis / m
Habitat	24200	8.43
Garage	7500	4.045
Lander	8500	1.56
Shield	5800	0
Total	46000	5.38

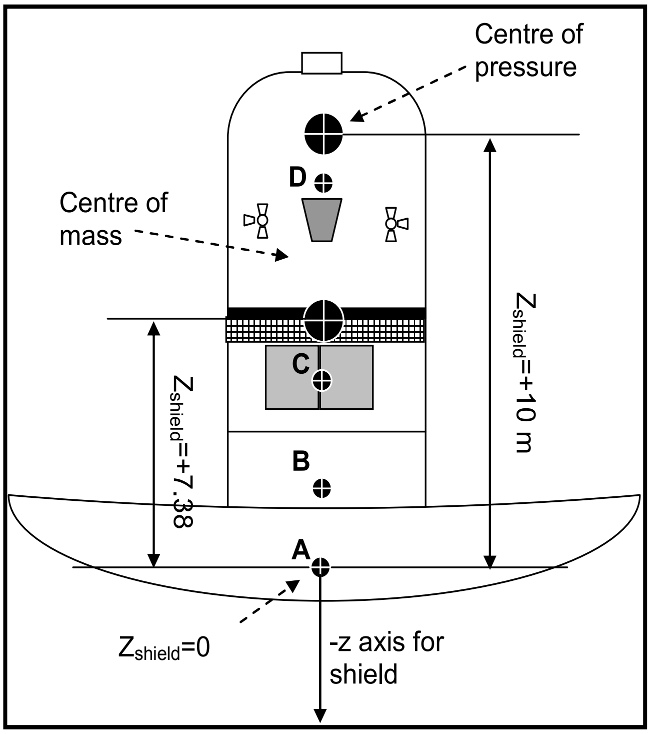
called aerobrake2D developed by the author. A vehicle with a fixed L/D was flown several times into the atmosphere of Mars from a start point (or entry point) of 125 km altitude and a start velocity of 7 km s^{-1} which corresponds to a low energy transfer to Mars. The velocity angle vector or the entry angle (relative to the horizon) was varied until the vehicle was successfully captured into orbit. Then the entry angle was decreased (more negative) until the vehicle experienced peak deceleration of 5 g (limit for a deconditioned crew). This was then the undershoot angle. Note in this case the undershoot case is not the entry angle for which the vehicle would impact the surface. Once the undershoot entry angle had been established the entry angle was increased (less negative) until the vehicle was no longer captured into orbit and flew off into space. The g level never exceeded the limit so this was then the overshoot angle. There was no accounting for uncertainties in navigation, atmosphere density or the aerodynamic properties of the vehicle during this process.

The aerocapture undershoot and overshoot boundaries were plotted as shown in the figure on page 14. An uncertainty of 0.4° in entry angle was assumed (from navigation, atmospheric and vehicle aerodynamic property uncertainties). This then makes the effective (safe) corridor 0.8° smaller than the actual corridor as shown on page 14. The information can then be analyzed to determine the best vehicle L/D value to use. The corridor for an L/D of 0 is only 0.2° which is too small to be certain of a successful aerocapture. It may be important to note the lower boundary of this particular corridor does not reach the 5 g limit. This is because the search algorithm used to find the boundaries used 0.1° step, a little coarse but good enough for this purposes. In any case it is clear that the corridor widens with increased lift capability. An L/D of 0.25 opens up the corridor wide enough for a successful capture into orbit. To reach the target orbit (e = 0.2) the vehicle has to reach the entry point at 10.7°. Therefore a blunt body design (as opposed to a slender body design) could be used for an aerocapture vehicle into Mars orbit.

The MTSV consists of four components that are assembled in Earth orbit before traveling to Mars. These are, from Bonin (2006), the habitat, garage, Lander and aeroshield (heat shield). In Orbiter they are assembled into a whole spacecraft using the docking ports facility. Each component has its own set of properties such as mass, drag, lift etc. For a single spacecraft, forces will act on the geometric centre of the mesh. For a multi-component spacecraft there will be an effective centre where forces will act. Table above lists the mass of each part of the MTSV together of the positions of each centre of mass relative to the origin of the heat shield. The centre of mass is calculated to be 7.38 m behind the centre of the heat shield.

It is essential for an entry capsule to maintain a forward facing heat shield for continuous thermal protection and for providing an effective drag surface. Stable flight can be achieved when the centre of mass is forward of the centre of pressure. Therefore it was desirable to define the MTSV model properties so the centre of mass was in front of the centre of pressure. The main pressure on the MTSV model in OSFS will be drag pressure. In reality lift would contribute but to keep the number of variables to a minimum (also OSFS only has a static atmosphere) only drag is modeled. The drag depends on the effective surface area (drag coefficient multiplied by the cross-sectional surface area). The effective surface area for the heat shield, normal to the z (long) axis is 252 m^2. The effective surface area of the other MTSV component (Lander module, garage, and habitat) was kept low so as not to add to the drag forces. The point where the drag acts on the shield was moved backwards by 10 m, placing it 3.22 m behind the centre of mass of the MTSV. The centre of pressure (or drag in this case) was placed at this point where guided by flight tests in Orbiter. □

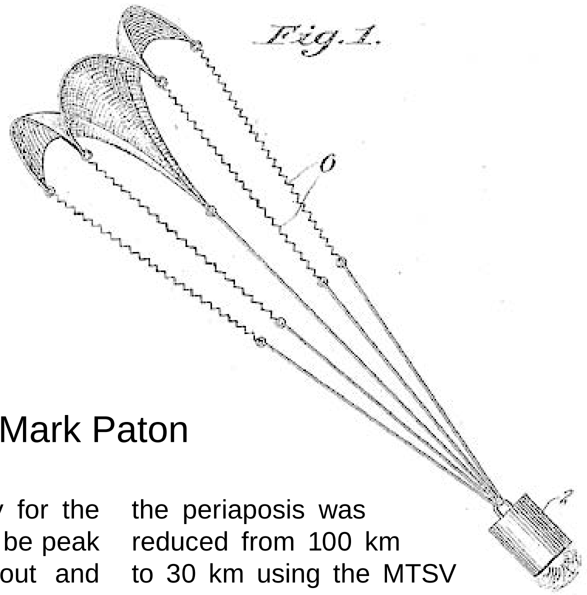
Continues in next Spaceprobe...



Aerodynamic stability MTSV location of the centre of mass (COM) and the centre of pressure (COP) for aerodynamic stability in Orbiter. Locations A, B, C and D show the centre of mass for the shield, Lander, garage and habitat respectively.

Piloted Mars Landers

Part VIII: Entry, Descent and Landing System design

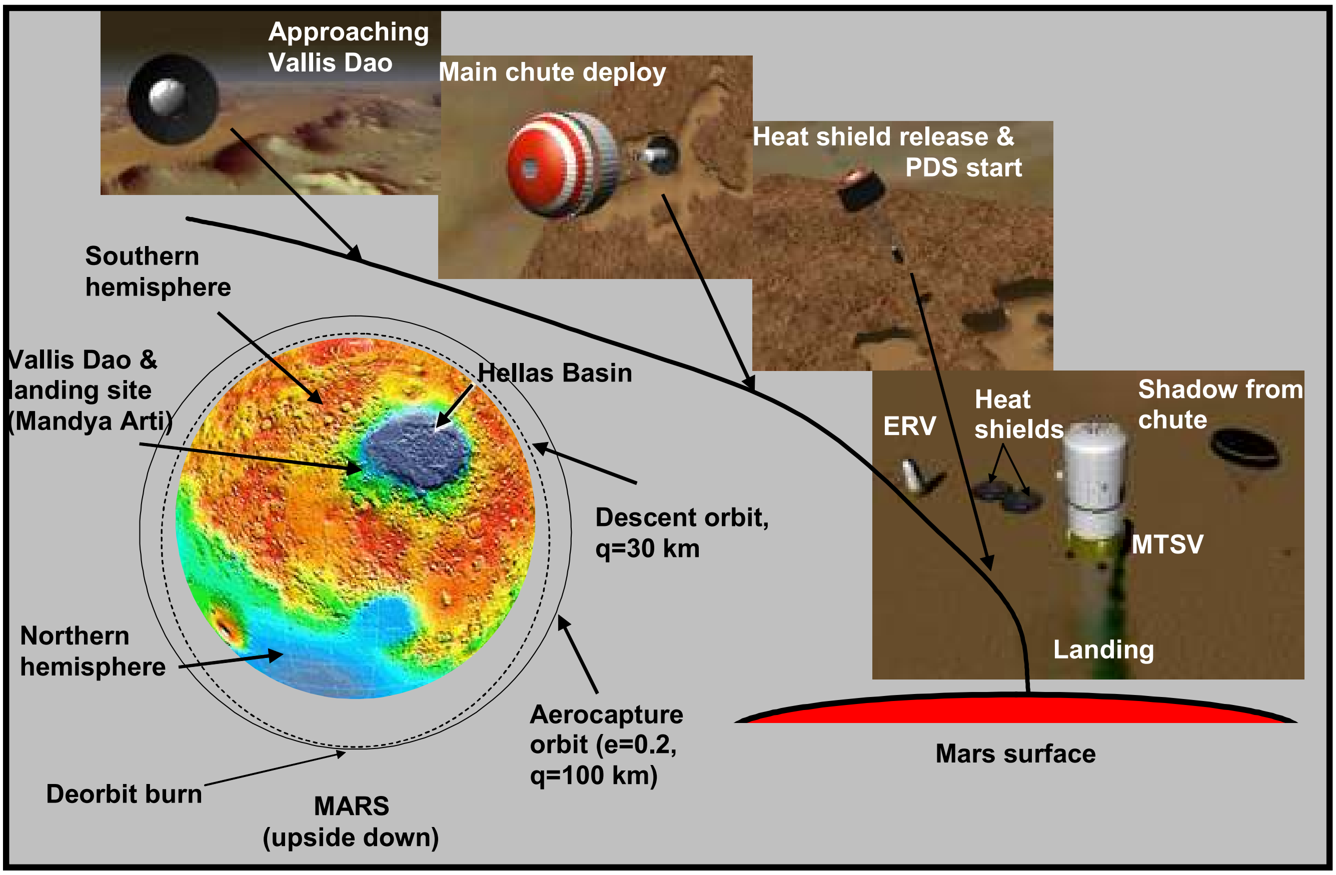


Series by Dr. Mark Paton

3.6 *Entry, Descent and Landing Systems have to reduce a spacecraft's velocity so a survivable impact or landing can be made within a predefined target area. Also for a human Lander the g levels should be constrained for human comfort during the descent (<5g). For our Mars Lander three types of decelerators were used, deployed in a sequence. These were a heat shield, parachutes and rocket engines.*

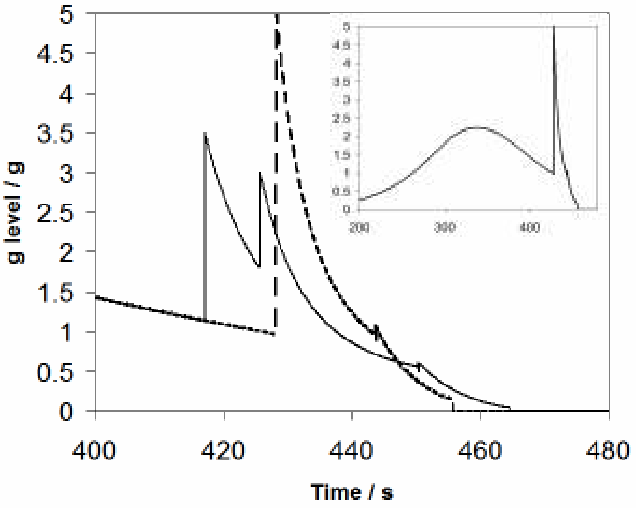
An expected sequence, say for the robotic Viking Lander, would be peak hypersonic deceleration about and heating at about 30 km (~2.5 minutes after entry), deployment of parachute and release of heat shield at 6 km (~6 minutes after entry) and initiation of rocket powered descent at 1.5 km (~9 minutes after entry) and landing about a minute later. Before descent the Mars Transfer and Surface Vehicle (MTSV) was in a fairly circular orbit with an eccentricity of 0.2 and periaposis of 100 km. This was found to be easily achievable using aerocapture technique described in the previous section (to within 0.2% of the desired orbit). To initiate descent the periaposis was reduced from 100 km to 30 km using the MTSV rockets at apoapsis. By the time the MTSV reached 30 km it would be experiencing maximum deceleration. It was found that the hypersonic deceleration load was within limits for human comfort.

However we found during descent experiments that the parachute was not large enough and did not provide enough drag to pull the Lander of the heat shield. The parachute diameter was fixed at 30 m as a practical maximum size. The heat shield was also fixed in size from the aerocapture



Descent trajectory. The MTSV ignited its engines to perform a deorbit burn, The MTSV begins its atmospheric entry at an altitude of 100 km traveling at 3.5 km s^{-1}, a 30 m DGB parachute is deployed at about 6 km altitude, at an altitude of 1.5 km the engines are ignited pulling the MTEV off the heat shield, at about 400 km the parachute is released and the MTSV heads off to land next to the ERV.

experiments. It was thought perhaps the parachute area could be increased just a little bit but the problem was more complicated than it seemed and the parachute would have to be huge. Simply scaling up the size of the parachute (say using a reference Lander like Viking) with the size of the whole vehicle does not work. This is because volume and mass scale up as the cube while surface area only scales up as the square. Therefore a characteristic length or diameter for a structure such as the heat shield will increase, as compared with the habitat characteristic diameter, as the power of 1.5. So if the diameter of the habitat is doubled then the diameter of the heat shield will have to be increased by a factor of about 2.8. This (perhaps) unexpected scaling is so the aerodynamic forces scale up in concert with the gravitational force.



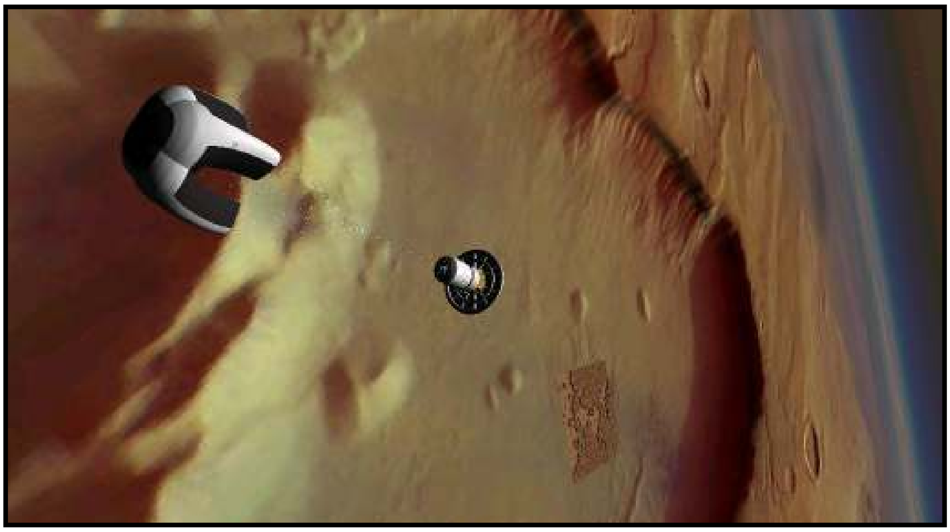
G levels at parachute deployment. The dotted line shows the g levels when using a single parachute. The solid line shows the g levels when using two parachutes. The inset shows a broad bump which is due to hypersonic deceleration during entry. The data is from the author's simulation program called aerobrake2D. The MTSV mass is 52 mT and the parachute areas are 525 m^2 (20 m diameter with C_D of 1.5) for the drogue parachute and 1050 m^2 (30 m diameter with C_D of 1.5) for the main parachute

A more obvious relationship can be found between mass and area. The radius of drag area scales in proportion with the square root of the mass. Therefore if the Viking Lander (~800 kg) is scaled up to a piloted Lander (~50000 kg) its 16 m diameter parachute would need to increase to ~100 m. A large parachute would take a long time to deploy and probably have stability problems. Another approach would be to reduce the size of the heat shield. With a 30 m parachute the heat shield should only have to be double the Viking Lander (~4 m) at 8 m to obtain positive separation between the shield and Lander at shield release. However this would not be large enough for aerocapture. A small heat shield would means that the MTSV would experience higher decelerations during aerocapture. Grant Bonin, the author of Mars for Less, suggested using the Lander's rocket engines to help pull the Lander away from the shield. This was tested and the extra deceleration was enough to pull the Lander off the heat shield.

The next task was to determine the optimum altitude for the release of the heat shield and the beginning of the terminal descent phase. For this purpose aerobrake2D was modified to simulate entry, descent and landing. The program was updated to change the parameters of the vehicle such as drag area and mass (for parachute deployment and shield release) triggered by reaching a specified velocity or altitude. For the powered descent a simple algorithm was implemented. Once ignited the engines were throttled at maximum thrust until the target touchdown speed was reached. The velocity was then maintained at this value until touchdown. During the descent the amount of fuel used was also calculated which manifested itself as a decrease in the thrust during a constant velocity descent. Several trial flights were performed to find the optimum altitude for engine start and shield release. A trial flight that produced a constant velocity descent rate from 10 m above the surface was chosen. From this the velocity and altitude triggers could be programmed into the MTSV autopilot and flown in the Orbiter Space Flight Simulator (OSFS). Discrepancies in Entry, Descent and Landing (EDL) results from flying the MTSV in aerobrake2D and OSFS led the author to compare the atmosphere models. This revealed an inconsistency (step change) in the density-altitude profile in the OSFS. The creator of OSFS was informed and kindly (and quickly) updated the module plug in (dll) for the Martian atmosphere.

During EDL simulations in aerobrake2D it was noticed that the g level at parachute deployment was exceeding 5 g, possibly too high for a deconditioned crew. To ease the load on the crew a drogue parachute with half the area of the main 30 m parachute was added into the EDL sequence before the main parachute. It acted to reduce the velocity of the MTSV so the load on the main parachute (and g levels) would be lower. The drogue parachute had to be deployed at Mach 3.1 implying significant amount of heating and high dynamic pressure. Attempts were made to calculate the temperature of the parachute and investigate if a parachute could be used at this velocity on Mars.

The stagnation point (in front of the shield nose) temperature of a Mars Pathfinder aeroshell travelling at Mach 3.2 will be 821 K from a Sutton-Grave correlation, assuming a nose radius of 0.375 m and with an ambient atmosphere temperature of 195 K. A parachute is a completely different (inverted) shape and size so this type of analysis may not be useful. Indeed the Sutton-Grave correlation shows that the temperature is dependant on nose radius, the smaller the radius the higher the stagnation temperature. Also the parachute is travelling at speeds in the supersonic velocity region (or very nearly, the boundary is very nebulous), not in the hypersonic region where the thermal physics are more complicated. At hypersonic speeds (> Mach 5) heating of surfaces is complicated as the high temperatures change the gas chemistry. At very high Mach numbers heating is also due to radiation as well as convection. At supersonic speeds (< Mach 5) aerodynamic heating

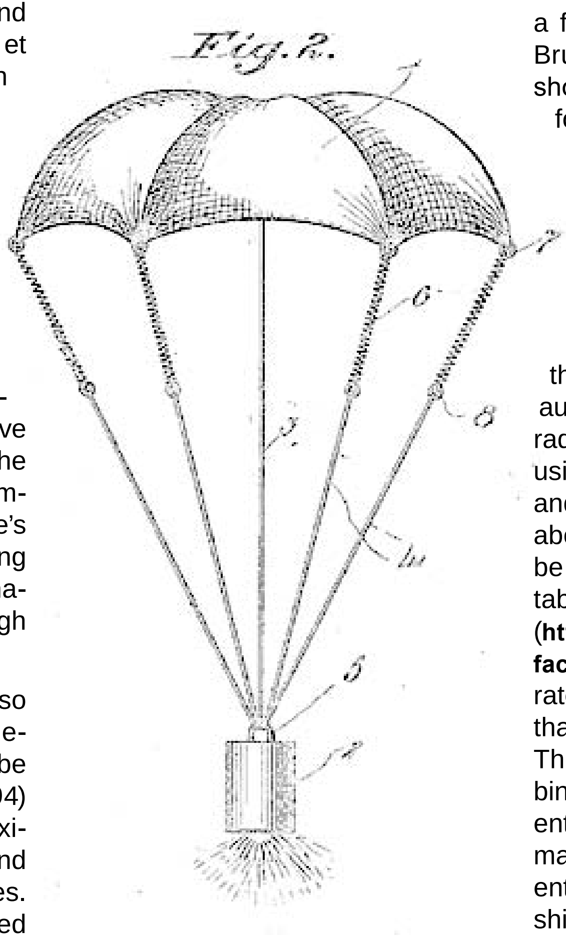


MTSV cross parachute. A cross parachute, impregnated with an ablative material, was added when it was realized there may be high temperatures (and high mechanical loads) .

occurs over flat adiabatic surfaces (like wings) when a gas is bought to rest via friction. Assuming the sides of the parachute are nearly flat (not a bad approximation for a cross parachute, for example) the temperature at the stagnation point will be 569 K. A simple analysis can be made by assuming all kinetic energy is turned into heat. This gives an average temperature of about 1619 K. This would be the maximum temperature possible.

Clearly the parachute will experience high temperatures. An accurate analysis would involve a numerical simulation such as undertaken by La Farge et al. (1994). Dynamic pressure and temperature analysis were conducted on a cross parachute at Mach 4. A stagnation temperature of 915 K was found with temperatures reaching 904 K at the skirts of the canopy. The majority of the structure experiences temperatures greater than 750 K. Nylon has a melting temperature of 522 K and Kevlar has a melting temperature of 750 K and both would be unsuitable. La Farge et al. decided to only consider a Mach 3 case. For the Mach 3 case they calculated an average canopy temperature of 373 K, significantly less than the Mach 4 case. However our EDL design demanded a > Mach 3 so some solution had to be found to enable the parachute to operate under high temperatures. Inflatable heat shield technology involves impregnating the fabric with an ablative material. At high temperatures the ablative material decomposes so limiting the heat entering the capsule's interior. It was thought impregnating the cross parachute with ablative material would allow it to operate at high Mach numbers.

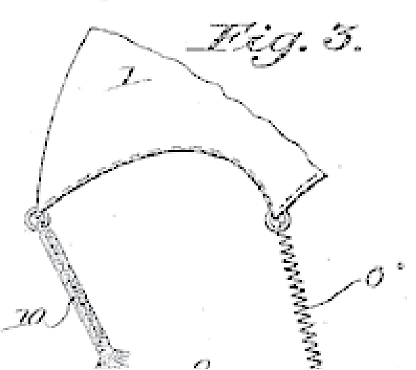
The dynamic pressures were not so much of a concern. At parachute deployment at 14 km altitude would be about 4 kN m^{-2}. La Farge et al. (1994) observed peak stresses of approximately 93 kN m^{-2} in the canopy and 27.6 kN m^{-2} in the suspension lines. Under these condition they concluded that the cross parachute should preserve structural integrity. The main 30 m parachute was released at Mach 2.2. This is inside the Viking heritage parachute box and so would not need to use any ablative materials for cooling. Keeping the main parachute attached during the powered descent phase reduced the amount fuel used, allowing for greater target cross-range and down-range correction capability. The main parachute was released at some time just before touchdown. The MTSV could then fly out from under the parachute in search of the Earth Return Vehicle (ERV) before the parachute falls on top of it.



The idea for the cross parachute design came after the presentation of the virtual prototyping paper at the Mars Society Conference. However a few weeks before the conference, Bruce Irving, suggested that we should use an inflatable heat shield for the MTSV. This would then solve a lot of operational problems, like the positioning of the Reentry Control System (RCS) thrusters and the shadowing of the solar panels. An inflatable heat shield could remain stowed until approaching Mars. A thermal analysis was made by the author on a heat shield with a nose radius and found that the temperature, using a Sutton-Grave correlation and a nose radius of 10 m would be about 900 K. The heating rate would be about 17 W cm^{-2}. During an inflatable technology demonstrator by esa (**http://www.spaceflight.esa.int/irdt/factsheet.pdf**) the maximum heating rate was 35 W cm^{-2}. It was concluded that such a heat shield could be used. The low temperature is due to a combination of a large heat shield and low entry speed from orbit (3.5 km s^{-1}). It may be interesting to note the Viking entry was from orbit and used a heat shield made of cork. It was a simple matter of replacing the mesh of the rigid heat shield with a new mesh that looked like it was inflatable. The mass and area values were kept the same as the time was limited to work out the numbers for a new EDL sequence.

We chose our landing site to be in Vallis Dao on the edge of Hellas Basin. The valley floor is much lower than the surrounding highlands giving a greater distance to decelerate (and denser atmosphere). In the OSFS it is possible to render landscapes as textured meshes. Planets are represented as a smooth sphere textured with an image based on spacecraft images. The mesh then sits on this sphere, the surface of the sphere being a solid surface. On Mars in OSFS there are no southern hemisphere lowlands or northern hemisphere high lands as on the real Mars, although it can be done if a mesh of the whole planet is made. Having 3D terrain went some way to making the final approach and landing more realistic.□

Parachute pictures from J.W. Taylor's patent, 1920.



Latest version of the MTSV (March 2007).

Property or component	Notes
Pre-entry mass	52 mT
Landed mass	38 mT
Fuel	Originally 6 mT (Bonin, 2006) of methane/oxygen, 2 mT for ~150 m s^{-1} delta V and 4 mT for ~70 s hover and down-range and cross-range correction (~0.5 km travelling at 10 m s^{-1}) extra 6 mT included for ~2 minutes hover for 5 km down-range and cross-range correction. Targeting not simulated yet..
Hover engine	4x100 kN, isp 327 s^{-1}, can land on 3 engines if one fails.
Main engine	50 kN thrust, part of a beefed up RCS system, used for deorbit and pin-point targeting on the surface
Landing gear	Originally DC-X type deployable gear (x4 pads), perhaps better deployed in Mars orbit after aerocapture. Also deployed outwards to increase slope tolerance.
Slope tolerance	22° calculated from centre of mass and position for 4.5 m dimaeter MTSV. Moving the landing gear outwards by one metre (i.e. expanding diameter to 6.5 m) will increase the slope tolerance by 8°.
Habitat diameter and height (or length)	6.5 m expanded, 4.5 m nominal, 12 m high
Living space	232 m^3 with 6.5 m diameter habitat or 90 m^3 with 4.5 m diameter habitat. Additional ~100 m^3 inflatable on the surface.
Heat shield type	16 m diameter, spherical surface cut from a sphere 20 m in diameter sized from thermal considerations, C_D=1.28, L/D=0.3, aoa=30°
Heat shield mass	1x6 mT rigid heat shield, or 2x2 mT (with gas, pumps etc) inflatable heat shield plus 1x2mT backup shield (inflatable heat shield mass requires further investigation)
Hypersonic guidance and targeting	Bank modulation based on Apollo guidance program, 2 km x 5.5 km uncertainty at parachute deployment (assuming extrapolations from Phoenix/MSL work) not implemented into simulation.
Parachutes	1 x 25 m Disc-Gap-Band parachute (388 m^2 effective area) deployed at Mach 1.8, 6.5 km altitude

Piloted Mars Landers take a step closer to Mars also in next Spaceprobe...

Tulevissa numeroissa

Muistattehan vielä numerossa 2/2006 esitellyn Juhani Hemmin nesterakettiprojektin? Juttu löytyy SATSin verkkosivuilta: **http://www.sats-saff.fi**.

Nastolalaiset linnut ovat alkaneet laajentaa reviiriään, sillä ne vaistoavat että ilmatilan yksinoikeus voi kohta olla uhattuna - nesterakettiprojekti etenee! Tästäkin projektista kertoo ensimmäisenä Avaruusluotain, pysy siis taajuudella!

Piloted Mars Landers

Part IX - More Mars Landers

This is the final episode in series by Dr. Mark Paton

3.7 MORE MARS LANDERS.

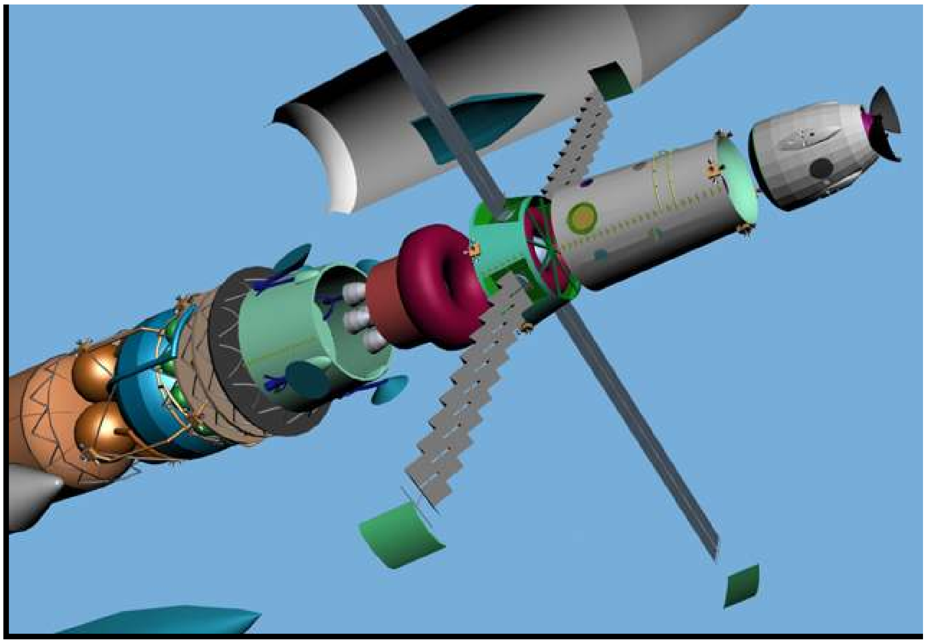
The Mars Direct project for Orbiter is a web based group consisting of a volunteer team of designers to implement the Mars Direct mission in OSFS. These are some images of their models. The Mars-Oz approach is to use a bent biconic shape that has good control authority for accurate navigation to a parachute release point. Andrew McSorley is using a wheeled Lander for his version of NASA's DRM 3.0. The wheels allow the Lander to be moved and docked with other Landed vehicles. Rough terrain is smoothed by bulldozers. In this was a large base can be built on Mars.

3.8 CLOSING REMARKS

A piloted Mars Lander has many sophisticated and interdependent systems for a soft landing on the surface. Using a combination of virtual prototyping in the OSFS and detailed EDL simulations it has been shown that the design for a Mars piloted Lander can be converged upon using an iterative process. A detailed description of the descent to the Martian surface, using in a piloted Lander, may be as follows.

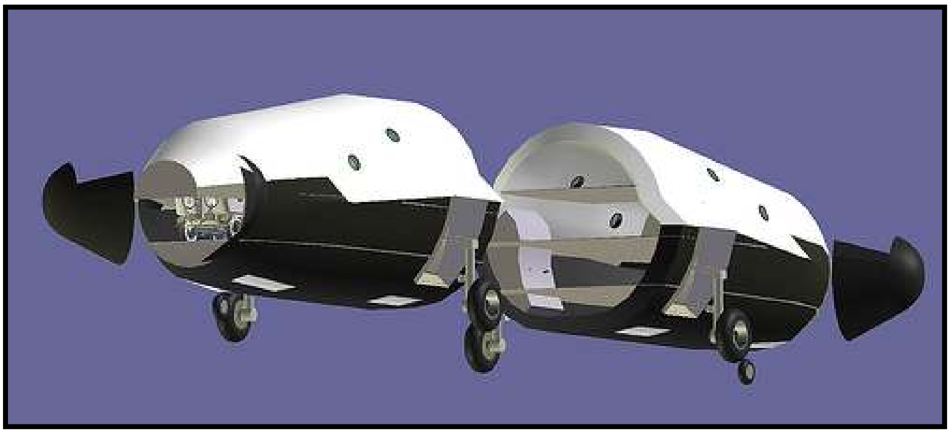
Entry begins at 100 km altitude at a velocity of 3.5 km s^{-1} and an entry angle of 4° to the horizon. The MTSV mass is 52 mT at entry including a 6 mT inflatable heat shield and 12 mT of methane/oxygen fuel. The spherical surface heat shield, with an effective area of 242 m^2 a diameter of 15.75 m and a drag coefficient of 1,28 is flown in a lift up orientation at an angle of attack of 30° to the flow, giving a L/D ratio of 0.3. A segment of the Apollo earth-entry guidance program is used to send roll commands to the MTSV bank thrusters. The MTSV rolls around its axis in response to uncertainties in the Martian atmosphere. At one point craters and hills on the floor of Hellas basin glides into view of the crew. The guidance computer soon decides to jiggle the MTSV around a bit and the crew see the horizon with a thin tenuous orange haze hanging above it. Maximum hypersonic deceleration occurs 5 minutes after entry and reaches 0.75 g. The MTSV then flies at a constant altitude of 40 km, covering 350 km in 3 minutes, before continuing its plunge downwards at 8 minutes after entry. Another deceleration peak of 0.75 g occurs at about 10 minutes after entry. Two minutes later after the second hypersonic g peak (12 minutes after entry) the Disc-Gap-Band supersonic parachute is deployed while the MTSV is at an altitude of 6.5 km and travelling at a speed Mach 1.8. Ejected from its canister the parachute takes about one second to inflate with a peak g force of 0.5 g on the crew. The MTSV slows down to Mach 0.8 (subsonic) by the time an altitude of 1.8 km is reached. Here the 400 kN thrust engines are ignited pulling the MTSV of the heat shield. The heat shield falls away and to the side. The MTSV is flying at an angle of about 45° to the horizon at this point. The valley walls of Vallis Dao can be seen looming in the distance. After having travelled over 1700 km across the Martian surface since entry the deceleration from the engines and the parachute combined turn the MTSV into a vertical descent. The Martian winds have blown the MTSV several kilometres of course during the parachute descent. At an altitude of about 400 m the parachute is released and the MTSV uses it's beefed up 50 kN RCS to moved forward out from under the parachute. The ERV location beacon is used to bring the MTSV to within 100 m where it gobbles the final ton of fuel for the descent, throwing up clouds of red dust past the crew's window as it softly touches down. Fourteen minutes after atmospheric entry thirty eight tons of Lander and four human beings are on the surface of Mars.

Well that is one description of a possible scenario for landing humans on



ERV model. A model of the Mars Direct ERV by Seth Hollingsead
http://www.eveminer.com/setheden/index.htm

Mars. However more work needs to be done to investigate other mission architectures to understand the benefits and drawbacks of different technologies, such as an all propulsive EDL or slender body Landers. □



Wheeled cargo Lander. A model under development. A Lander may have wheels, making construction of a large base easier (in concert with bull dozers. Model her is by Andrew McSorley. It is part of his implementation and iteration of NASAs DRM 3.0 in OSFS. http://orbit.m6.net/Forum/default.aspx?g=posts&t=10846

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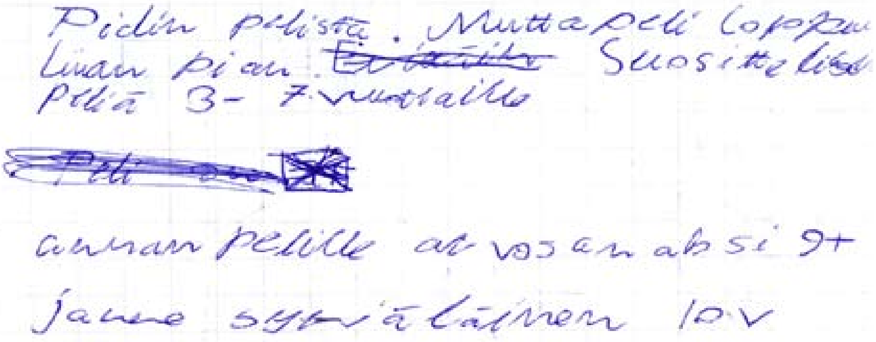
Joululahjavinkki: Avaruusseikkailu

Medallion Kidz: Avaruusseikkailu (pc)

”1940-luvun lopulla innokas astronomi Max Mutteri havaitsee teleskoopillaan maata lähestyvän luotaimen. Luotain törmää meteoriittiin, ja osa siitä sinkoutuu eri planeetoille”...

Avaruusseikkailu on kauniisti toteutettu ja opettavainenkin peli, jossa pääsee rahoittamaan tutkimusta ja laukomaan raketteja. Janne Syrjäläinen Hämeenlinnasta koepelasi pelin läpi yhden viikonlopun aikana, tässä hänen arvionsa:



Pidin pelistä. Mutta peli loppu
liian pian. ~~Erittäin~~ Suosittelisin
peliä 3-7 vuotiaille

[illegible]

annan pelille arvosanaksi 9+

Janne syrjälainen 10v