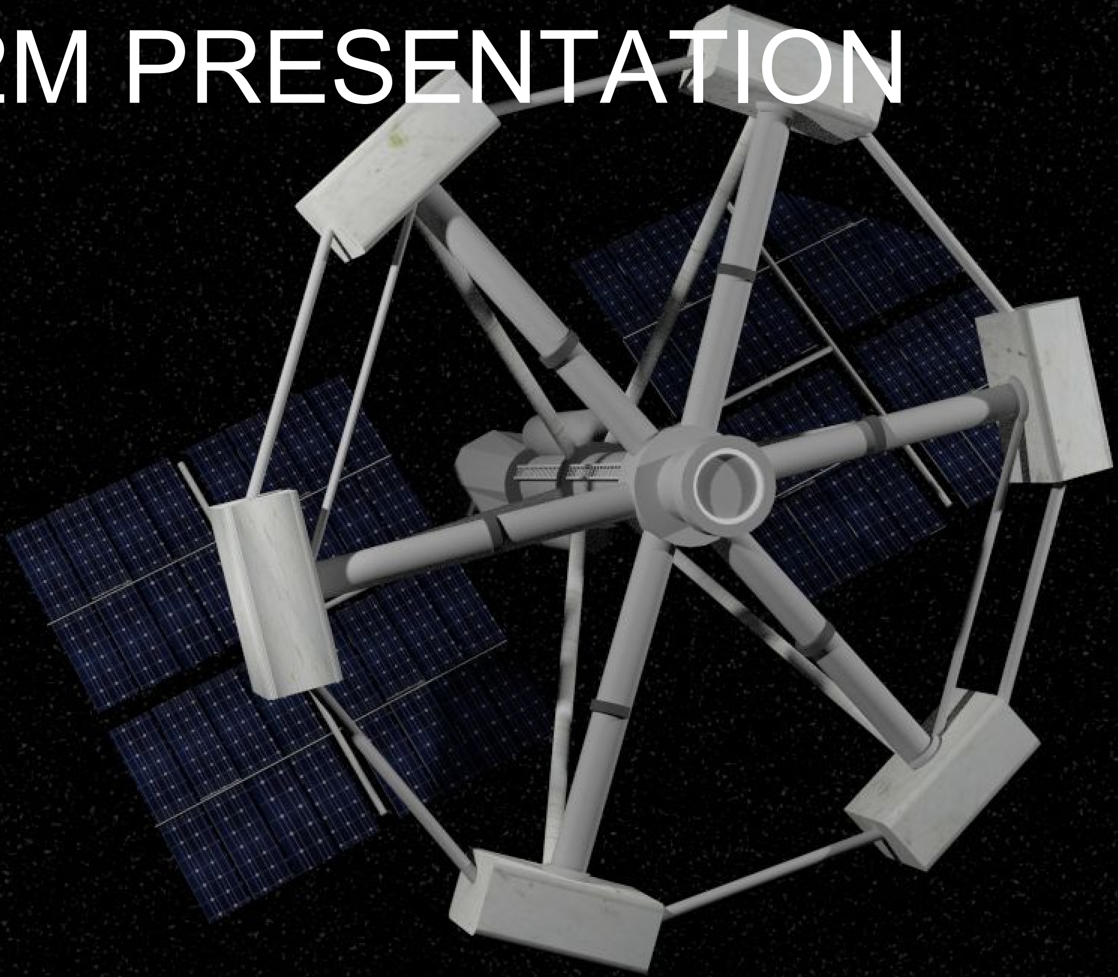
PGS M2M PRESENTATION



Original design by Oliver Gent
*model used throughout

Contents

Marking Topic: Mission objective and benefit

Objectives

- To send 6 astronauts to Mars to carry out experiments investigating the geological and biological characteristics of Mars, spending two months on the surface and safely returning the astronauts back to Earth.

- We must ensure that we keep long term health impacts from the journey to a minimum.

- The first mission will be used to do preliminary research and construction for a permanently manned base on Mars.

- Our mission will focus on reusability and long term aspects to make several missions economically sustainable and therefore benefit research more than other solutions.

- During further missions the modular base on Mars would be expanded.

- The data collected from the experiments and the experience gained in the first mission should allow us to develop the next few missions.

The assumption made in our mission is that there is a method of building the core ship in space as the space shuttle was used to construct the ISS

Mission Conclusions

We organised the team according to individual interest and expertise to undertake research in mission critical areas. These are shown on the contents page.
We have found that the success of our mission will rely on the safe and efficient resolution of these key points

- Best use of time for the human crew (using journey time usefully)
- Targeted experiments to achieve our objectives
- Reducing cost per mission to a minimum rather than a single journey
- Ensuring expansion and replacement possibilities

We decided using the ‘slides’ format would be most effective to present our idea as it breaks up the information and displays it visually better than the conventional method.
This also makes managing the sections given to people more organised.

Reusability

Since the ISS is being retired in 2020, this means there will be a need for a replacement within the next decade or so. The ship should start to be under construction in space by 2030 in order to make the 2035 ideal department date. The new ship is an ideal opportunity to replace the ISS as it will have the capability to carry out research on the journey to and from Mars, to make best use of the time.

With a crew of 6, the ship should be able to be as productive as the ISS but with the advantages of new technology added to the core of the ship. During earth orbit it could also dock with a secondary part to increase production if required, but only the core would travel to Mars to decrease mass and journey time. During orbit the ship can also be used as the ISS is, as it is during the journey to Mars.
Since the ship is designed to have a long life span, it will be able to make multiple journeys to Mars, and if required modules can be easily replaced when damaged to further increase lifetime.

With new advancements in technology, transferring components to space from Earth is far more economically viable than it has been in the past. Using reusable rockets means the rockets only need to be refuelled each journey, and there is less cost involved with collecting the rocket (used to be parts scattered) as it can land in a chosen place on land or at sea.

We need another ISS because it unites nations with a common goal, to research and investigate our world and what is beyond it. Involving nations in this way not only helps research but it strengthens the bonds between countries. It also sparks interest in science for people of all ages and helps inspire many to a career in science.
Beyond this, we also have a gap in an important front of research. We need to keep on pushing boundaries constantly. This ship is also efficient in time and money, filling in the gap of the missing ISS and also giving us a ship to travel to mars with.

Biological Experiments

Experiments to be carried out on the surface of Mars: These are some of the reasons that make up the purpose of the mission.

1. Continue search for biosignatures of microbial life
   The Curiosity and Opportunity rovers have been scouring the surface of Mars for biosignatures, though this process could be improved with the help from a team of humans as a Mars rover can travel larger distances with a human driver. It can also carry much more measuring equipment than unmanned rovers can.

2. Use Martian soil to attempt plant growth in controlled conditions
   In uncontrolled conditions Martian soil cannot sustain growth. Irregular weather patterns, including extreme temperature variation and dust storms mean that any plants must be grown within the Mars base. The astronauts would carry out tests to compare growth in Martian soil to growth in ‘plant pillows’ using the VEGGIE system onboard the spacecraft.

3. Measure the gravitational effect on plant growth
   Plants are sensitive to gravity, and respond to this stimulus with geo-tropisms (growing in the opposite direction to the force of gravity). With Mars's gravity at just a third of that on Earth, plant growth will be affected.

4. Test to what extent conditions must be controlled for sustainable plant growth
   The light, radiation, temperature, gravity, humidity and carbon dioxide levels all affect the growth of plants. The astronauts will take readings of the external conditions from different areas of the surface such as shaded areas compared to unprotected soil. They can measure radiation, carbon dioxide levels and light, and then simulate them in the Mars base in a semi-controlled environment using their readings.

Biological Experiments

5. Locate organic carbon compound signatures
The Curiosity rover has been slowly searching for these traces of organics as one of its main purposes. Discovery of these compounds could suggest that Mars once may have been able to sustain life. The carbon organics are easily destroyed by the harsh radiation on Mars, which means they are most likely to be located deeper under the surface. The presence of humans on Mars will make it much easier to drill into the surface to find these traces of carbon compounds.

6. Collect soil samples for testing on the return journey
The return journey of another 9 months is an opportune time to continue testing samples. The more soil that is collected means that more experiments can be carried out on the return journey using the measurements collected from the surface. The testing of the soil will not be carried out when on the surface of Mars, as it can be carried out on the return journey, instead of using up valuable time on Mars.

How do these experiments help us to achieve our aim?
These experiments will be carried out on the first mission to Mars, and will act as a research basis for the future missions that will be carried out due to the reusable nature of our mission. The objective is for these experiments to result in biological knowledge and insight that can be used on consecutive missions. This preliminary research will allow time and money to be saved on future returns to the planet, as these experiments should be conclusive in determining what is and what is not possible, allowing future missions to focus on different objectives.

Geological Experiments

1. Continue to gather rock samples from Martian surface
   Although rovers have been able to collect data about the rock types, this will be the first time that humans will be able to actually collect samples and analyse them in a laboratory environment. This will provide us with data to create a catalog of rock and mineral types and help us start to piece together a geological timescale of Mars. If any fossils are found this could help us answer the question about other life in the universe and tell us more about the origin of life on our own planet.

2. Use gravimeters to map areas of Mars
   We can take gravimeters on the rover and travel around the martian surface monitoring variations in the gravitational field. Positive anomalies result from excess mass and a negative anomaly results in a deficit in mass such as low density rocks. This will allow us to start to understand the structural geology of Mars.

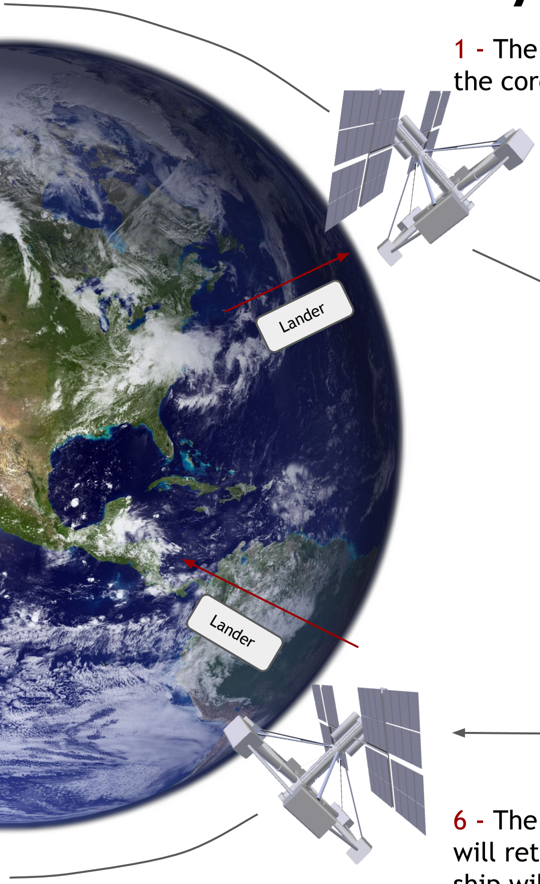
3. Monitor Martian dust storms
   Much is still unknown about how exactly the dust storms form. We can take advantage of having astronauts on Mars who can take observations on how they originate and any correlation between the size of the storms and any atmospheric changes. Also setting up permanent weather stations on mars so mission control can get live accurate data

4. Seismic reflection surveys from Martian surface
   Using a triggered explosion that sends down a series of seismic waves we can create a detailed picture of structure below. The seismic waves bounce back off a reflective layer and get picked up by geophones positioned around an area. These will be pinpointed from our base. Dependent on time taken for waves to return we can determine the depth of beds of rock and this will allow us to create a more detailed internal view of Mars

How do these experiments help us to achieve our aim?
These experiments will give us a clearer understanding of the geology of Mars and this can be used to analyse the mineral deposits present. This data is key to whether or not we continue sending missions in the future but also determining the possibilities of colonising Mars. Knowing details of the Martian resources allows us to plan ahead and potentially make the bases on Mars eventually self sustainable.

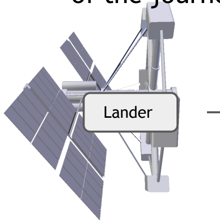
Marking Topic: Overall Mission Strategy

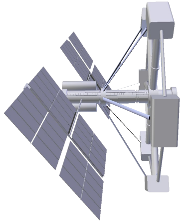
The Journey



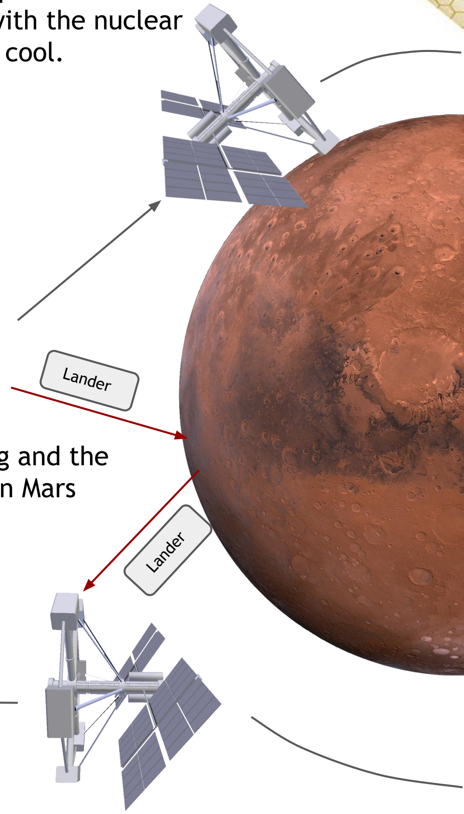
1 - The crew will travel from Earth to the core ship, in the lander.

2 - Using a Hohmann transfer orbit the crew will travel from the Earth's orbit to Mars. The core starts spinning from the beginning of the journey for artificial gravity





4 - The core ship will orbit mars autonomously with the nuclear reactor running cool.



3 - The core will stop spinning and the lander will detach and land on Mars

5 - Using the Hohmann transfer orbit the team will travel from Mars to the Earth's orbit.

6 - The lander will then detach and the team will return to the Earth's surface. The core ship will remain in Earth orbit.

Astrophysics

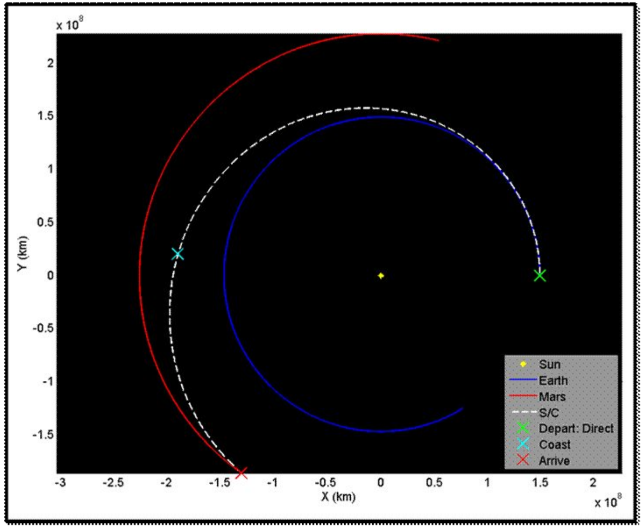
The Orbit of Mars

How does the orbit of Mars affect our mission?

- We need to know a time schedule for the mission, this means we need to know precisely when we need to leave
- Flight paths have a huge affect on amount of time spent in space, we need the most fuel and time efficient route to Mars
- If there are construction delays, we need to know when our next opportunity is
- The orbit also affects communication times, we need to know if we can't communicate at certain times and what the delays involved will be.

Where Mars will be when we arrive? (not when we leave Earth)
relevant facts about Mars:

- Mars has the most elliptical orbit of any other planet in the Solar System
- Mars orbits the sun every 687 days
- On average, the distance to Mars from Earth is 140 million miles (225 million km).
- The value of G on mars is 3.75 (0.38*g*)
- Average distance between Mars and the Sun = 1.5227 AU
- Average period of orbit = 1.8822 years

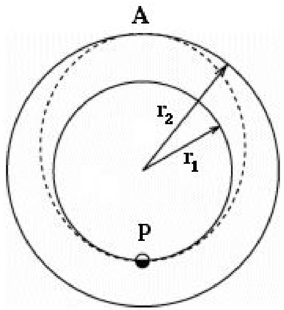


Hohmann transfer orbit

Hohmann transfer orbits could be used however ballistic capture reduces fuel cost and provides more flexible launch windows.

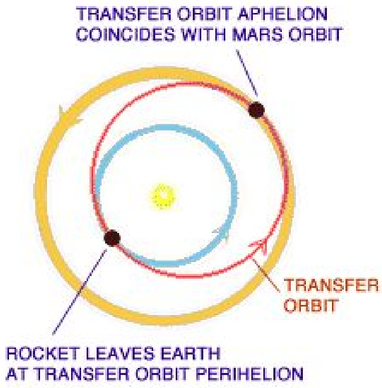
- It is best to search for an orbit that can take the ship from Earth to Mars in the minimum time and whilst expending the minimum amount of fuel. We should launch when the arrival at Mars orbit coincides with the arrival of Mars itself.
- The direction of the ship should mean it is easy to match velocities with mars.
- This is an ellipse with perihelion P (point closest to the sun) at the orbit of Earth and aphelion A (point most distant from the sun) at the orbit of Mars.

Communication satellites are injected into their final orbits in a similar way; r=1.1, RE=1.1 (Earth radii) and the synchronous orbit is 6.6RE. We launch from P by giving the rocket extra velocity in addition to V0, injecting it into the larger ellipse.



It will not work to simply wait until Earth and Mars are closest to each other and their orbits are aligned because:

1. Gravity will bend the trajectory of any spaceship launched from Earth. If the rocket is already in orbit around Earth, this can be dismissed as gravity is weak and orbital motion is slow.
2. However, the rocket is also orbiting the sun at the same time as the Earth (velocity= 30 km/sec). Let V0= 30 km/sec. If it is fired when mars is closest, V0 is transverse to the aiming direction so the ship will start moving in a different direction away from mars and by the time it covers this distance Mars would have moved significantly.
3. Our solar system is dominated by the sun’s gravity. All objects travel in objects or trajectories, which are part of conic sections according to Kepler’s laws. These are ellipses, generally curved in this case.



This illustration shows a simplification of the process, as both Earth and Mars’ orbits are not perfect circles or on the same plane

Gravitational Slingshots

It could be useful to slingshot around the moon and use gravity assist to conserve fuel and speed up.

When Voyager was sent out into the Solar System, it used gravitational slingshots past Jupiter and Saturn to increase its velocity enough to escape the Sun's gravity.

It involves flying very close to the planet, as the spacecraft approaches it speeds up and then it slows down when it starts to move away. Each planet has an orbital speed travelling around the Sun. As the spacecraft approaches the planet, its gravity pulls the much lighter spacecraft so that it catches up with the planet in orbit. It's the orbital momentum from the planet which gives the spacecraft a speed boost. The closer it can fly, the more momentum it receives so the faster it flies away. To kick the velocity even higher, the spacecraft can fire its rockets during the closest approach, and the orbit will multiply the effect of the rockets.

Our journey:

- Fastest possible: 942 hours
- Slowest: 6,944 hours
- On average: 225.0833333 days.
- Round trip time: 400 to 450 days
- With on-orbit staging it could be a lot faster: 245 days

- 186,282 miles per second.
- Therefore light shining from the surface of mars would take:
- At a minimum: 182 seconds/just over 3 minutes
- At a maximum: 1,342 seconds/just over 22 minutes
- On average: 751 seconds/just over 12.5 minutes

Summary; Launch Window

- About every 26 months, Mars and Earth reach a position in their respective orbits that offer the best trajectory between the planets.
- A delay that interferes with the launch window can cause the entire launch to be scrubbed.
- We want to launch our spacecraft during Mars opposition, and Mars opposition happens every 2 years, 2 months. The reason to launch a mission to Mars during opposition is because this is the time when Earth is nearest to Mars.
- The best time to launch, in terms of how much energy is required for the trip, is a few months before that happens.
- Straight line results in huge inefficient orbit; therefore we are using the hoffman transfer orbit
- Best to leave when it is 34,647,420 miles from Earth. This is the closest recorded distance.

We hope to carry out the journey to Mars during 2035

Previous Launches:
Mars Odyssey (NASA): Apr 7, 2001
Mars Express & Beagle 2 (ESA): Jun 2, 2003
Mars Exploration Rover Spirit (NASA): Jun 10, 2003
Mars Exploration Rover Opportunity (NASA): Jul 7, 2003
Mars Reconnaissance Orbiter (NASA): Aug 12, 2005
Phoenix (NASA): Aug 4, 2007
Phobos-Grunt (Russia): Nov 8, 2011
Curiosity (NASA): Nov 26, 2011

List of the ideal dates to leave for Mars that fit with the launch Windows:
11/03/2016
30/04/2018
18/06/2020
07/08/2022
26/09/2024
15/11/2026
03/01/2029
22/02/2031
11/04/2033
30/05/2035
07/18/2037

Marking Topic:

Spacecraft, human protection, propulsion, launch and assembly design

Engineering

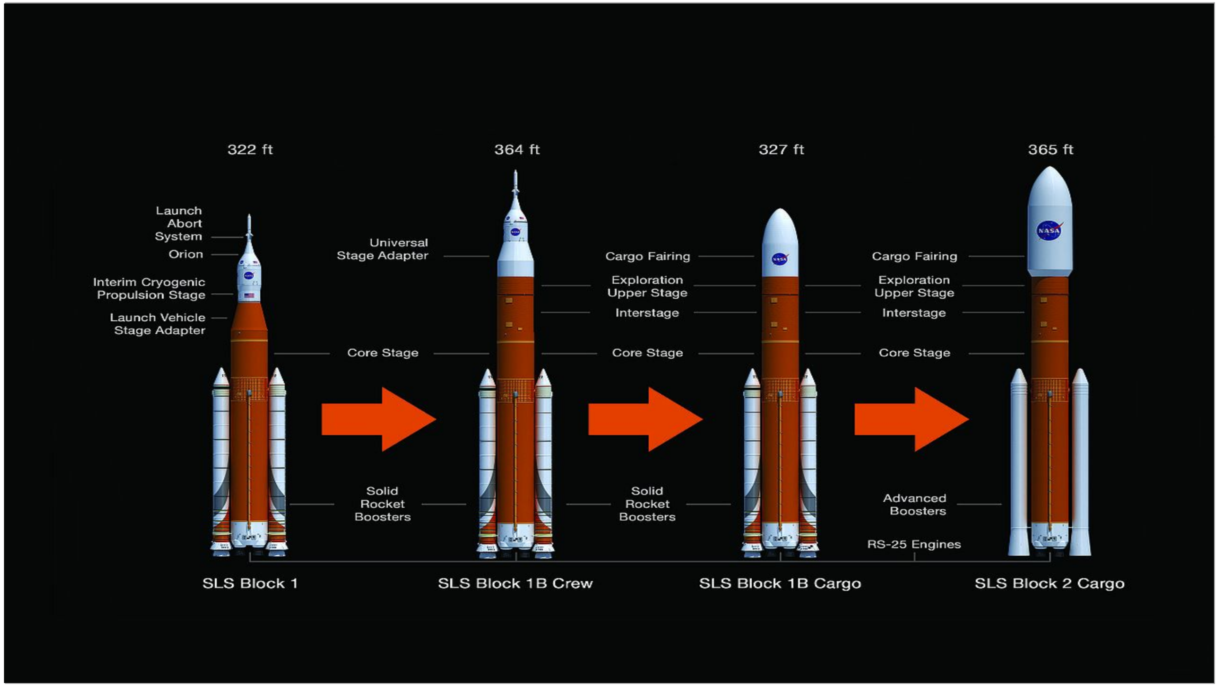
Propulsion

Building the Ship

- The Core ship will be built on Earth but assembled in space
- We estimate that the core will weigh approximately 350 tonnes
- In order to take such a large mass into space, multiple missions will be required
- To achieve such a task, two options were considered;

SLS (Space Launch System)

- NASA's current space programme, SLS received senate approval in September 2011 following the cancellation of the Constellation programme in 2010.
- It plans to evolve its rocket until by 2030 it is capable of launching the Block II Cargo (130 tonne payload to LEO).
- However, the Block 1B Cargo will be ready for launch by next year (70 tonne payload)
- Predicted to cost 18 billion dollars until 2030 after which it will cost 3 billion dollars per annum.



Building the Ship

SpaceX

- Founded by Elon Musk in 2002, SpaceX is a privately funded company whose goal from the beginning has been the colonization of Mars.
- Uses reusable rockets that land vertically on Earth after carrying their payload to Space.
- Other reusable rockets exist such as the Blue Origin. But despite Blue Origin recently becoming the first company to reuse a rocket we believe that SpaceX's rockets are more suited to the needs of our mission.
- SpaceX's Falcon Heavy (payload 53 tonnes) is expected to launch later this year.

SpaceX was chosen for the following reasons;

- SpaceX is a commercial company whereas SLS is senate funded. This means that all decisions would need senate approval and more importantly, funding for the program could be cut or even ceased at any time.
- SpaceX is planning to have an even larger SHLV (Super Heavy Lift Vehicle) launching by 2030
- SpaceX works out as being cheaper, despite more missions being required due to its inferior payload.

Launch System	Mass to LEO	Cost per launch	Cost per tonne to LEO
SLS Block II Cargo	70T	$500M (likely to be more)	$7.1M/tonne
SpaceX Falcon Heavy	53T	$90M	$1.7M/tonne

If the Falcon Heavy is used, seven launches will be required. Once the ship is complete, a final mission will carry the crew to the core ship.

Interplanetary Propulsion

Why we should use Electric Propulsion (vs nuclear or traditional liquid fuels)

1. Electric thrusters have a high specific impulse. The definition of specific impulse is the impulse produced per unit mass of fuel. Impulse is the amount of thrust produced multiplied by the time. Specific impulse is therefore a measure of how efficiently an engine uses its fuel. We want this to be as high as the higher it is the smaller the mass of fuel that the ship will have to carry to get to Mars and back. It is designed to be used for long periods of time unlike liquid fuel rockets which are designed to be used for brief, high thrust bursts.
2. We plan to make our ship a reusable one that can be used for multiple missions. Because of the nature of the fuel it is far easier to refuel this rocket while it is in orbit as the fuel is very compact. A liquid fuel rocket would require a lot of fuel for such a journey making it harder to refuel.

When it came to choosing which type propulsion system to use, we knew that ours had to fit certain criteria;

1. Have a lifetime long enough to conduct multiple missions of this length
2. Be able to provide the necessary thrust to move a ship as large as ours, (operate at MW levels of power)
3. Have a high efficiency
4. Be able to take the ship to Mars and back in a short enough time that the crew would not be permanently damaged by radiation.

After some research, several engines were ruled out, mostly due to their short lifetimes or being inferior to a similar engine. The choice was reduced to the Variable Specific Impulse Magnetoplasma Rocket (VASIMR), Electrostatic Ion Thrusters and finally Magnetoplasmadynamic thrusters (MPDTs), more specifically the Lithium Lorentz Force Accelerator (LiLFA).

Interplanetary Propulsion

Electrostatic Ion thruster

- Usually fuelled by Xenon gas
- Very efficient with both their fuel and their power but have very low thrust.
- They have been shown to work for periods up to 1.8 years and longer tests are currently taking place.
- Provide a good amount of thrust over a large power range making them attractive when using solar power (where input power decreases with distance from the Sun). But not only is our ship not using solar power to power the engines, it is also not venturing very far away from the Sun. (light intensity is still quite strong on Mars
- We could only have a powerful enough rocket by greatly increasing the thrust. This is not ideal as firstly this would increase the size (and hence the mass), and secondly the power imparted to the exhaust increases with the square of its velocity while thrust increases linearly so as we increase the thrust the efficiency will decrease.
- Ideal for unmanned deep-space missions but for our mission, using them would make the mission take too long.

MPDT

- Unlike most MPDTs, the LiLFA uses lithium gas as its fuel.
- Lithium has a lower first ionisation potential meaning more power can go to thrust generation instead of ionisation.
- Lithium also has a higher second ionisation potential reducing frozen flow losses (energy put into the gas that is not converted to kinetic energy).
- Has demonstrated a superior efficiency to most engines of its class; 48%.
- Its multiple cathodes lower the density of the current which lowers the temperature inside preventing evaporation of the cathode. This erosion shortens the life of MPDTs.
- Has been tested for prolonged amounts of time at Princeton University and has shown erosion free operation for 500 hour tests.

VASIMR

- VASIMR is a two-stage plasma propulsion device.
- First it converts the gas to a plasma using radio waves, then it accelerates the ions out of the back.
- Because it uses radio waves to energise the plasma, there is no erosion of any electrodes as in the other two increasing its lifetime greatly.
- Designed to operate at very high power levels (potentially hundreds of MW) allowing it to produce large amounts of thrust.
- Manufactured by ‘Ad Astra’, whose current engine the VX-200 operates at only 200 kW but it's said to be design is highly scalable.

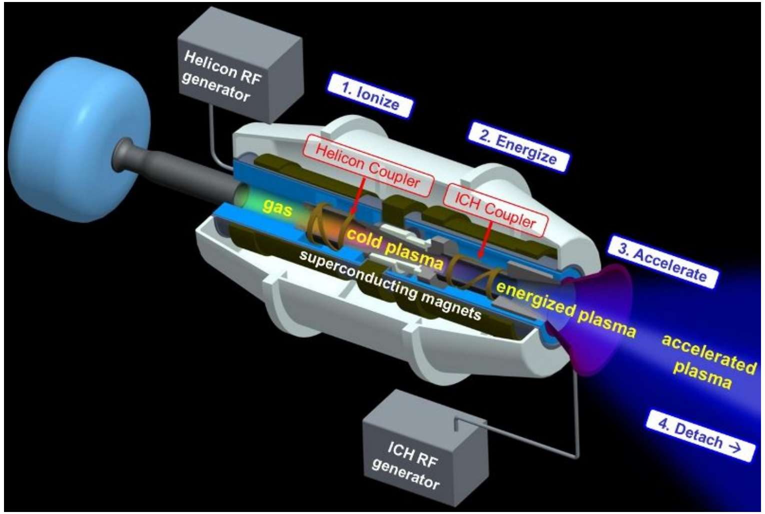
Interplanetary Propulsion

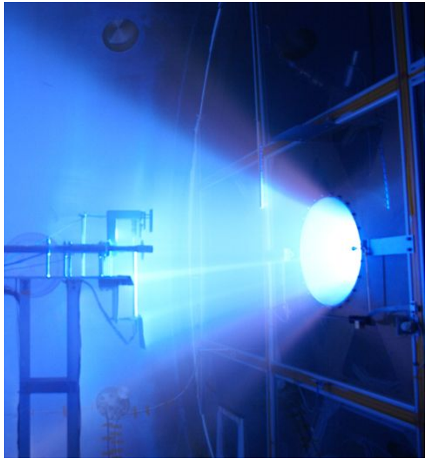
It was decided that the VASIMR engine was best suited to being the primary propulsion system for the ship. The manufacturer Ad Astra claims their design is highly scalable so we will assume an engine of this design will be able to produce the necessary thrust.

How it works

1) Propellent gas (usually argon) is fed into the engine where the first RF generator and the helicon coupler work together to turn the gas into a 'cold plasma' (roughly 5800K).
2) The superconducting magnets confine the plasma, a mixture of electrons and ions.
3) The Ion Cyclotron Heating section uses the second RF generator to generate ICH waves that push only on the ions as they orbit around the magnetic field lines. This acceleration of the particles heats the plasma to over 1 million K.
4) The final section passes the ions and electrons into steadily increasing magnetic fields. This sends them into a spiral parallel to the direction of the thruster. They move in the opposite direction at speeds of up to 50,000 m/s, generating thrust.

	Power (kW)	Thrust (N)	Specific Impulse (s)	Propellant
NASA Evolutionary Xenon Thruster (NEXT) (Ion Thruster)	7.7	0.327	4300	Xenon
VASIMR VX-200	200	5	5000	Argon



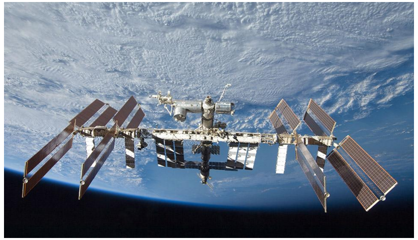


Engineering

Core Ship

The Construction of the Ship

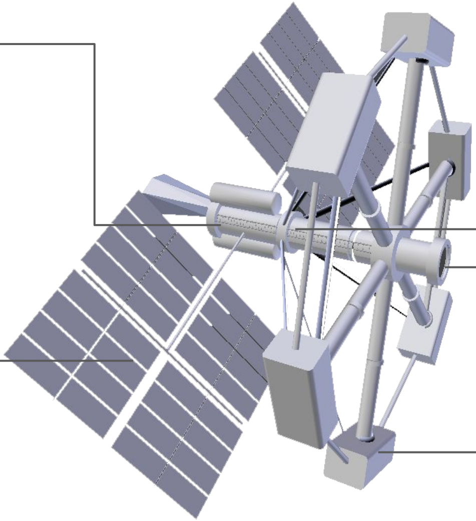
Due to the size of the ship, it will need to be constructed in space with all the modules which compose it, being launched up. This process is normally very expensive and risky as it means multiple spacewalks have to be made to pull the modules together. The procedure is even more risky at first as there is only one module to work from to begin with.



The ship has artificial gravity in the living modules. This is produced by the whole ship spinning along its z axis (passing through the central cylinder). This means that there are no mechanical weak points.

Power modules, nuclear reactor location. These can be interchanged with other modules to update the technology or do repairs. Also where the rocket is located.

External access features for easy maintenance on the ship



Docking port for lander or maintenance. The ship's manual navigation will be controlled from the lander when it is docked.

Solar panels, for power when the ship is not in interplanetary flight (in orbit around mars or earth) or in emergencies.

Living space modules for the crew. These are accessed through the columns attaching them to the central cylinder

Living spaces

Crew quarters (all artificial gravity)

Sleeping quarters.
These need to offer the astronauts privacy, as not much will be available with such small internal space. They also need to be personalisable so the astronauts have their own space. Since the main crew quarters will be in an artificial gravity area, there may be opportunities to create familiar surroundings to the astronauts on the spaceship. However this may not be possible as it creates waste volume.

Gym area
This is important for the astronauts to counteract the effects of space travel and lack of space to move around in. It also is needed to make sure the astronauts are still physically fit for their mission on Mars. Having artificial gravity makes it easier to provide effective activities.

Lounge area/kitchen
This area is important as the total time the astronauts spend in space travel is going to be over 14 months. This also provides a good social point for the astronauts where they can spend their time in comfort. The supplies for the journey will be kept somewhere else, in the rest of the spacecraft not in the artificial gravity section where space is relatively important.

Command centre
This is where the main controls are, for making emergency operations and following through the movements needed to put the ship into Mars orbit and earth's orbit.
Here also will be various computer stations. From this module there will be big clear panels so that visual orientation can be made also. When manoeuvres are being made, the spinning will probably stop to reduce disorientation when looking out of the viewing pane.

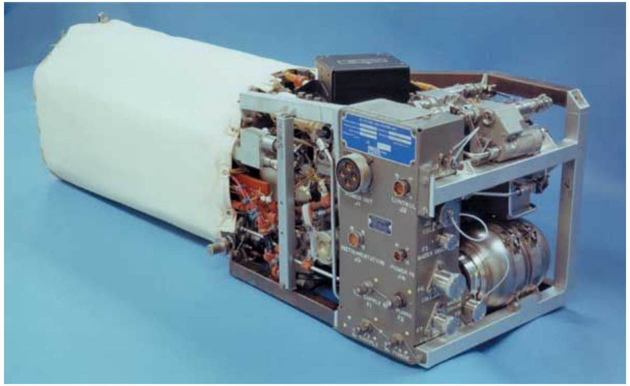
Ship systems and power

Electrical Power Sources:

- Solar Panels
- Fuel Cells
- Nuclear Reactor

Systems Requiring Power:

- Life Support Systems-Fuel cells
- Computer Systems-Fuel cells
- Propulsion-Reactor
- Mechanical Mechanisms-Fuel cells
- ALL supplemented by solar power apart from the propulsion



Nuclear Reactor

Providing the Power

The greatest challenge associated with the use of any electric thruster is providing the necessary electrical power. For engines as large as we require them to be, the energy required cannot be stored on board without greatly increasing the mass of the ship. Therefore it must be produced in situ for the duration of the mission. Solar power is not capable of producing enough power to provide such high thrust without dramatically increasing the mass of the ship. The most viable option is nuclear power. A nuclear reactor has the highest energy density of any energy source which would make it ideal for long distance space travel as it would not increase the mass of the ship too much.

Currently the most promising technology for nuclear fission in space is the SAFE-400 (Safe, Affordable, Fission Engine), it is an example of a ‘Heat-pipe Power System’

- Research started in 1994, since then it has been tested and proven to work with Ion drives
- Produces roughly 400kW of thermal power which, using Stirling cycle or Brayton cycle converters can be converted into approximately 100kW of usable power
- Uses uranium nitride as fuel and a helium xenon gas mixture as its working fluid which is passed into the heat exchange system
- Only 50cm tall and weighs just over 500kg so possibly multiple could be housed in the back of the ship.
- Could be used in conjunction with a thermoelectric engine harvesting waste heat in order to increase efficiency
    - Thermoelectrics is generating current from a temperature difference.
    - Since the discovery of graphene, its usefulness has increased dramatically.
    - Powerful enough example does not exist yet to be the primary power source.
    - Ideal for space travel as it has no working parts so more reliable

Shielding from radiation

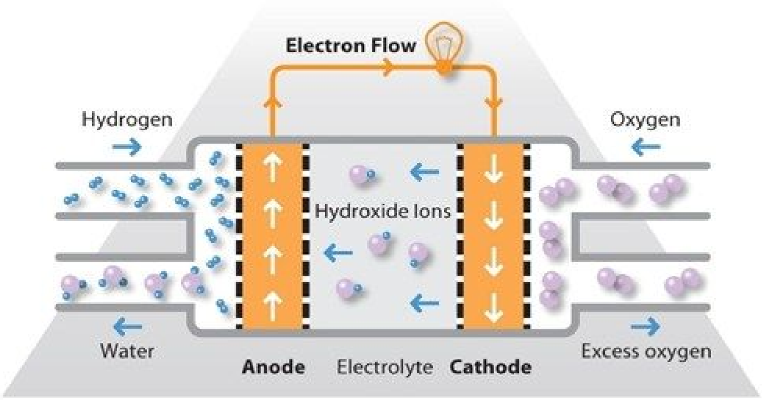
The reactor will likely be the only area of the ship using high density radiation shielding as this adds a lot to the mass. It is necessary in case there is a problem with the reactor as some form of meltdown could be catastrophic for the crew.
It is very possible that in the near future material scientists will discover a material that is both good at reducing radiation, while also being light and strong enough to hold structures.
Were the reactor failure it should be possible to ration electricity and use stored energy in the batteries to power the engine although this is not guaranteed as for some sections of the journey the engine has high demands.

Fuel cells

Fuel cells were used in the space shuttle program to provide electricity to the ship. The fuel cells take in Oxygen and Hydrogen and convert it to electricity, as well as this they also produce water and heat, bi-products that could be used elsewhere in the ship to provide crew heating when not in the their space suits during transit and obviously liquid water. In addition to the fuel cells we will store electricity in batteries when there is less demand than supply.

The fuel for the cells is fuelled by oxygen and hydrogen which can be obtained from stored water or just stored oxygen and hydrogen.

- The System works as seen in the diagram, feeding in oxygen and water creates hydroxide ions that makes an electron flow and therefore electricity.
- On the Space shuttle they used 3 fuel cells which each acted as their own independant supplies which provided a 28v “d.c. Bus”.
- The hydrogen can be obtained simply from propellant storage of liquid hydrogen or obtained in the reverse process using water. Oxygen will be easily produced from the life support systems, so any excess oxygen can be used for the fuel cells.



Fuel cells

In our ship we will be able to upscale the fuel cells, because obviously in the space shuttle, size and weight was of slightly higher concern.
The full size and weight specs of the device are:

- 14 inches high
- 15 inches wide
- 40 inches long
- Weighs 255 pounds.

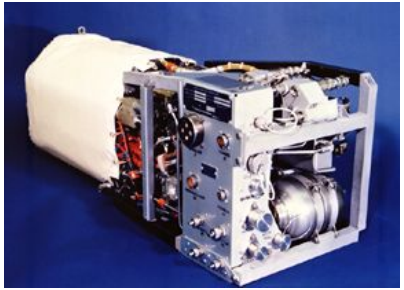
The voltage and current range of each is 2 kilowatts at 32.5 volts dc, 61.5 amps, to 12 kilowatts at 27.5 volts dc, 436 amps. Each fuel cell is capable of supplying 12 kilowatts peak and 7 kilowatts maximum continuous power. The three fuel cells are capable of a maximum continuous output of 21,000 watts with 15-minute peaks of 36,000 watts.
For the space shuttle the average power consumption of the orbiter was approximately 14,000 watts, or 14 kilowatts, leaving 7 kilowatts average available for payloads. Each fuel cell was serviced between flights and reused until each accumulates 2000 hours of on-line service. For our application, the idea of servicing each module will be a very real concern and something we will have to consider. As well as that, the 2000 hours of reusability is far less than our flight time just for the outward journey. We may have to have redundancy for the sake of replacements.

Storage:

- To ensure we have electricity at all times we will need to have an array of batteries on board. This will ensure that we have reserve energy in times of high demand and will not waste energy at times of low demand.
- Currently, even the ISS still uses NiCd which are not the most energy dense batteries available. The reason for this is because as you increase the energy density of a certain mass of battery, it becomes more volatile. Only recently have aircraft manufacturer's been able to use lithium ion battery packs which has not gone ahead without a few issues from manufacturers such as boeing who put in some very unsafe measures.
- In order to ensure maximum efficiency we will use energy dense batteries and put in safety precautions such as measuring the voltage constantly of all the cells, ensuring they don't drop below minimum voltage or overheat. We will probably end up using either Li-Ion or Li-Po, which if used correctly should be no issue. obviously at this point it is very hard to see where the battery technology will be going but for a mission such as this it is definitely a requirement to have the best possible batteries.

Use:

The fuel cells will be used as the general supply on the ship for the computer systems, life support systems etc. Because of the risk of failure we will have redundant fuel cells on the ships that can be easily turned on in the event of an emergency. In addition to the back up fuel cells we will be generating power from the solar panels on the ship. While this will obviously have a massively decreased efficiency and power output, it will be useful in the events of an emergency.
As well as being used on the ship we will also be able to have them on the surface of mars to power the bases systems. These fuel cells will be supplemented again with other power systems such as turbines and solar panels.



Solar Panels

- While the space shuttle used Fuel cells, the ISS exclusively uses solar cells to charge up batteries.
- For times out of the sun the ISS uses Nickel-hydrogen batteries. These specific batteries used in the ISS have a life span of 6.5 years which should be more than enough for our mission even with redundancy however leaving processes running on Mars after the mission could be problematic. Because Nih2 batteries have a low energy density we may end up using Li-ion instead as comparatively they are long lasting, can have many more discharge and recharge cycles and have a much higher energy density.
- Solar cells peak in the ISS as of December 2005: 160 Volts DC
    - The arrays can degrade causing a loss of power over time due to ionizing radiation.
    - currently the efficiency of solar cells for space related applications is around 40% however in the coming years this figure can only increase. Researchers have already created solar cells capable of 50% efficiency however at the moment they have to be handmade. It is safe to say that such processes will be automated far prior to the launch window therefore can be used for the ship.
- Much like the Fuel cells the solar cells will be fed into batteries before going to the ship's systems. This allows for a buffer to store any excess and supply more when it is needed.

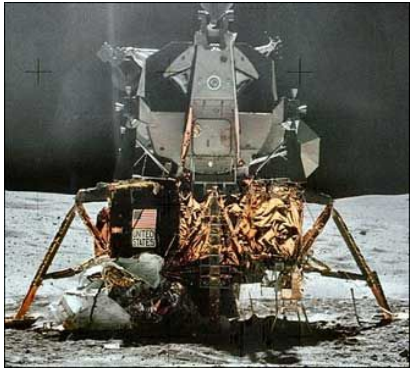
- The Solar panels should be present in a similar fashion to how they are on the ISS, preferably facing the sun at all times which will mean they will have to have a large degree of movement.
- As we get closer to mars the solar panels will obviously become less and less efficient however they should still act as a good energy resource, even if they are semi-redundant.
- Solar panels will also likely be used on our settlement on Mars itself. because of the nature of the landing we will have separate solar panels for on the ground. To reduce carrying weight we will be using Thin film solar (photovoltaic) panels. While these are definitely less efficient than those used on the ship they are extremely light weight which will make the landing easier as well as making the setup of the base less strenuous on the astronauts.

Planet lander

Requirements
Journey 1 - Dock to the ISE (the core ship) this can be done with with disposable stages or a reusable rocket to get to the station.
Journey 2 - Land on the Martian surface from Martian orbit.
Journey 3 - Take off from the Martian surface and the end of the mission (much easier than earth due to less gravity and air resistance)
Journey 4 - Re enter earth's atmosphere to be collected.
The core pod should also be reusable.

Current Methods of landing on Mars (for rovers/stationary units)
Stationary landers can drop from parachute shell and use retrorockets to slow their way to the ground. Mobile units cannot use these as a rover cannot be burdened with parts which serve no purpose on touchdown. Another method is to enclose the rover in a structure covered in airbags. once this aeroshell drops off, the underlying structure opens up to expose the payload. The last method used is if the payload is too heavy for just airbags, retrorockets are used on a separate structure called a sky crane. This sky crane is attached via a lanyard, which upon touchdown is detached and the skycrane will crash away from the payloads touchdown area (since its rockets will still be firing).

Journey 2 and 3
Obviously since our lander will be potentially carrying 6 people, aeroshells can't be used. However this may be useful for dropping off other supplies. Therefore the lander should land on Mars in the same way reusable rockets land on earth, except gravity is weaker on Mars so potentially less fuel is needed. Also the same lander will be used to take off from, so something to take into account is the fuel costs of doing this.



Moon lander: also landed and then took off, but the base (gold section) was left behind. The aim is to not need to do this, to make the lander fully reusable.

Planet lander

Journey 1 and 4

getting to the space station from earth is the most fuel draining section of the trip for the lander. The lander will also carry the astronauts from earth to the space station. For this section of the journey I think that a reusable rocket, similar to those used to carry the space station parts up, can be used to carry the lander up, instead of the lander using up its internal fuel at any point in this first stage (except for maneuvering). The lander will have to be made to ensure it can survive the exit and reentry of earth's atmosphere in the same way the space shuttles did.

For the reentry into earth's atmosphere the lander can use parachutes completely, unlike on mars. However making it a plane like the space shuttle is unnecessary as it won't need to be used as often, and this adds a lot of extra mass, development and therefore cost. Instead It could land like the apollo capsules and be picked up from the sea. These pickups are expensive however. Potentially the lander could use a mixture of parachutes and retro thrusters, using parachutes to do the main descent but then close to ground level the parachutes can be detached and the retro thrusters can do the last section onto a landing pad. Parachutes cannot do the last leg and have the lander land on the ground because it would still be going too fast for this. The area of the parachute has to be increased massively to reduce the lander to an acceptable speed to land with.

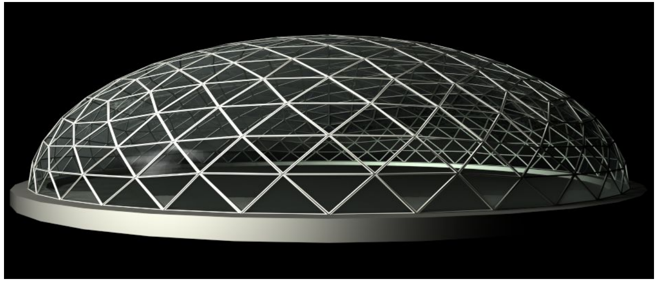
The space shuttle had to enter earth's atmosphere backwards and fire its thrusters for 3 minutes to reduce its speed to 200 mph. Parachutes cannot be released at high speeds, so the lander would have to do similar and then use parachutes for the middle journey, then rockets again for the landing. The hardware to do this will already be there as it has to land and take off from the martian surface. The problem again is how much fuel can be spared. However the lander can refuel from the main ship before reentry. In the event of not enough fuel for landing the capsule should be able to land in water bodies and rely on the initial reduction in speed and the parachutes.

Engineering

Mars Structures

Modular Base construction

Specification
-quick and easy to construct
-light so to reduce payload weight
-stored compactly
-shield the astronauts inside from radiation
-safe enough to rely upon for normal use.
-facilitate any experimental/equipment needs
-allow astronauts a degree of personal space



Considering the specification, a Geodesic structure fits these requirements. This is a thin shell structure which is super compact and very strong.
The structure could be made of a composite material and the panels held by the structure being radiation shielding.
The base needs to be able to reduce radiation hitting the astronauts to a minimum as they will be spending up to two months on the surface of mars. This base would not be enough to allow astronauts to live on the surface for prolonged periods of time.

The structure will be able to protect the astronauts from the martian storms and give them a large pressurised space where a space suit is not needed. It will also give space for experiments to be prepared and for equipment to be stored.

The ‘Queen B mars structure’ offers a credible solution to a martian base, NASA gave it first prize in the ‘mars base challenge’. The project uses depleted uranium as radiation shielding and a honeycomb modular construction. Variations of this format would be a realistic solution.

Mars Rover

For the experiments on Mars we will need a rover for the transportation of crew, supplies and samples. It can also be used for heavy lifting during the construction of the base. It will be helpful for transporting crew long distances outside of their spacesuits. The rover will be pressurised allowing longer time outside the rover at destinations.. A rover will also be helpful as it will allow us to survey a far greater area of the Martian surface. It will also allow the astronauts to take rock and soil samples back to the base for further study or storage so that they can be taken back to earth.

Transport

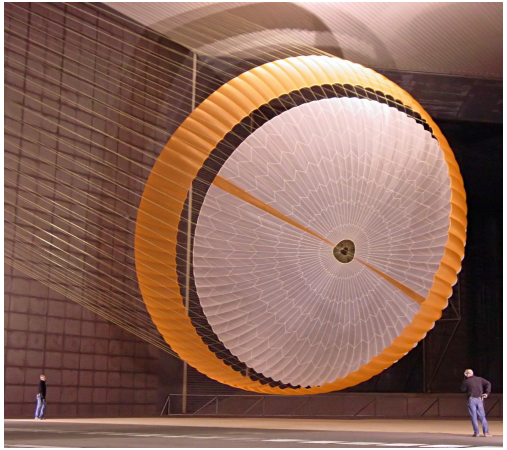
The rover will be designed to be as light as possible but it is impractical to launch the rover with the main ship. It will transported to the landing site separately in an earlier launch similar to those that took previous rovers to Mars. This mission will start with one Falcon Heavy launch, like those used in the main mission, to launch a payload into LEO. The payload would consist of the rover, the heat shield (for entry into the atmosphere), the backshell with parachutes and the cruise stage of the rocket. The cruise stage of the rocket would consist of;

1. Heaters to keep the electronics warm
2. An automated navigational system that uses a star scanner and a sun sensor to navigate, making corrections with small pulse thrusters
3. A communications system

   All of these first three components will be powered by solar power

4. Unlike the main mission, this rocket would have a hydrogen fueled engine. This is because its lighter mass makes it better suited to an initial burn followed by a cruising heliocentric transfer orbit, like those taken by previous rover missions.

Before entry into the atmosphere the cruise stage would separate from the backshell and the rover would begin its free fall to the surface. Once it has reached its peak deceleration. a large polyester and nylon parachute will deploy. Because of Mars' thin atmosphere this will not be enough and a rocket assisted descent (RAD) will be required. Following the separation of the heat shield, these rockets will fire. One element of complexity that can be removed from our rover is that it can land with its RAD rockets, backshell and any attachments necessary to soften the landing still attached and they can be separated manually by the crew when they arrive.



The parachute will be similar to that used in the Mars Science Laboratory mission that took the Curiosity rover to Mars

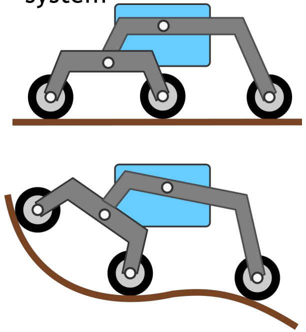
Mars Rover

Because of the higher speed and payload mass of our rover compared to that of the rovers currently on Mars, our rover will have several key differences:

- Mars rovers are currently powered by a radioisotope thermoelectric generator. This uses the heat from plutonium-238 decay to produce electricity at the junction of two different types of wire. It has no moving parts. This is not powerful enough for our needs (NASA's Curiosity rover currently only moves at 30m/hour). Instead we will use a Stirling radioisotope generator (SRG). This is a stirling engine that is powered by heat also from plutonium-238 decay.
- It will also have solar panels on the roof to power the inside systems and batteries inside to store any power generated in this way. The same batteries will also store energy from the SRG as the plutonium produces heat continually.
- The tyres will be made of nano-carbon composite. Transport of air pressurised tyres would be hard as ambient air pressure will change throughout the journey.
- Current Mars rovers use the rocker-bogie suspension system. Ours will not because our rover will have a much heavier chassis and will also have larger tyres, meaning that such a suspension system (where the chassis is close to the ground), will not be necessary.
- The rover will have onboard a drill for excavation and a crane for the transportation of samples and to aid in the construction of the base.

NASA manned rover

The rocker-bogie suspension system



Space Suit Compatibility:
The Z series space suit attaches to a rear hatch, which is designed to function as an air lock with the NASA Mars rover. This enables the astronaut to climb out the back of the suit, straight into the pressurised rover in minimal time, meaning they can be in a pressurised cabin for prolonged periods of time, and don't have to wait for a decompression and then re-pressurisation of the rover cabin. The air lock system can be seen in the picture above, showing that up to two astronauts can use the rover at once.

Psychology

Mental health considerations

Giving astronauts the ability to have some choice on what they do each day and how they want to do it (to a certain extent) such that they are not just carrying out instructions is vital for mental well-being.
However, choices available to them must feel sincere. A false sense of autonomy may lead to detrimental side effects. The Astronauts actions will be ‘Voluntary’ but ‘Unfree’, thus careful consideration must be made.

A great deal of effort must be made to ensure that as much of the surroundings as possible on the vessel/base are as recognisable thus reminding the astronauts of Earth. The addition of a telescope with which the Astronauts can view Earth may also improve psychological well-being.

Evidence suggests that Russians were more prone to stress during isolating tasks whereas Americans, coming from such a highly individualistic culture are arguably more enriched with regards to self-preservation and self-worth. Thus they are arguably, able to handle stress levels and isolation better. This is reflected in scores on the Hofstede model, Russia is 39 and the US is 91. The Hofstede model compares factors such as individualism, power distance, indulgence etc for each country.

(On MIR and ISS) The support role of the commander was significantly and positively related to group cohesion among crew members, and both the task and support roles of the team leader were significantly related to cohesion among people in mission control.

‘Psychological Closing’- Over time, isolated crew show decreases in the scope and content of their communications and a filtering in what they said to outside personnel (group crew)

- Crew members interacted less with some mission control personnel than others, perceiving them as opponents. There was a tendency of some crew members to become more egocentric. This effect may be exacerbated by the duration of the voyage. Due to distance, they may feel that their obedience is less necessary and therefore develop levels of autonomy that may be detrimental to the mission.
- However, on the ISS, the crew members themselves became more cohesive by spending time together (joint birthday celebrations, for example) In a study of 12 ISS cosmonauts, researchers reported that personal values generally remained stable.

Data from the Mars 500 program suggests that it is most effective to allow astronauts to plan their own routines. The study found that high work autonomy (where the crew members planned their own schedules) was well received by the crews. Mission goals were accomplished, and there were no adverse effects.

- During the high autonomy period, crew member mood and self-direction were reported as being improved, but mission control personnel reported more anxiety.

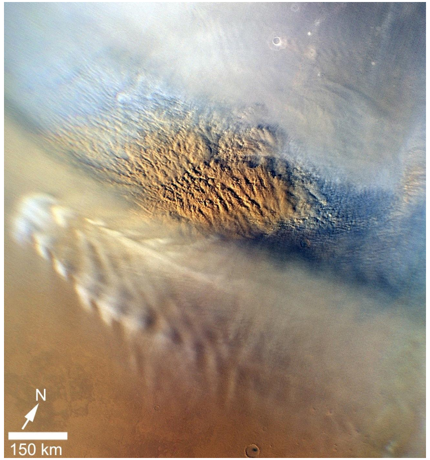
Geology

Martian Weather and Hazards

Mars is composed of around 95% carbon dioxide with an atmosphere around 100 times thinner than that of Earth. This thin atmosphere causes the planet's temperature to fluctuate throughout the day. In the summer the planet can reach highs of 20 degrees and -90 degrees celsius at night. In the winter it can reach lows of -140 degrees. These temperature differences cause warm and cold fronts resulting in the formation of dust devils and dust storms that can cover areas from days to weeks. Although Mars has a thin atmosphere it can still generate clouds and wind. These clouds are mainly composed out of Carbon Dioxide and occasionally snow falls from them around the size of red blood cells but again these composed of Carbon Dioxide.

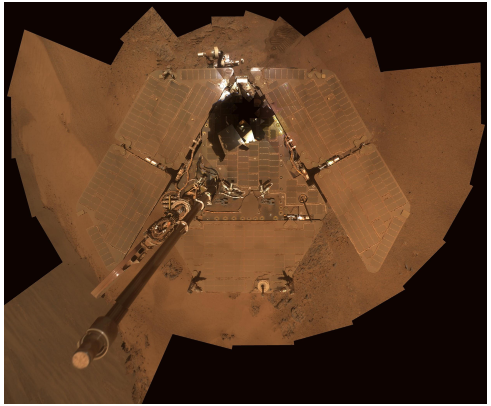
Dust storms are a key feature of the martian weather system. The storms are not as destructive as media have perceived, storms can reach up to 60 mph however according to NASA planetary scientists due to the thin atmosphere this would feel more like a breeze. However they pose other problems, one being vision. During the storm particulates are raised into the atmosphere and these will impair the vision and so will affect some of the tasks being carried out. The main problem is the particulates of dust. They are around one micron in diameter and slightly electrostatic. This will cover all the equipment such as solar panels. This could cause them to no longer provide power if blocked from sunlight it and get in mechanical areas reducing the lifespan of the equipment so will need sweeping off regularly. A dangerous scenario is if a severe storm occurs, these can cover the whole planet in dust for many months. This could seriously affect the mission as power will become limited. This occurred to some of the rovers in smaller storms and they had to go into shutdown mode until it had passed .

Areas of Martian surface are in fact not solid ‘earth’. Areas of the surface are comprised of what is referred to as "foo-foo dust". This is essentially meter deep (possibly deeper) areas of fine particulates and dust. This ground appears stable from satellite imaging and safe to the naked eye however it is very dangerous to traverse as you could sink in it. This could pose a problem for the rover but also the astronauts when they are roaming the area.

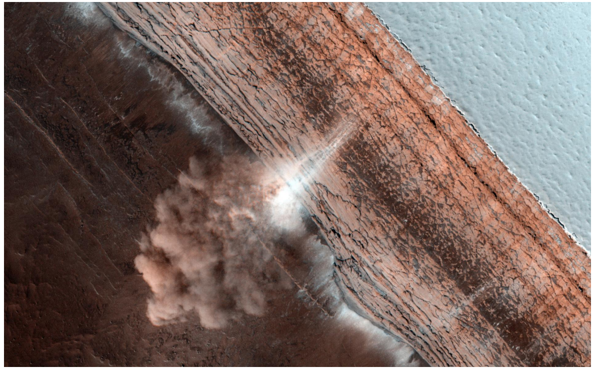


Martian Weather and Hazards (cont.)

Avalanches also occur on Mars, mainly around the poles of the planet. In 2008, The Mars Reconnaissance Orbiter took images of a Martian avalanche, which displaced large amounts of material over 180 meters. Therefore we do not plan to land in this area to ensure this won't affect our mission



A secondary result of the dust storms is the formation of highly corrosive compounds, mainly Hydrogen Peroxide, which is toxic to life. Therefore, concerning producing food using Martian soil, this may be impossible however this will be a key experiment in determining the prospects of colonising Mars. Hydrogen Peroxide is also a powerful oxidising agent, potentially causing an environmental hazard near the base. If there was an oxygen leak from the base there is the possibility of a very big explosion

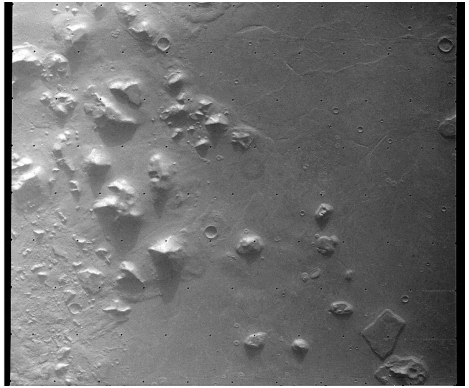


Asteroid Strikes may also pose a danger to our mission. Due to a lack of Atmosphere, Asteroids will not 'burn up'. Whilst a direct impact will be very unlikely, if Mars is hit by anything of noteworthy size, it could result in tremors of some kind and may unsettle any unconsolidated sediment. To guard against this we must ensure our base is secured to firm geological structures.

Landing Sites

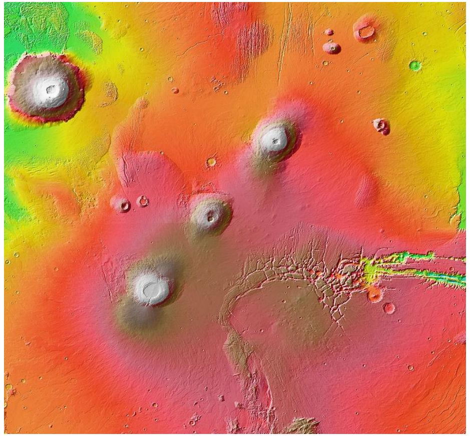
Possible location: Cydonia

The area borders plains of Acidalia Planitia and the Arabia Terra highlands.This area has some interesting geological structures, including flat topped mesa-like structures. It also contains a complex of intersecting valleys. This area is between the heavily cratered South and the flat plains to the North. These flat plains will allow us an area to land safely and build our base. However this area does not provide protection and has not been visited to before so may be dangerous for first mission.



Possible location: Tharsis Montes

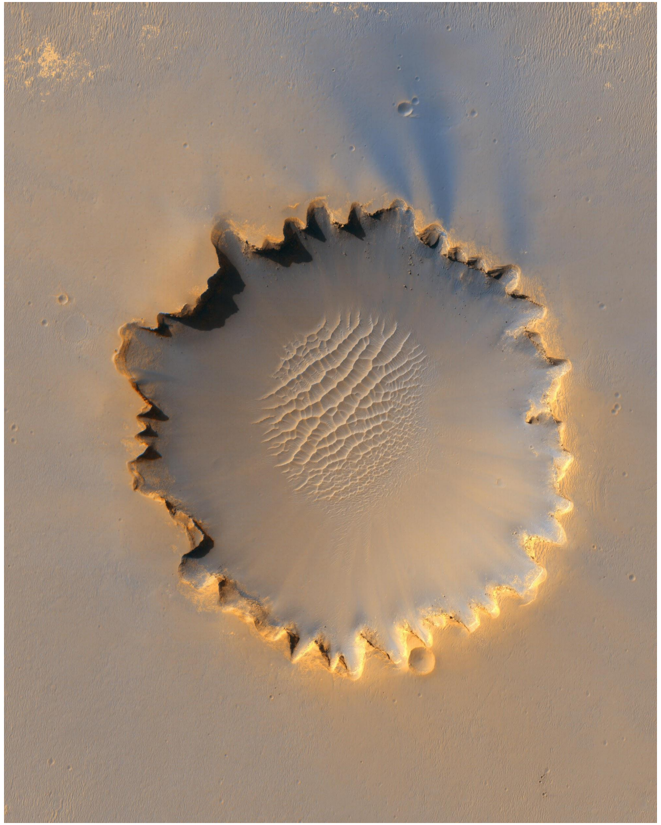
Tharsis Montes is the largest volcanic region on Mars. It is approximately 4,000 km across,10 km high, and contains 12 large volcanoes. The largest volcanoes in the Tharsis region are 4 shield volcanoes named Ascraeus Mons, Pavonis Mons, Arsia Mons, and Olympus Mons. This area would hold great scientific interest, we would be able to take samples of the igneous rock and by determining its composition we would be able to create an idea into internal structure of Mars. However this location could be very dangerous to land near or on one of the volcanoes as they have great heights and steep slopes. Landslides could occur and damage our lander and base, could cost lives and waste valuable resources



Landing Sites

Possible location: Victoria Crater

Victoria crater provides one of the best known locations for a mission to Mars. It was explored by the Opportunity rover in 2006. The rover has collected data on much of the location and we have a topographic map of the crater. This will mean that we will have a key knowledge of the size and the problems that will occur with landing here, these therefore can be planned for in advanced. It has an entrance at Duck Bay and this will allow us to travel to nearby locations in our rover. A key factor in the location for our landing site is that it provides scientific interest and holds the capabilities for research. The crater has many areas of exposed rock which will mean our astronauts will be able to collect rock samples from the rock faces and analyse them in the base along with collecting data from the surrounding area. The crater's ridges will provide some protection for our base from the harsh environment of Mars.
A problem with this location is that the centre of the crater may not be stable enough to hold a base on it. If this is the case then we must ensure that we take necessary steps to secure the base. This location has also already been visited before, we could take this opportunity to explore an area that is completely new however this will have a higher risk factor.



Biology

Space Suits

Space Suits on Mars:

The space suits for use on the surface of Mars must be able to carry out the following:

-Must allow excellent mobility on Mars, as the astronauts will be wearing a suit whenever they go out onto the surface for all purposes
-Must be able to supply oxygen for the astronaut to breathe, and must be able to remove carbon dioxide
-Must protect from the Sun’s radiation
-Must be able to keep the astronaut warm as Mars’ average temperature is around -60 degrees C
-Must be able to be taken on and off quickly and without the help of another astronaut

Launch:

-EVA (extravehicular activity) for use on launch in case of a loss of cabin pressure, and for any jobs where the astronaut needs to be in open space, which can be used in combination with an EMU (extravehicular mobility unit) for untethered work outside the spaceship. An EVA suit can vary in levels of pressurisation. Lower pressures within the suit may require pre-breathing (breathing pure oxygen) for a few minutes before the suit is put on if the astronaut is leaving a pressurised environment such as a space ship. This is to remove dissolved nitrogen from the body to prevent decompression sickness. If the suit is pressurised with pure oxygen at 4.3 PSI, then pre-breathing should not be necessary.

The model of suit that would be used for this purpose would be the Z series of suits currently in development by NASA. The latest in the series is the Z2, a rear entry space suit, which works by having the astronaut climb in through the rear hatch (pictured, right). This allows the astronaut to effectively dock with a spacecraft, Mars base or a Mars rover. The hatch on the back of the suit is a small airlock, so the astronaut can climb straight in, saving a lot of time, and pre-breathing isn’t necessary as the suit is exactly the same pressure as the pressurised Mars base or other pressurised environment that they just came from. This is particularly useful when combined with a rover, which lets the astronaut climb straight back in and start driving immediately.

Space Suits on Mars

BioSuit

The BioSuit, designed by MIT (pictured) is a revolutionary design for a space suit for use on the surface of Mars. Traditional space suits work by pressurising the air around the astronaut's body to simulate that of earth pressure directly on the skin. This suit would also utilise a pressure of 4.3 PSI (one third of an atmosphere). Unlike a conventional suit, the BioSuit uses muscle-like fibres to tighten around the body to create mechanical pressure.

The only gas-pressurised section of the suit is the helmet, filled with 100% oxygen for the astronaut to breathe. The helmet is connected directly to the life support system on the astronaut's back, and can use a standard Portable Life Support System (PLSS) as used on the Z series space suits. The main advantages of this suit is that it is ultra lightweight and compact when compared to conventional suits for EVA purposes. The suit is unbeatable in practicality, as the low thickness and weight of the suit makes physical actions much more convenient.

Possible Limitations of the BioSuit:

- The BioSuit is highly specific for each user as it has to tighten perfectly around the body
- The memory alloy structures currently require heat to stay tight around the skin
- The current prototypes rely on natural sweating to keep the astronaut cool, and so after long periods of physical exertion this could cause problems
- Losses in muscle mass on the journey could cause the suit to no longer fit the astronaut that it was custom made for

Astronaut Health

ISS021E007807

Muscle Wastage:

Mars's gravity is only 38% as strong as Earth's. This means that effectively astronauts would be 62% stronger on Mars than they were on Earth for the same muscle mass. Just like on Earth, if muscle is not used it does not get replenished when cells die. However, the main problem isn't the gravity on Mars, as at least on Mars there is some gravity. The bigger problem is the 18 months of journeying in zero gravity to get from Earth to Mars and then back again. A study by Robert Fitts from Marquette University found that astronauts could lose more than 40% of their muscle mass, giving a 30 year old astronaut the strength of an 80 year old one. These figures are despite frequent exercise. On the ISS astronauts typically carry out around 2.5 hours of exercise using a treadmill, bike and weights, though the Fitts study suggests that even this is not enough to sustain muscle mass of the astronauts. This will cause some serious issues if the astronauts are using the BioSuit on Mars, as if they have changed in size and mass over the 9 month journey to Mars, the custom fitted memory alloy suits will no longer fit correctly, and will not apply the desired mechanical pressure to the skin. This could render the suits completely useless if the astronauts do not maintain their muscle mass. The Z series suits will not be affected by this change.

Bone Deterioration:

Just like with muscles, when cells inside the bones die, they are not needed to be replaced in the same volumes that they would need to be on Earth. As there is no gravity in space the bones do not need to be close to as strong to support the weight of the body. Astronauts can lose as much as 1% of their bone mass each month. This can result in higher calcium levels in other parts of the body, and can cause problems such as kidney stones. A 20 month mission could result in around a 20% loss in bone mass, which would have a serious impact on the performance and strength of astronauts. Combined with a 40% loss in muscle mass, these decreases in strength could mean that the astronauts would never fully recover from the mission once they returned to earth. However, the spacecraft we have proposed for this mission will feature an artificial gravity system, meaning that the body will act just like it would on Earth, and therefore astronauts would not experience bone and muscle mass loss with regular exercise. The only time on the mission where the astronauts will experience these effects will be during the 60 days spent on the surface of Mars. At one third of Earth's gravity, astronauts can expect to lose around 0.5% of their bone mass, and around 3% of their muscle mass, which will not cause negative effects to strength upon return to Earth.

Life Support

Life Support Systems:

- The astronauts will be in very similar conditions travelling to Mars and on the Mars base as current astronauts on the ISS
- The ISS uses The Environmental Control and Life Support System (ECLSS)
- The functions that this system carries out are as follows:
    - Provide Oxygen for breathing
    - Provides water for consumption and hygiene
    - Removes carbon dioxide from the cabin air
    - Filters microorganisms out of the cabin air
    - Maintains cabin air pressure
    - Maintains constant temperature and humidity
    - Fire and smoke detection

The nine month journey to Mars puts the astronauts in very similar conditions to that of the ISS, and so it is appropriate to use the same life support system for a ship of similar size. Our ship will be slightly smaller than the ISS, meaning that the ECLSS system will be more than capable of sustaining life for the duration of the mission to Mars. The same system can also be used on the surface of the planet, although as the base grows in size over future missions, a larger life support will be necessary. A second ECLSS unit will be carried on the ship to be used on the surface of Mars, as this system is known for being very reliable with minimal failures. This system is also designed to support up to 10 astronauts on the ISS, whereas our mission is taking 6 astronauts, again showing that this system is well within its capacity. By 2030 it is likely that this system will have

Radiation Shielding

A large part of the human protection is protection from radiation during the flight from Earth to Mars. The main problem associated with shielding from radiation is that the material generally has to be very dense and therefore have a large mass. On the ISS, astronauts are partly protected from radiation due to Earth's magnetic field, but once they travel out of this shield they only have their ship for protection.For protecting the nuclear reactor(s) it may be necessary to use high density materials, as this is only in a small area, so shouldn't cause problems with requiring too much extra fuel. However, for the rest of the ship another alternative is needed as it needs to cover a large area and must protect astronauts from low levels of radiation. Also, for the Mars base moving heavy materials is impossible so another alternative would be ideal. The best solution would be a radiation shielding material that is strong enough to be used as a structural material.

-On the surface of mars 0.64 millisieverts of radiation per day.
-During the interplanetary flight 1.84 millisieverts per day.
-ESA limits its astronauts career radiation dose to about 1.01 sieverts.

There are two main ways to protect astronauts from radiation in space:

1. A physical shield

A material currently being developed by NASA is hydrogenated boron nitride nanotubes, or BNNTs. Hydrogen is one of the most effective elements at blocking protons and neutrons, as it is a very similar size due to it normally consisting of a single proton and electron. The tubes consist of nitrogen, boron and carbon, with hydrogen filling the empty air spaces between the tubes. As is usually the case with nano-structures, they are also incredibly strong, which means that they could potentially be used as a structural material, something that polyethylene is not strong enough to do. Polyethylene would have to be integrated into another material to be used, which would add a lot of weight to the ship:

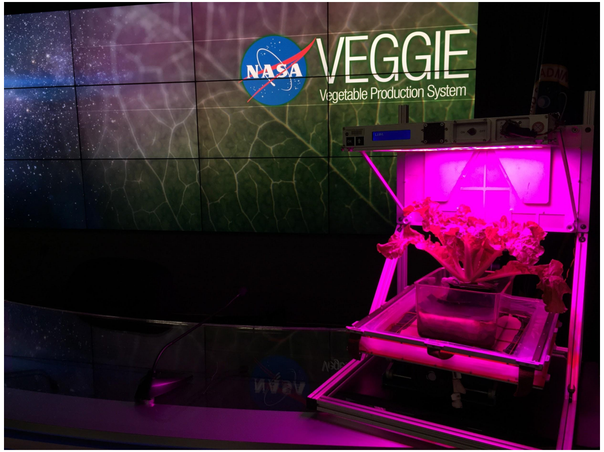
2. A force field

A small electric or magnetic field around the spacecraft would be able to protect the ship from radiation in the same way that Earth's magnetic field protects us from radiation. This shield would have to have a fairly substantial amount of power to prevent the particles reaching the ship. An electromagnetic field also has the advantage of shielding astronauts from all kinds of radiation, not specifically just GCRs and their secondary radiation for example. In 2016, this technology is not yet available close to a size small enough to be used on a spaceship on the journey to Mars, though as the development progresses this may become possible.

Space Plants & Food

It is already known that it is not sustainable to grow plants in uncontrolled conditions in Martian soil in the same way that it is on Earth. The uncontrollable dust storms on Mars are already enough to prevent the growth of plants on the surface. Therefore it is essential that some conditions are controlled. One of the experiments that will be carried out on the surface will investigate to what extent these conditions will in fact need to be controlled. This is a very important experiment to conduct on Mars, as sustainable method of growing plants will be vital for any plans to colonise Mars in the future.

NASA have developed a vegetable production system called VEGGIE, which is currently being tested on the ISS, and uses small pillows that have plant seeds embedded into them, and contain a growth media that releases fertiliser to help the plants grow. All that is needed to start the germination of the seeds is a small amount of water. This system is very compact and would allow astronauts to grow their own food at the same time as carrying out experiments, which will help to vary their diet and contribute to their well-being over the duration of the mission. The plants grown through the VEGGIE system can be used as dietary supplements though the astronauts will still need to eat dehydrated food like they currently do on the ISS.

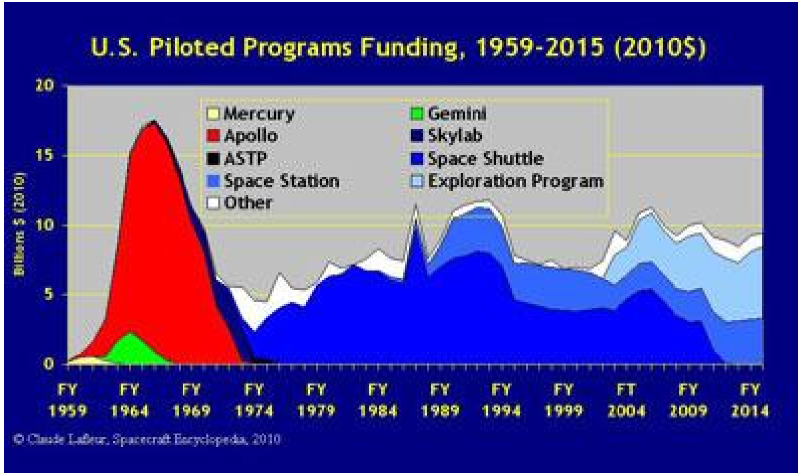


Marking Topic:

Optimising Cost and Schedule

Economics

Financing and Budget



Source: http://www.thespacereview.com/article/1579/1

Why will institutions/ companies invest?

- We can set up and repair instruments
- Improve communications
- Create a better understanding of the habitability of Mars
- We will give data in return for using satellite communications
- Private companies request certain experiments on mars and in-flight
- Cooperation from multiple nations

Companies and institutions are likely to invest in the development of our mission with the prospect that we can carry out one of a kind experiments during the flight and whist on Mars for those private contractors. NASA and other space exploration schemes will offer us finance or usage of their instruments if we provide data and maintenance towards their work. With the tools and the major added benefit of a manned mission we can carry out activities more efficiently than robots and help improve communications and infrastructure. By cooperating with multiple nations our mission to Mars will gain support internationally. With our reusable rocket and multiple flights our Mission to Mars can become more economically viable.

Comparisons

Comparing commercially available rockets:

NASA's SLS-1/EM-1 space program has an estimated cost of $18 billion in total and $3 billion a year thereafter. $6 billion has been spent on the development of the Orion space rocket and $2 billion for launch facilities which means after its first flight it could become commercially available for less, however it will take time for the rocket to be redeveloped and tested as it will probably be used by NASA for their own future missions. Also, the cost of the program does not include the cost of their Deep Space Habitat which hasn't been fully developed yet so there are uncertainties to the cost. Overall, by using NASA's spacecraft costs can become high.

SpaceX has been developing its Falcon space rockets, capable of carrying a high payload. In order to keep costs low for fuel consumption and rocket hire the Falcon Heavy will be the most suitable spacecraft to relay materials into LEO through 7 launches which could acquire multi-launch discounts.

Comparing space suits:

With the planned combination of space suits we plan to keep costs low at $74 million, including the price of spare emergency suits. By using MIT's BioSuit, we can keep costs low. Since NASA's Z series suits have not been used in space before we could get a discount or reward for testing the suits for them.

Comparisons cont.

Comparing similar missions:

Apollo 105 billion USD
Ther costs for Apollo includes 6 flights, however our budget should be significantly lower since we do not need to carry out as much research and development.

International Space Station $110.65 billion USD
The ISS cost for the last ten years includes development, assembly and running costs. Our mission is comparable to this figure since we will be designing a base in space similar to the ISS, however, our costs will not be predicted for that far into the future yet.

MarsOne Mission $100 billion: (estimates)
$100 billion includes costs of each flight including return and estimates the first flight at $6 billion and flights thereafter to be $4 billion each. Our mission to Mars is similar in that it will be looking to benefit from multiple flights and commercially benefiting from our program. After our first exploratory mission and improve our reputation private companies will invest in our program by requesting certain experiments and research.

Curiosity Mars Mission $2.5 billion
The Curiosity Rover gives an idea of the costs of a small scale unmanned mission, to give an idea of the cost of a larger scale mission.

Apollo costs (millions USD)	1973	2010
Spacecraft	79.45	34465.41
Saturn 1	7.671	3327.68
Saturn 1B	11.312	4907.146
Saturn V	68.711	29806.83
Launch vehicle engine development	8.542	3705.52
Mission support	14.323	6213.317
Tracking data	6.641	2880.866
Ground facilities	18.303	7939.841
Operation of instalments	24.206	10500.56
	239.159	**103747.17**

Sources: ISS website, NASA website, MarsOne

Breakdown of costs

Breakdown of costs:

- Spacesuits
- Fuel/ emergency fuel
- Rocket
- Modules
- SEV
- Ground support/ launch
- Satellite support
- Consumables
- Instruments
- ECLSS/ power (solar arrays)
- Base

Satellite support/ communication relays in place:
Satellite support from NASA ExoMars Orbiter, NASA reconnaissance orbiter and MAVEN
These satellites could be used for internet and communications with earth. These satellites could be used for free in return for data from our Mars mission.

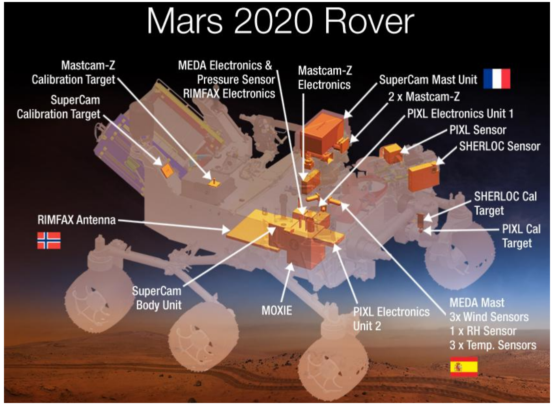
What is already there:

There are currently and about three rovers carrying instruments of Mars. The Curiosity Rover and Mars Express are too far away geographically from the planned landing site. However, the Opportunity Rover is stationed near the Victoria Crater so astronauts can carry out maintenance tasks or use the instruments on the Opportunity rover. This reduces the expenditure spent on new instruments and can provide a basis for activities the astronauts do on Mars. Although other rovers may have more advanced instruments, repairing and improving an existing rover is more efficient and much more cost effective that bringing new untested instruments.

The planned 2020 Mars Rover Mission carrying $130 million of instruments has not confirmed a landing site yet but if it is close to the Victoria Crater it may carry useful instruments for the astronauts, lowering our overall costs.

What is already there:
Panoramic Camera (Pancam)
Miniature Thermal Emission Spectrometer (Mini-TES)
Mössbauer Spectrometer (MB)
Alpha Particle X-Ray Spectrometer (APXS)
Magnets
Microscopic Imager (MI)
Rock Abrasion Tool (RAT)

What may be there in the future when we arrive:
NASA Mars 2020 Rover



Sources: NASA website

Breakdown of costs

	Quantity	Price (USD) millions	Price
MIT BioSuit (custom made)	12	2	24
EVA/ Z-series suit	6	4.4	26.4
ILC Dover EMU suit	2	12	24
ECLSS life support	2	20	40
Water	6	13	78
Astronaut wages	6	0.1	0.6
Falcon Heavy Rocket	7 launches	90	630
Fuel		2775	2775
SpaceX flight to Mars	2	36000	72000
Fuel cells		5	5
Nickel- hydrogen batteries	3	1	3
Space craft modules	6	60	360
Solar Arrays		1	1
Consumables		42	42
Mars Base and materials	6	267	1602
Satellite support		10	10
Tools and instruments		100	100
Research devlopment, engineers, ground support			
Space Exploration Vehicle	1	1000	1000
Adapted from apollo:			
Mission Support	1	62.2	62.2
Tracking and data acquisition	1	28.84	28.84
Ground facilities	1	79.49	79.49
Operation of installations	1	105.13	105.13
			78996.66

Estimated budget: $80 billion

Sources: http://www.wired.com/2013/01/mars-infographic/, ILC dover webite, NASA website