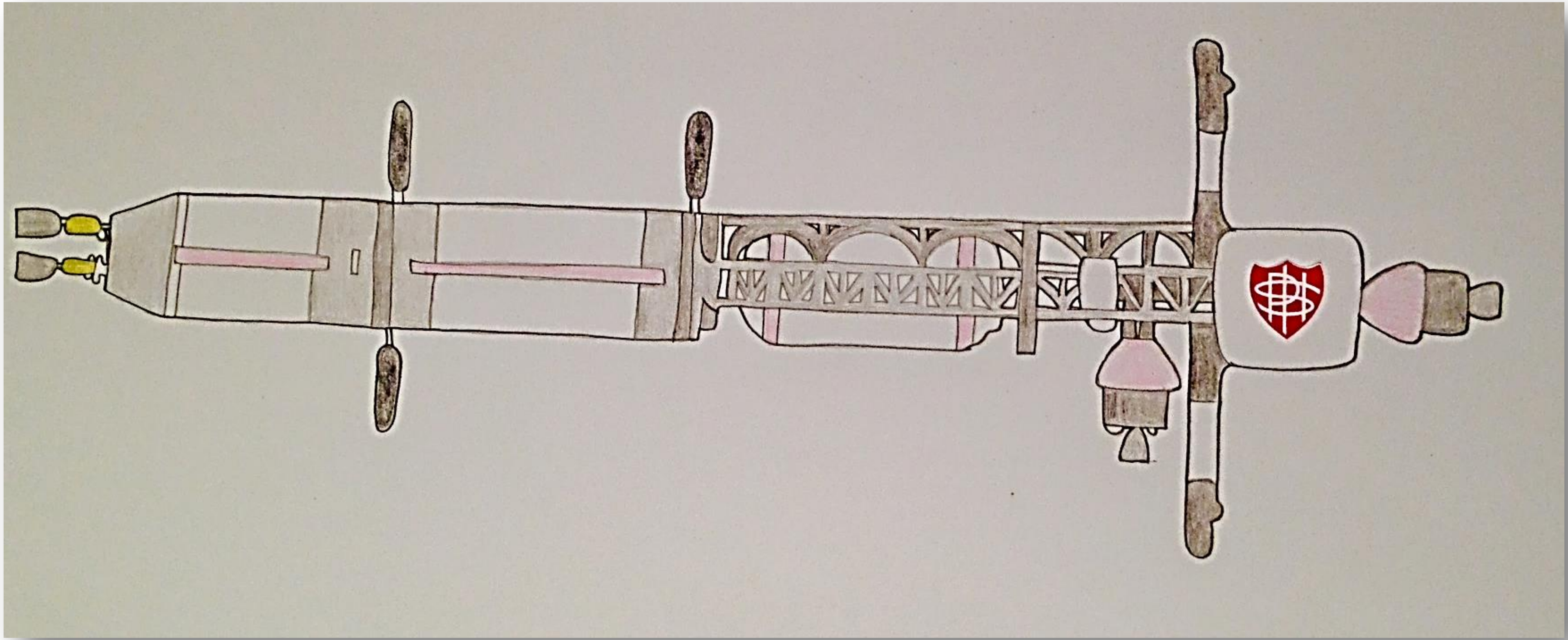
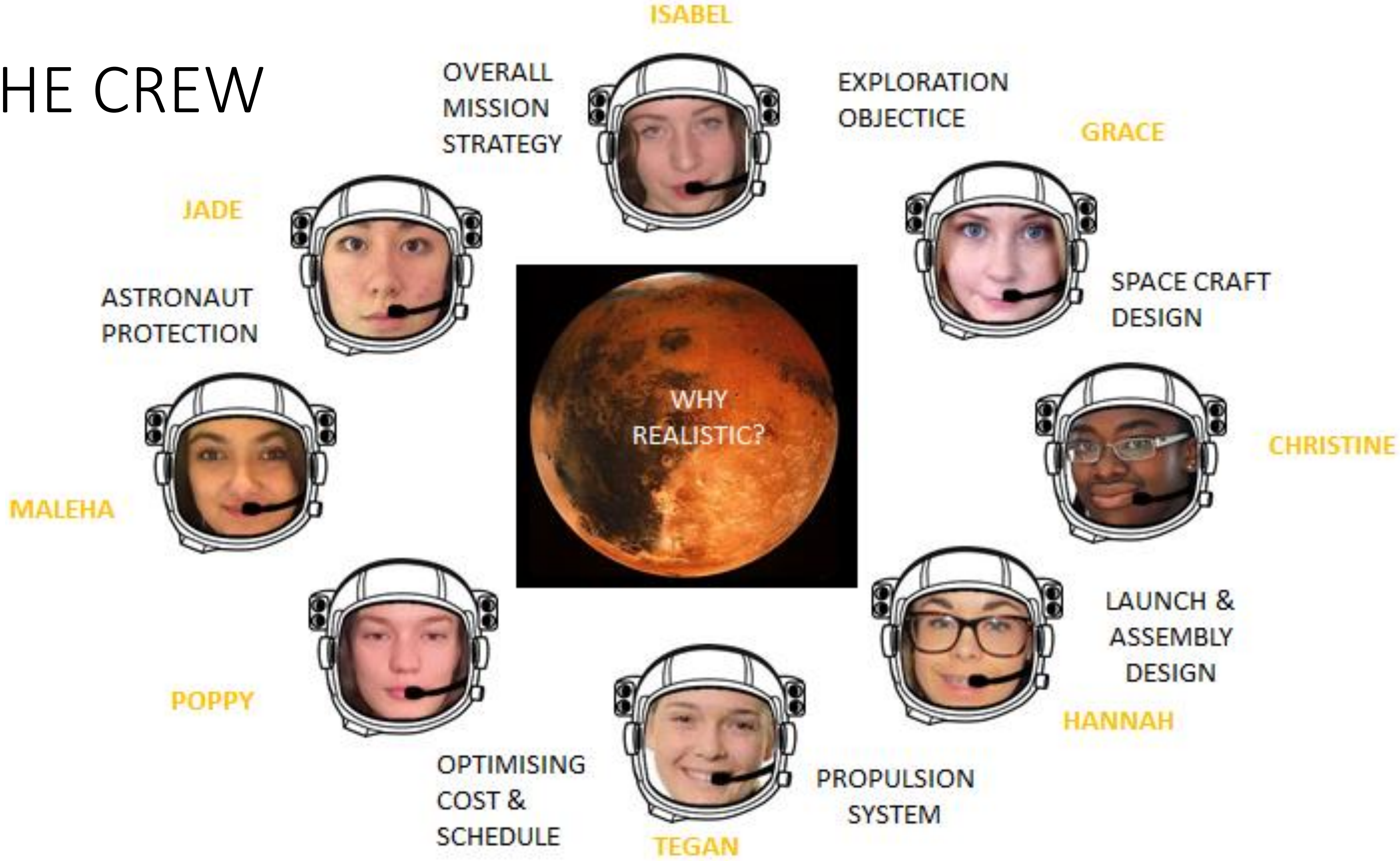
MISSION TO MARS (M2M)



“PHS #1”

THE CREW


ISABEL
OVERALL MISSION STRATEGY
EXPLORATION OBJECTICE
GRACE
SPACE CRAFT DESIGN
CHRISTINE
LAUNCH & ASSEMBLY DESIGN
HANNAH
PROPULSION SYSTEM
TEGAN
OPTIMISING COST & SCHEDULE
POPPY
MALEHA
ASTRONAUT PROTECTION
JADE
WHY REALISTIC?

PHS#1
Overall Mission Strategy

Summary

MISSION STRATEGY OVERVIEW

Stage 1
Launch from International Space Station (ISS)

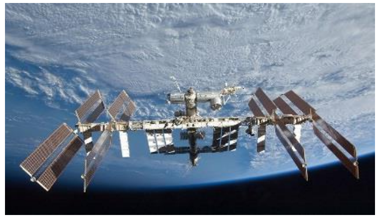
Stage 2
Transit to MARS orbit

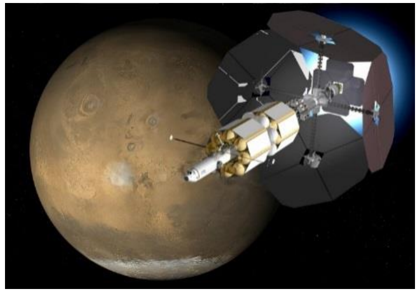
Stage 3
Entry Descent & Landing
EDL to Mars

Stage 4
Exploration
Human Sustainability on Mars

Stage 5
Ascent of MAV to reconnect to MARS orbit

Stage 6
Transit to ISS





Mars Ascent Vehicle MAV

Lander + Rover + Habitat
Site Selection & Construct Habitat

Mars Manned Vehicle MDV/MAV

The Rover

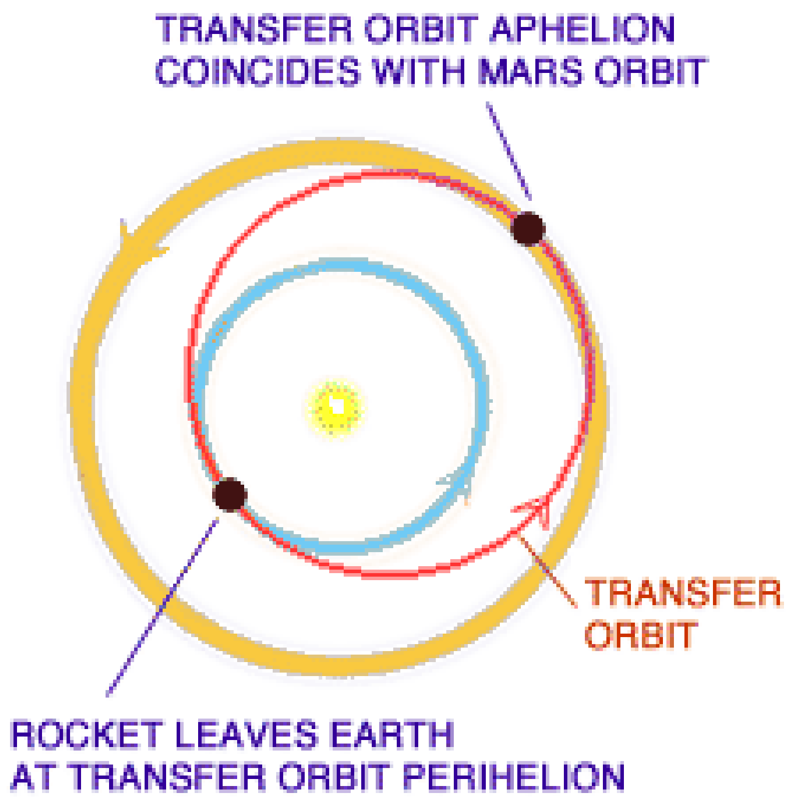
TIME TO MARS: DEPENDS ON THE ROUTE, MARS ALIGNMENT (THE LAUNCH DATE) & SPEED OF SPACECRAFT

Time taken to get to Mars & back

- The Route
- The Opposition Date
- The Propulsion system

THE ROUTE - THE HOHMANN TRANSFER ORBIT

- The most efficient route to take from Earth's orbit to that of Mars is called the 'Hohmann Transfer Orbit' .
- The illustration shows a simplification of the process, as both Earth's and Mars' orbits are not perfect circles.
- In orbital mechanics, the **Hohmann transfer orbit** is an elliptical orbit used to transfer between two circular orbits of different altitudes, in the same plane.
- The orbital manoeuvre to perform the Hohmann transfer uses two engine impulses which move a spacecraft onto and off the transfer orbit.
- This manoeuvre was named after a German scientist, Walter Hohmann.



THE LAUNCH DATE – WHEN & WHY?

- **When?** Launches always happened roughly 2+ years apart.
- **Why?** Because we want to launch our spacecraft during Mars opposition, and Mars opposition happens every 2 years and 2 months. The reason to launch a mission to Mars during opposition is because this is the time when Earth is nearest to Mars.
- However, the best time to launch, in terms of how much energy is required for the trip, is a few months before that happens (comparing the actual launch dates with the Mars opposition dates below).

LIST OF MARS OPPOSITION DATES/DISTANCES

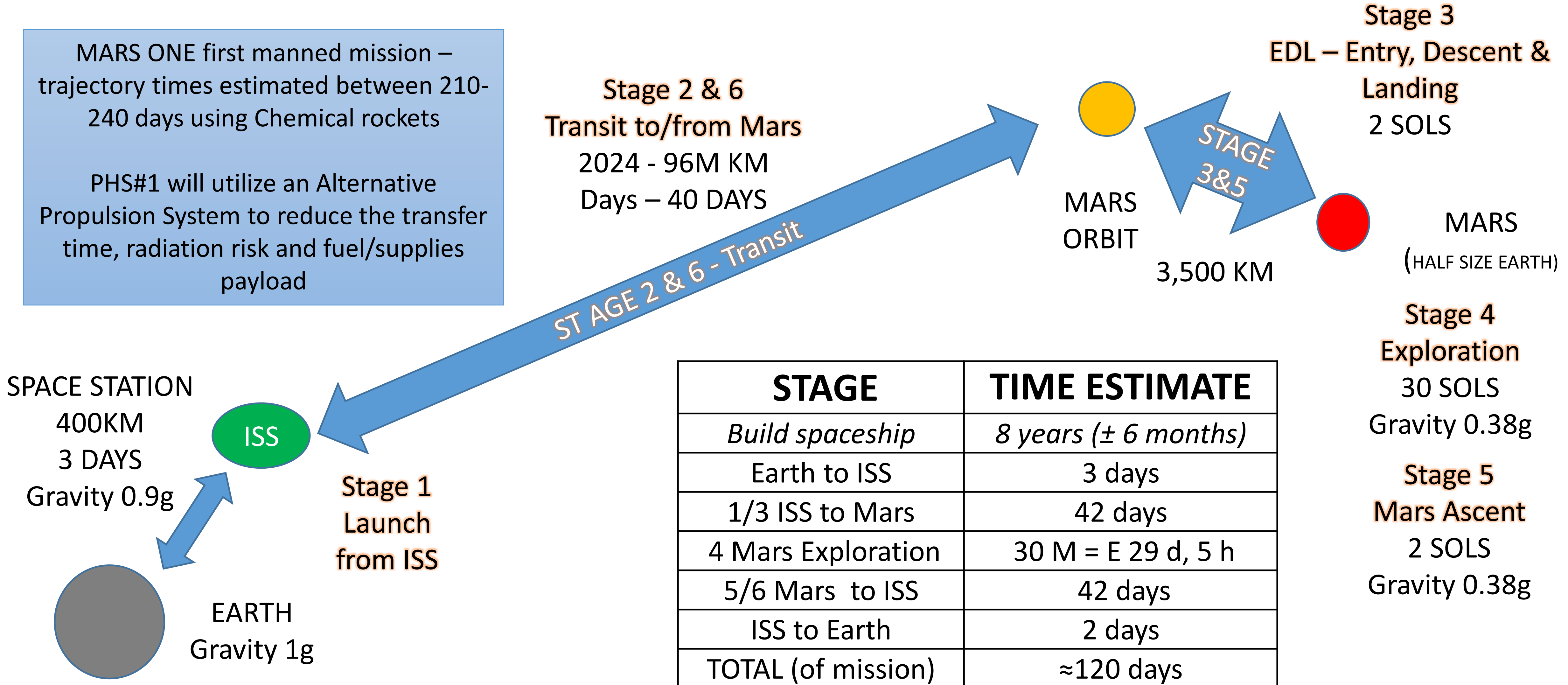
-2 Months	Million Km	**Closest**	Million Km
29.03.16	117	**29.05.16**	75
25.05.18	94	**25.07.18**	57
06.08.20	88	**06.10.20**	62
25.09.22	118	**25.11.22**	82
06.11.24	140	06.01.25	96
12.12.26	135	**12.02.27**	101

Projected launch date

PHS #1 – SCHEDULE OVERVIEW

MARS ONE first manned mission – trajectory times estimated between 210-240 days using Chemical rockets

PHS#1 will utilize an Alternative Propulsion System to reduce the transfer time, radiation risk and fuel/supplies payload



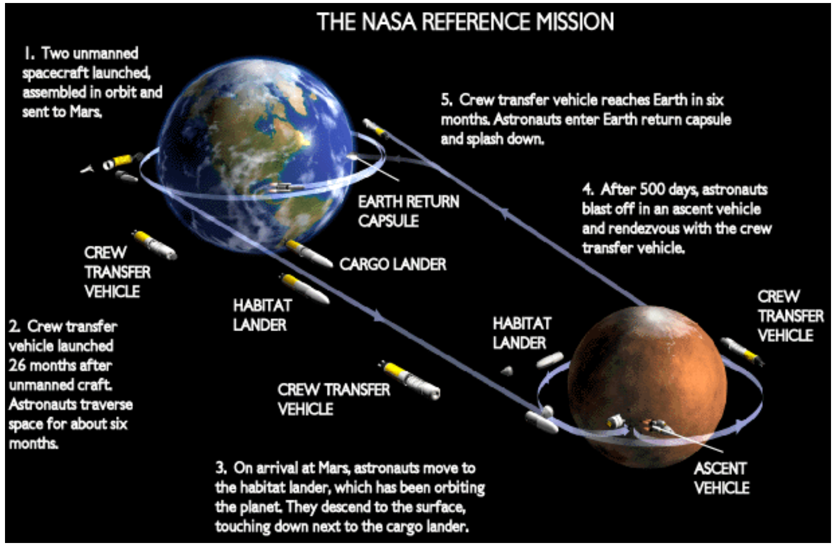
STAGE	TIME ESTIMATE
Build spaceship	*8 years (± 6 months)*
Earth to ISS	3 days
1/3 ISS to Mars	42 days
4 Mars Exploration	30 M = E 29 d, 5 h
5/6 Mars to ISS	42 days
ISS to Earth	2 days
TOTAL (of mission)	≈120 days

TIME TAKEN TO GET TO MARS

Unmanned Missions:

- Viking 1 (1976) – 335 days
- Viking 2 (1976) – 360 days
- Mars Reconnaissance Orbiter (2006) – 210 days
- Phoenix Lander (2008) – 295 days
- Curiosity Lander (2012) – 253 days

NASA REFERENCE MANNED MISSION TO MARS



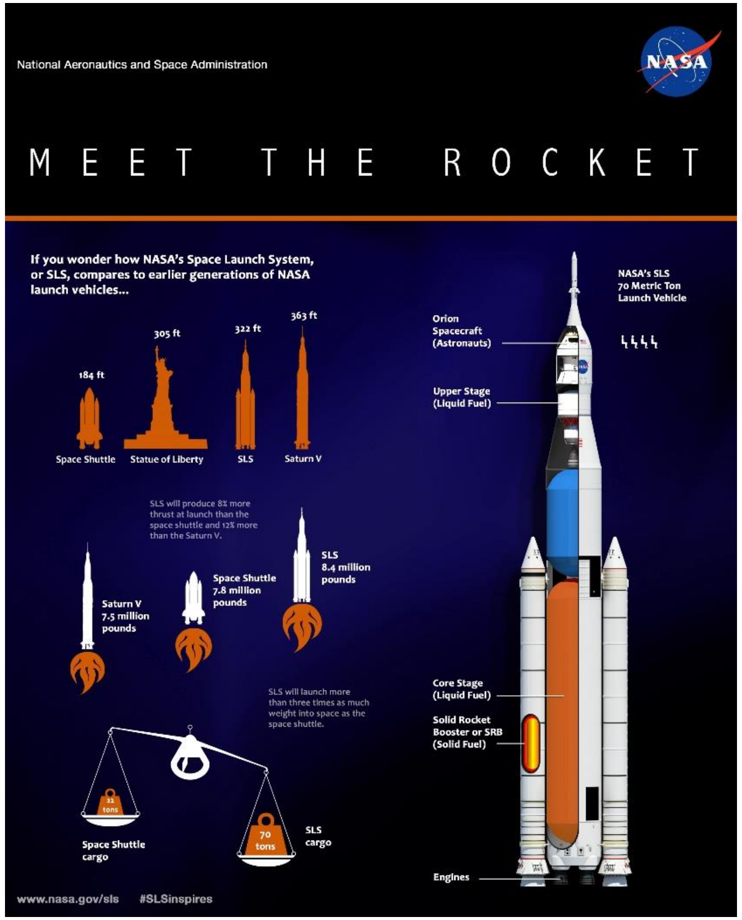
PHS#1 based around reference Mission

IDEAS TO REDUCE TIME TAKEN

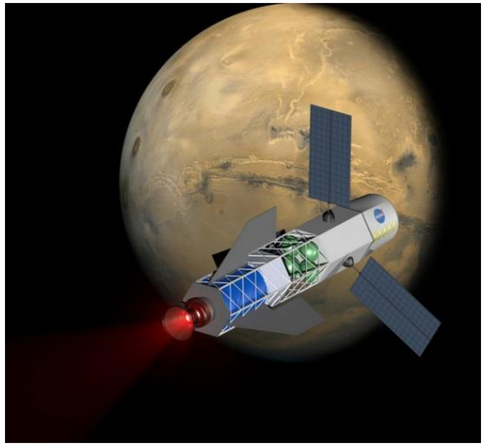
- When looking at the schedule there are several things you need to consider. The first is the time spent to build the spaceship. Robert Frost, a NASA engineer that designs spaceships, estimated that “building a new spaceship can take 4 to 10 years depending on its complexity and the resources of the manufacturer”. As no craft has been made for a manned mission to Mars before, we supposed that it would take a long time to build – about 8 years.
- The time taken to journey to the ISS (400km above the Earth) is difficult to estimate. Heavier ships (such as the STS) take longer that lighter ones (such as Soyuz) and it also depends on time taken to dock. We propose that we assigned a few days after leaving the Earth, for travelling to and resting on the ISS before we leave for Mars.
- The time taken to get to Mars, despite the Hohmann Orbit and the Opposition Launch date, is 7 months using traditional spacecraft (i.e. chemical rockets)
- For example, Curiosity Lander (2012) – 253 days
- The time taken to travel to Mars for unmanned missions is roughly 250 days; ideas to reduce time taken include consideration of a different propulsion methods in order to reduce risk on astronauts and minimize payload e.g. fuel / supplies needed
- If we left Earth on the 6th of November 2024, we would arrive on Mars on the 19th of December. We aim to spend 30 Mars days there (which is approximately 29 Earth days) to collect water and soil samples, before we journey back to the ISS. We would return to the ISS around the 28th of January 2025.

SPACECRAFT – PROPULSION SYSTEM OPTIONS

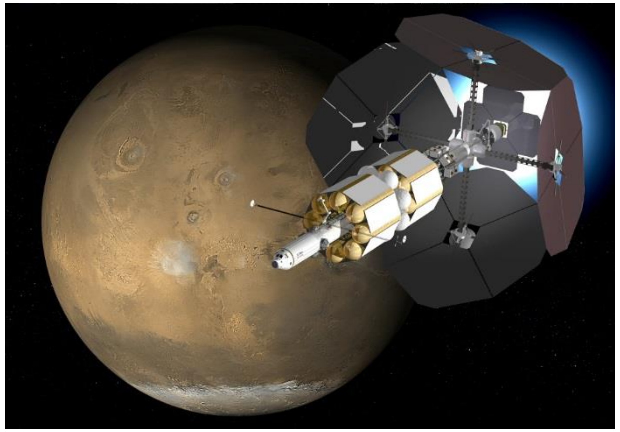
Chemical rockets
SLS



Nuclear Fusion



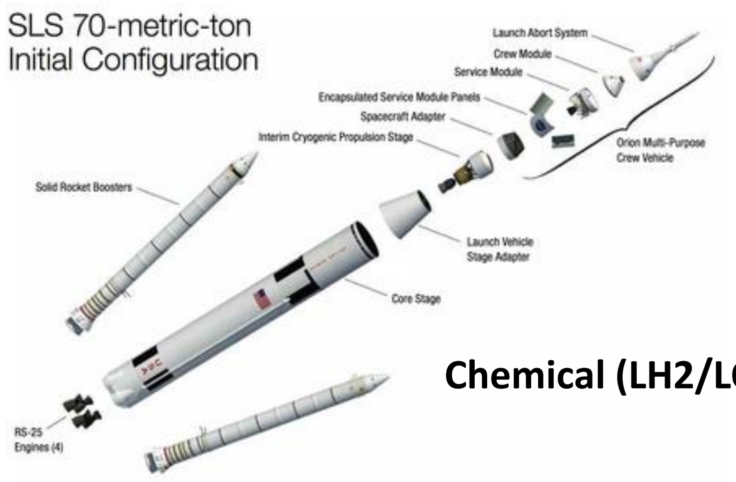
Electric Propulsion VASIMR
Ad Astra



Electrical and Nuclear propulsion systems reduces the time taken to get to Mars from 210 days with Chemical rockets to 40 days!

PROPULSION SYSTEM – CHEMICAL ROCKETS

- Chemical rockets like **SLS** – Space Launch system or **ATLAS 5 Heavy Lift** will only be used to transfer the 15-20 tons of equipment needed to undertake a Mars mission from Earth to the International Space Station..
- The main issue with these chemical rockets is that they burn fuel very quickly, so can only be used for brief burst, most of the time the rocket will just be on the Mars Trajectory Orbit with no engine propulsion.

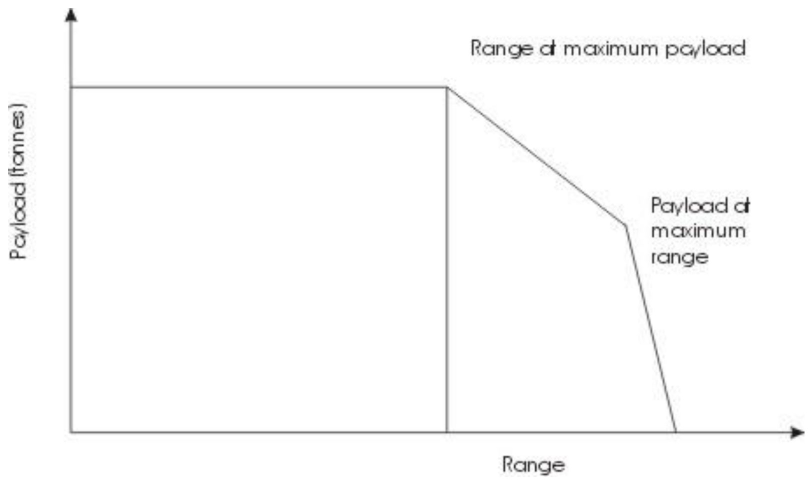


Chemical (LH2/LOX) rocket

These Chemical Rockets will be used to get the various components of the Mars Transit Vehicle into the Low Earth Orbit of the International Space Station.

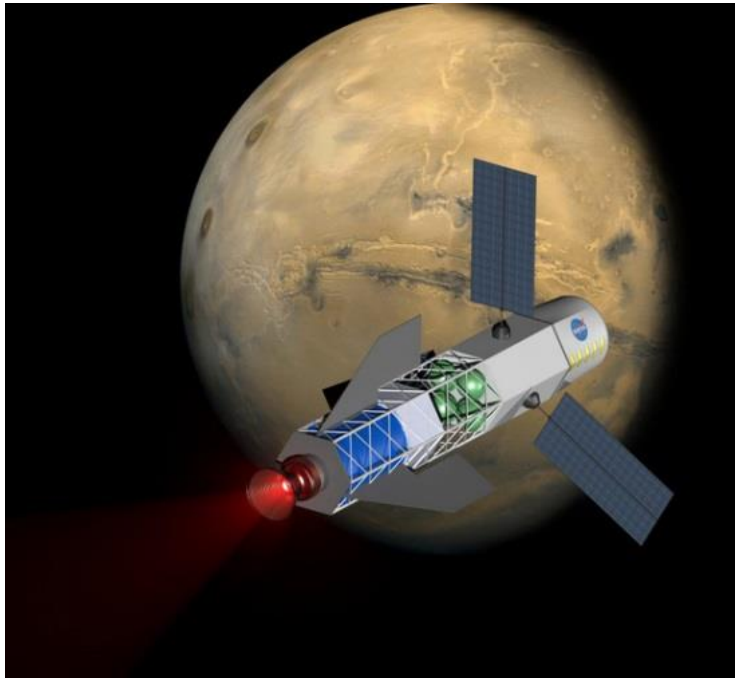
Payload Versus Range Graph

- The vertical line on the graph represents the range at which the combined weight of the aircraft, maximum payload and needed fuel reaches the maximum take-off weight (MTOW) of the aircraft.
- If the range is increased beyond that point, payload has to be sacrificed for fuel.
- The diagonal line after the range-at-maximum-payload point shows how reducing the payload allows the fuel (and range) to increase when taking off with the maximum take-off weight.
- The second kink in the curve represents the point at which the maximum fuel capacity is reached.
- Flying further than that point means that the payload has to be reduced further, for an even smaller increase in range.



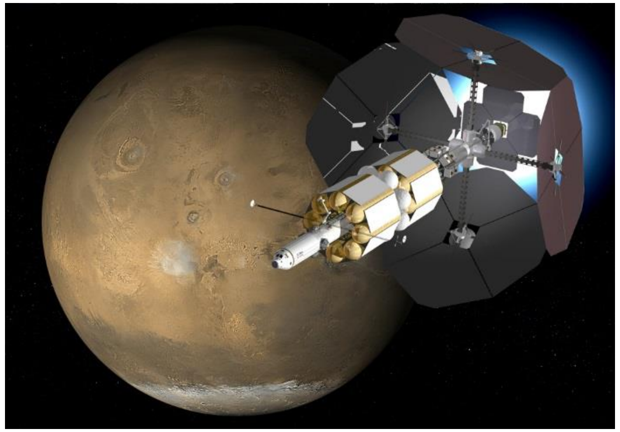
PROPULSION SYSTEM – NUCLEAR FUSION

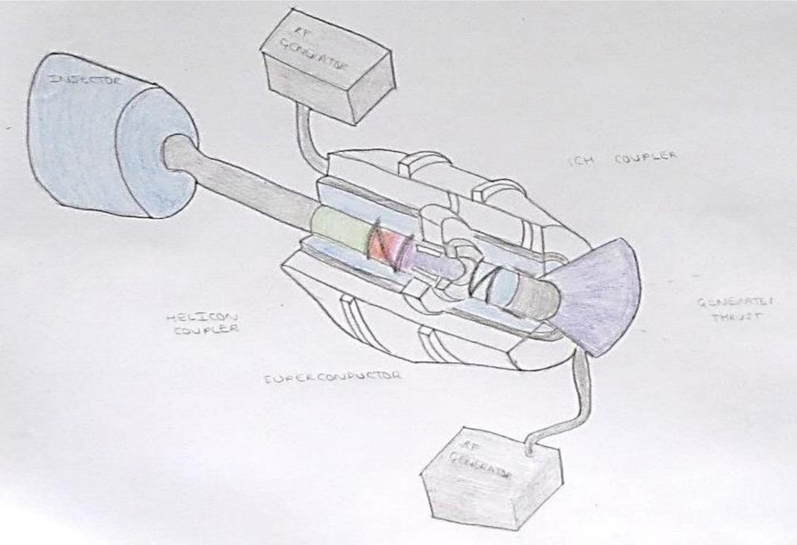
- Nuclear Fusion occurs when the nuclei of two or more atoms combine, resulting in a release of energy. The sun and other stars convert this energy into light, and the same process gives hydrogen bombs their destructive power.
- Nuclear Fusion could occur by compressing a specially developed type of plasma to a high pressure with a magnetic field.
- A sand-grain-sized bit of this material would have the same amount of energy as current rocket fuel, this would reduce the weight of fuel dramatically.
- To get this fuel to propel a rocket to Mars, a powerful magnetic field could be used to cause large metal rings (made of lithium) to collapse around the plasma material, compressing it to a fusion state, but only for a few microseconds.
- Energy from these quick fusion reactions would heat up and ionize the shell of metal formed by the crushed rings.
- The hot, ionized metal would be shot out of the rocket nozzle at a high speed. Repeating this process roughly every minute would propel the spacecraft.



PROPULSION SYSTEM – ELECTRIC PROPULSION

- There is a new electric propulsion system under development called VASIMR (Variable Specific Impulse Magneto Plasma Rocket).
- VASIMR is a plasma-based propulsion system.
- The VASIMR works by expelling fuel out of its exhaust just as a normal chemical rocket does: the difference is that it expels more violently, exhausting its fuel mass out as a plasma, which is as hot as the interior of the Sun and moving at more than 50 kilometres per second.
- This means that VASIMR gets a lot more thrust out of a given mass of propellant than ordinary chemical rockets can: though unlike them it needs electrical power to work, ultilising a Solar Electric Propulsion (SEP) system using gas for fuel.
- A traditional chemical rocket will burn up fuel very quickly, once in orbit. Therefore it can be used only in brief bursts. It will spend almost all its time coasting along unpowered. Therefore, a journey to Mars would take 6 months for a conventional spacecraft.
- However VASIMR can keep on exerting its fairly small force for many weeks without using any more fuel, which gradually increases the speed of a spacecraft significantly. As a result VASIMR spacecraft could get to Mars in just 39 days.

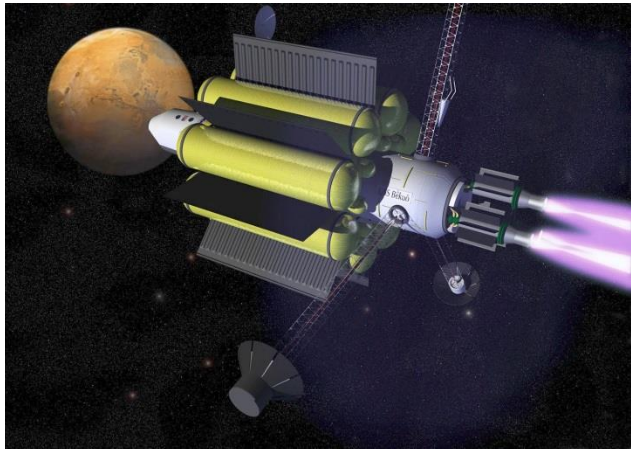




Ionisation chamber

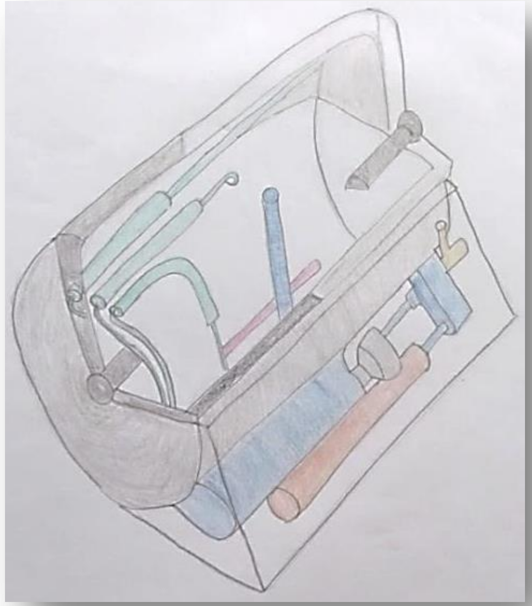
VARIABLE SPECIFIC IMPULSE MAGNETO PLASMA ROCKET - VASIMR

- VASIMR would be able to travel to Mars much more quickly than a traditional chemical-powered rocket, and then once on Mars the spacecraft can refuel on Mars for the return flight to Earth.
- The VASIMR engine could also help protect astronauts from the dangerous effects of radiation during their trip, as their time in space would be reduced.
- In the near future, VASIMR could even help keep the International Space Station (ISS) in orbit without requiring extra fuel to be brought up from Earth.
- An electric power source is used to ionize fuel into plasma.
- Electric fields heat and accelerate the plasma while the magnetic fields direct the plasma in the proper direction as it is ejected from the engine, creating thrust for the spacecraft.
- The engine can even vary the amount of thrust generated, allowing it to increase or decrease its acceleration.
- It even features an "afterburner" mode that sacrifices fuel efficiency for additional speed. Possible fuels for the VASIMR engine could include hydrogen, helium, and deuterium.



VASIMR FUEL TYPE

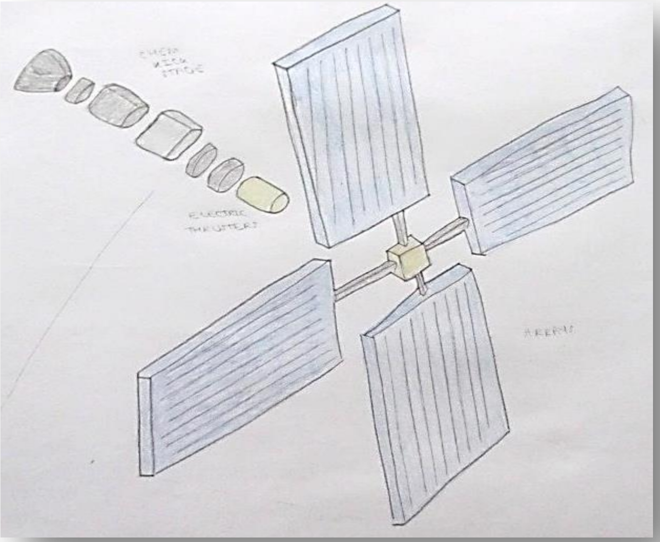
- The use of hydrogen as the fuel for the VASIMR project has many advantages, according to researcher Franklin Chang-Diaz.
- In addition to being the director of the Advanced Space Propulsion Laboratory, Chang-Diaz is an astronaut who has flown into space on seven missions, more than any other NASA astronaut. "We're likely to find hydrogen pretty much anywhere we go in the solar system," he said. What this means is that a VASIMR-powered spacecraft could be launched with only enough fuel to get to its destination, such as Mars, and then pick up more hydrogen upon arrival to serve as fuel for the return trip home.
- Another benefit of hydrogen fuel is that hydrogen is the best known radiation shield, so the fuel for the VASIMR engine could also be used to protect the crew from harmful effects of radiation exposure during the flight.
- Electrical power sources for the VASIMR engine could include such things as a nuclear power system or solar panels.



Hydrogen Fuel Tanks

SOLAR ELECTRIC PROPULSION

- The Solar Electric Propulsion (SEP) stage contains a series of thrusters. These thrusters can either be electro thermal, electrostatic or electromagnetic.
- Solar Electric Propulsion is often considered better than traditional chemical propulsion, as SEP does not need to carry a chemical propellant (internal power source) with the spacecraft all the time.
- SEP occurs due to an external power source, it uses solar energy captured by the SEP stage solar arrays. The solar arrays are photovoltaic solar panels that produce electricity from sunlight.
- The electricity produced by the arrays would power both the SEP stage and the Mars Transit Vehicle (MTV).
- 68 spacecrafts have used a form of SEP in their operations, including NASA's Dawn spacecraft.



Solar Array

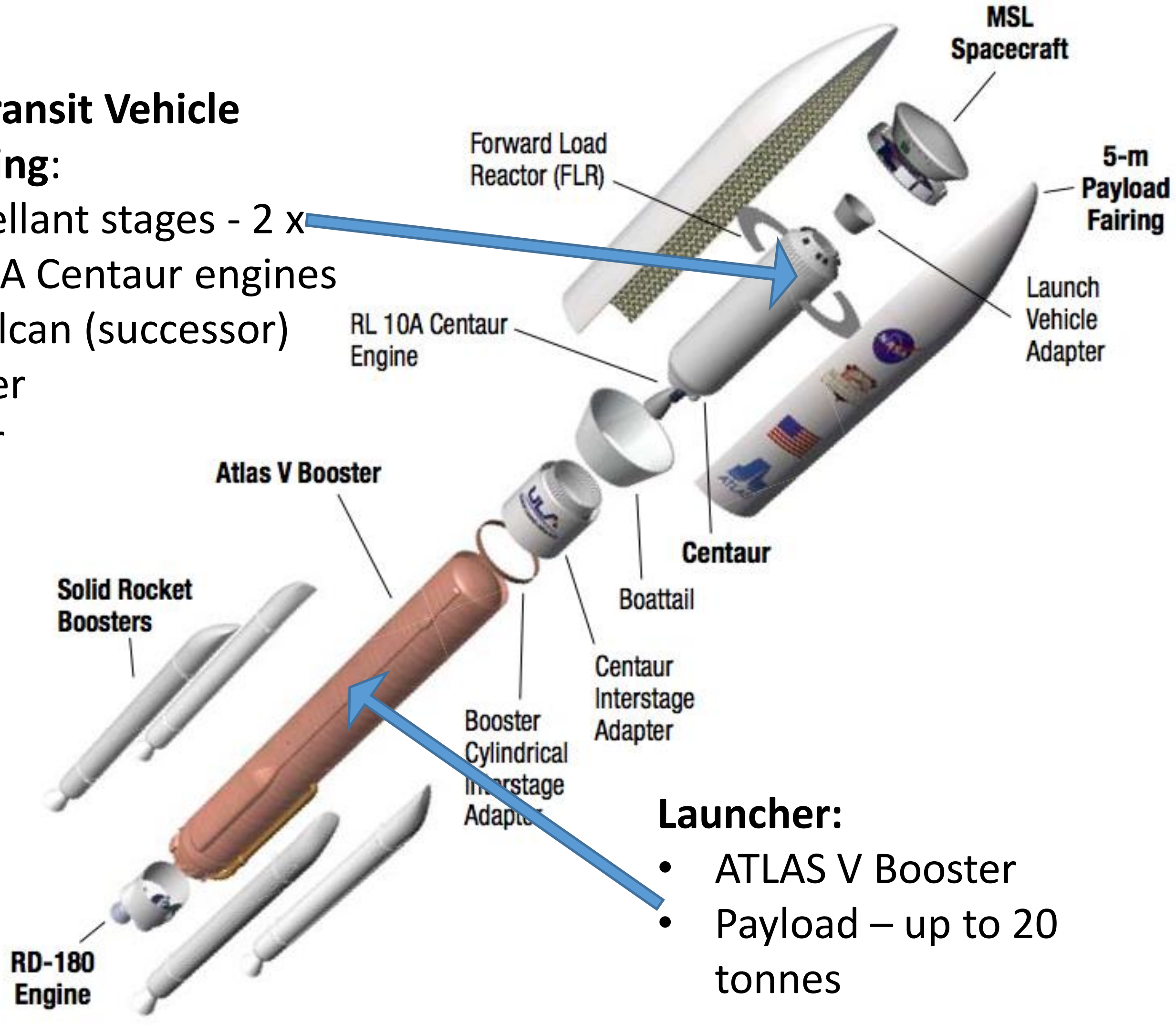
SEP allows an additional propulsion system which can be used in conjunction with VASIMR to power the spacecraft and provide electrical power for the MTV.

The Design of the Spacecraft

- Spacecraft Assembly
- Launch from ISS
- Transit from ISS to Mars
- Mars Orbit
- Landing on Mars
- Ascending from Mars
- Transit from Mars to ISS

LESSONS LEARNT FROM SPACECRAFT DESIGN OF UNMANNED MISSION TO MARS

MARS Transit Vehicle comprising:
- Propellant stages - 2 x RL 10A Centaur engines or Vulcan (successor)
- Lander
- Rover

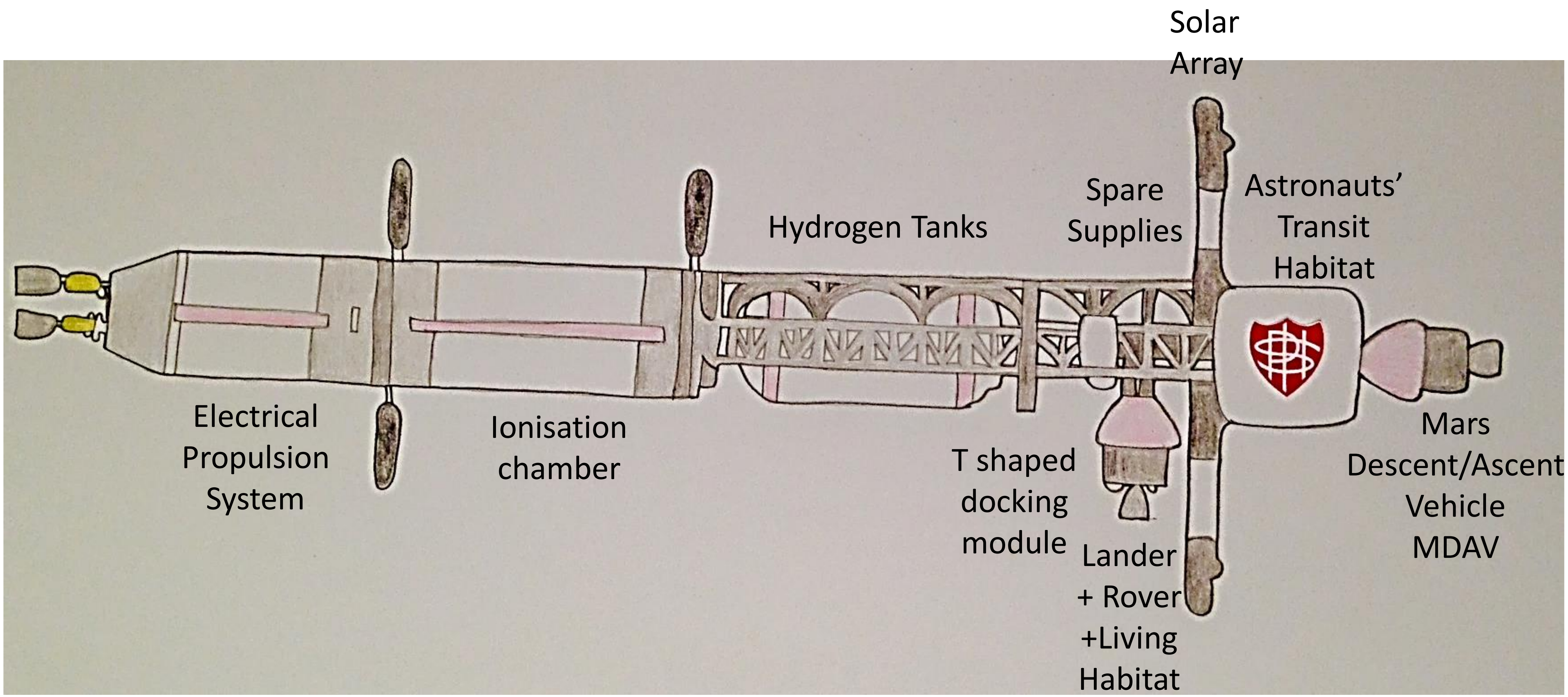


Launcher:
- ATLAS V Booster
- Payload – up to 20 tonnes

Up to now only unmanned missions to Mars have been completed, some have been unsuccessful because the equipment was not robust, was too complicated and could not be repaired remotely.

Key Design Considerations for a manned mission, would include:
- Simplicity
- Durability
- Capacity to be repaired easily using facilities on board in both space & on Mars

PHS#1 - SPACECRAFT ASSEMBLY



THE MARS TRANSIT VEHICLE - MTV

Circa 100 metres long

STAGE 1 - THE LAUNCH FROM ISS

- The various components of the Mars Transit Vehicle (MTV) would be transferred to the International Space Station (ISS) into low Earth orbit using large chemical rockets like SLS / Atlas Heavy Lift (see slide 11).

- The MTV would then rendezvous with the Launch Stage (previously transferred & attached to the International Space Station). The Launch Stage is a chemical propulsion unit utilised for the launch from the ISS.

- The entire MTV (complete with Launch Stage) would separate from the ISS into the Mars Transfer Orbit, by firing the Launch Stage chemical propulsion unit.

- Once the fuel is completely utilised in the Launch Stage it will be separated from the Mars Transit Vehicle.

- The MTV would then deploy its solar arrays, the Electric Propulsion System is activated to propel the MTV to Mars.

The International Space Station "ISS"

STAGE 2 - MARS TRANSIT HABITAT

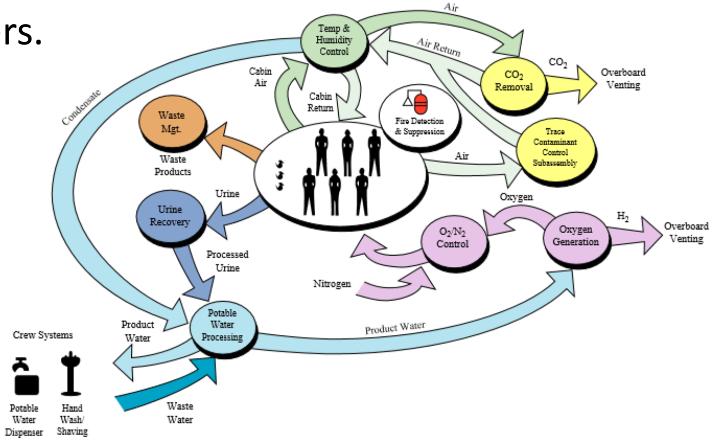
The basic design components of the Mars Transit Habitat include:

- The PHS#1's life support system is based on the ISS Environmental Control and Life Support System (ECLSS) which provides or controls atmospheric pressure 14.7 PSI, has a fire detection and suppression system, controls oxygen levels &waste management and water supply, and maintains temperature at 20-21 degrees C.
- It collects, processes and stores waste and water produced by the crew. The process recycles fluid from the sink, shower, toilet and condensation from the air to produce oxygen via electrolyses process and recycled water via a distillation process.
- Oxygen is produced by the Elektron (Electrolytic Oxygen Generator) system, electrolysing water into hydrogen and oxygen, the crew also have a back-up option in the form of bottled oxygen and solid fuel oxygen generation canisters.
- Carbon dioxide is removed from the air using another system like Vozdukh, other products from humans like methane and ammonia from sweat are removed by activated charcoal filters.

Mars Transit Habitat

Water & Food supplies

- When astronauts travel into space, NASA scientists determine how much food will be needed for each mission. For example, an astronaut on the ISS uses about 1.83 pounds (0.83 kilograms) of food per meal each day. About 0.27 pounds (0.12 kilograms) of this weight is packaging material. Longer-duration missions will require much more food.
- A crew of 4 to Mars for 6 months would need to carry approx. 2,000kg of food.



Environmental and Life Support System

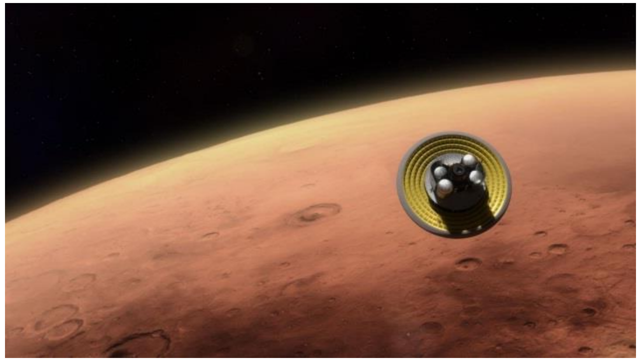
STAGE 2 -MARS TRANSIT HABITAT

Navigation/Communication System

- The communication system consists of a satellite in orbit around Mars, over the Mars landing site, one in orbit around the sun, and ground stations on Earth.
- The satellite over the Mars landing site is always in the same place in the sky on Mars, receiving data from the landing site and transmitting it to Earth. On Earth the data is received by ground stations using large satellite dishes. The Mars satellite enables almost 24/7 communication, which is interrupted only when Mars is in between the satellite and the Earth.
- This is solved by placing a second satellite in an orbit around the sun, trailing 60 degrees behind the Earth. With this second satellite in place, when Mars is in between the Mars satellite and the Earth, the signal can be relayed by the second satellite.
- Once every 26 months, the Sun is exactly in between Mars and the Earth - lasting about six weeks. The second communications satellite will also be used to relay signals during this period.
- However, when the Sun is in between Mars and the Earth and at the same time Mars is in between the Mars satellite and the second satellite, we will have no contact with Mars for about two hours. Fortunately this is a rare situation and occurs when it is after midnight on Mars.

STAGE 3 - MARS ARRIVAL & LANDING

- When a MTV enters orbit around Mars it must adjust its velocity.
- Aerobraking allows a MTV to reduce the high point of an elliptical orbit by repeated brushes with the atmosphere at the low point of the orbit. This saves a considerable amount of fuel.
- Because the braking is done over the course of many orbits, heating is comparatively minor, and a heat shield is not required. This has been done on several Mars missions such as Mars Global Surveyor, Mars Odyssey and Mars Reconnaissance Orbiter, and at least one Venus mission, Magellan.
- Once the MTV has established a low Mars Orbit, the Lander would then be deployed (incorporating the Rover and the Inflatable Living Habitat & living systems). This ensures the majority of weight is deployed to Mars & a living habitat established.
- The Crew remain on the MTV until the Lander has arrived on Mars and deployed the Rover securing a suitable landing site. The communication system is established and the inflatable Living Habitat erected with associated Life Support Systems, remotely.
- As most of the weight has already been deployed by the Lander, the Astronauts can then be transferred using the Mars Descent/Ascent Vehicle. It utilises less fuel and a lower weight structure to ensure it can achieve the Ascent stage at the end of the mission.

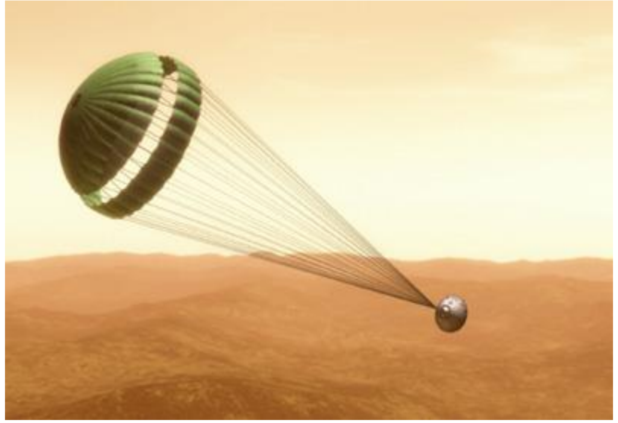


An inflatable shield would deploy when The Lander and the Mars Descent Vehicle enter the Martian atmosphere.

LANDING ON MARS
https://www.youtube.com/watch?v=h2I8AoB1xgU
Seven Minutes of Terror!

STAGE 3 – LANDER LANDING SEQUENCE ON MARS

- The Entry, Descent and Landing (EDL) phase begins when the spacecraft reaches the Mars atmospheric entry interface point (3522.2 kilometers or about 2,113 miles from the center of Mars) and ends with the Lander on the surface of Mars in a safe state.
- The EDL sequence for the PHS#1 mission is an adaptation of the Mars Pathfinder method:
  - An aeroshell and a parachute decelerate the lander through the Martian atmosphere.
  - Prior to surface impact, retro-rockets are fired to slow the Lander´s speed of descent and airbags are inflated to cushion the Lander at surface impact.
  - After its initial impact, the Lander bounces along the Martian surface until it rolls to a stop.
  - The airbags are then deflated and retracted, and the Lander petals and rover egress aids are deployed.
  - Once the petals have opened, the rover deploys its solar arrays, making the system fully operational.



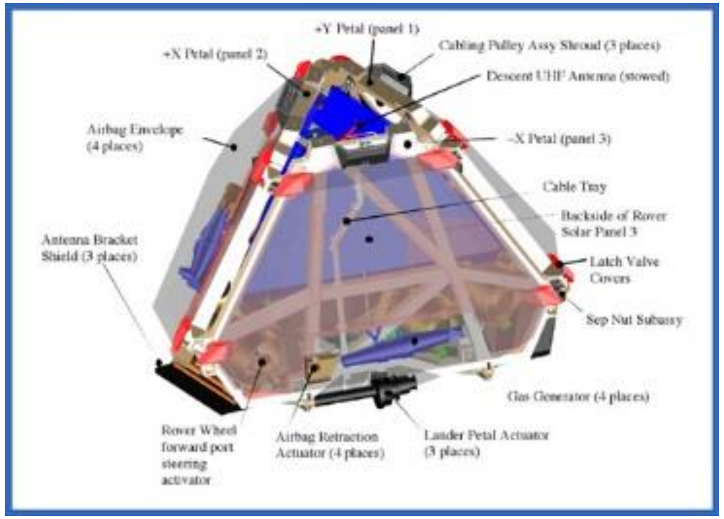
On Entry deploy chute – 1600mph to 1000mph

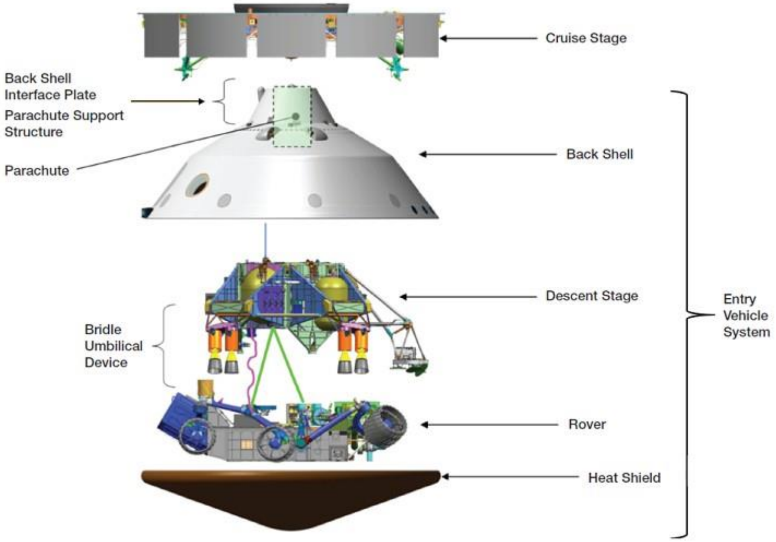
Near surface turn on thrusters – reduce to 200mph – deploy Rover

Just before impact – deploy airbags / shock absorbing legs

THE LANDER STRUCTURE

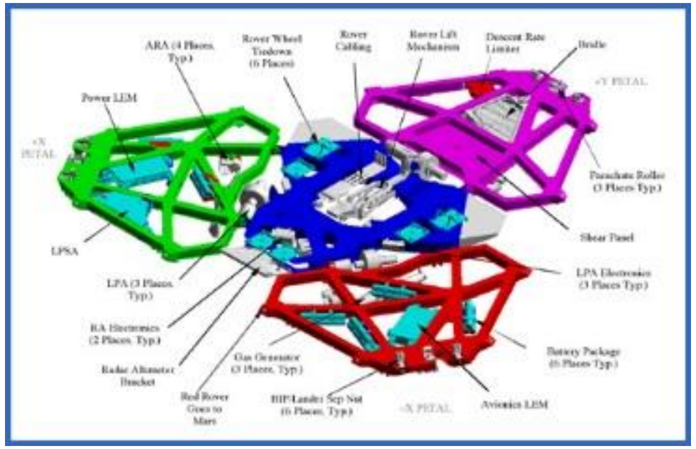
- The spacecraft Lander is a protective "shell" that houses the rover and protects it, along with the airbags, from the forces of impact.
- The Lander is a strong, lightweight structure, consisting of a base and three sides "petals" in the shape of a tetrahedron (pyramid-shaped).
- The Lander structure consists of beams and sheets that are made from a "composite" material.
- Composites such as fiberglass are made of strong fibers or fabrics that are stiffened with a glue or "matrix".
- The Lander beams are made out of carbon-based layers of graphite fiber woven into a fabric, creating a material that is lighter than aluminum and more rigid than steel.
- Titanium fittings are bonded (glued and fitted) onto the Lander beams to allow it to be bolted together.
- The Rover is held inside the Lander with bolts and special nuts that are released after landing with small explosives.





LANDER DESIGN & ROVER DEPLOYMENT

- The three petals are connected to the base of the tetrahedron with hinges
- Each petal has a hinge with a powerful motor that is strong enough to lift the weight of the entire Lander.
- The Rover and Lander would weigh about 530 Kg on Earth, but only about 200 Kg on Mars.
- By having a motor on each petal it means that the Lander can make sure the Rover is upright no matter which side the Lander finally rests on, on the surface of Mars.
- Accelerometers are contained in the Rover, which detect which way is the surface of Mars by measuring the ‘pull’ of gravity.
- By knowing which direction is the surface of Mars, the Rover computer can control the correct lander petal to place the Rover upright.
- Once the base petal is down and the Rover is upright, the other two petals are opened.
- The petals open so they are flat, this can occur even if the two outer petals land on rock as the motors are strong enough to hold the middle petal, with the Rover on like a bridge over the surface of Mars.
- On Earth, the flight team can control the Rover to adjust the petals to allow the best pathway for the Rover to drive off of the Lander onto the surface of Mars, without damage.



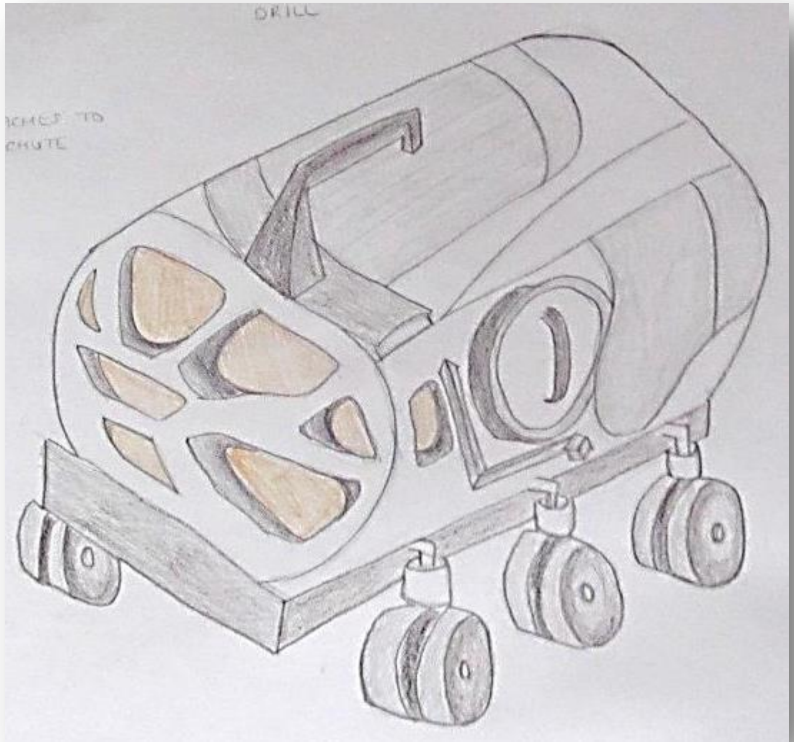
LANDER DESIGN FOR ROVER DEPLOYMENT

How is the Lander designed to move the Rover safely onto the surface of Mars?

- The egress phase of the mission is the process of moving the Rover off of the Lander.
- The wheels of the Rover cannot get caught up in the material of the airbag or drop off a sharp drop, so the Rover must be able to drive off of the Lander safely.
- Before the Lander petals open, the airbag is dragged towards the Lander to get them out of the path of the Rover, this is done by a retractor system contained in the petals of the Lander.
- To fill in large spaces between the petals of the Lander, small ramps (ramplets) connected to the petals fan out, and form a circular area.
- The circular area provides many directions from which the Rover can exit the Lander, they also lower the height of the gap between the Lander and the surface of Mars, which reduces the likelihood of the Rover being damaged.
- The ramplets are made from Vectran cloth (similar to Kevlar), and cover difficult obstacles and airbag material which could damage the Rover wheels before it's had the chance to reach the Martian surface.
- Three hours is allocated in order to retract the airbags and deploy the petals of the Lander.

THE ROVER

- The Rover for our mission is not a scientific Rover.
- It is a capable and powerful tool, with a robotic hand to carry out a wide variety of tasks. The Rover is accompanied by a trailer, which is used to transport landing modules and for power generation.
- The Rover's tasks include:
    - Deployment and maintenance of the human settlement on Mars.
    - Autonomous travel to locate the most suitable location for Living Unit.
    - Measure the amount of water in the soil.
    - Move the Lander to the preferred locations on the trailer.
    - Remove the protective panels from the Lander.
    - Unroll and lay down the thin film solar panels.
    - Extract (from the Lander) and assist with inflation of the Living Unit.
    - Connect the air tube between the Life Support Unit and the Living Unit.



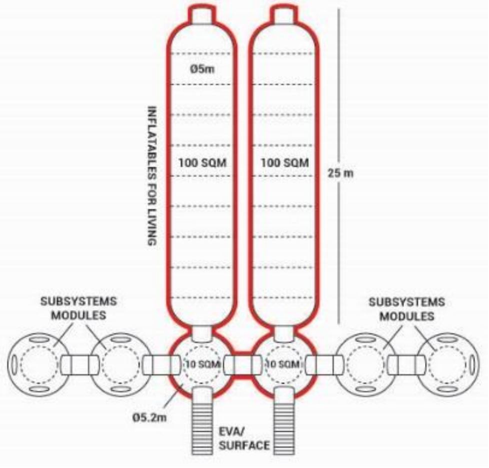
Dual purpose
Remote Control / Manually operated Rover

LIVING UNIT – INFLATABLE HABITAT

- The **Living Unit** is an inflatable living section with an airlock which will be used by the astronauts when leaving the sealed, habitable settlement.
- It will be set in place by the Rover and filled with breathable air by the Life Support Unit prior to the arrival of the astronauts.
- The Lander contains construction materials for the astronauts to construct rooms, floors and install electrical outlets.
- The Lander itself contains the 'wet areas', such as the shower and kitchen.

Architecture

- The outpost architecture consists of six modules and two elongated inflatables.
- The main area is inside the inflatables and provides about 200 square metres for daily living and food production.
- The two-centred modules will provide access technology to the surface of Mars and the four remaining modules will mainly contain subsystems supporting the entire Living Unit.

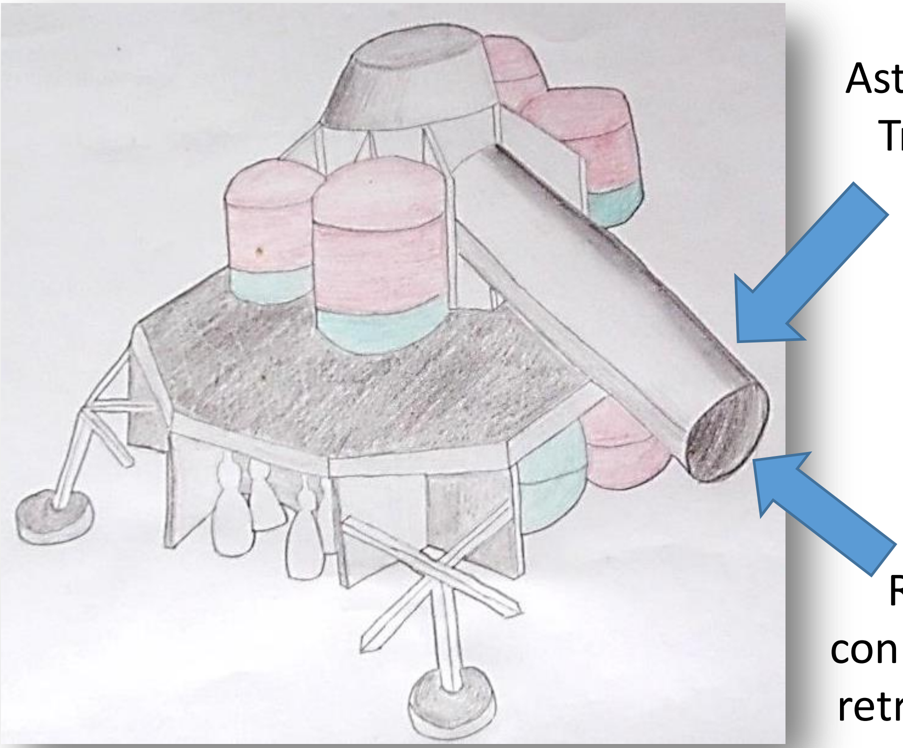


Interior design

- The interior design has to fulfill the needs of both the everyday tasks and the entire life cycle for a human being and crew.
- It must also comply with the requirements of allowed mass and volumes to be transported and later "unfolded" inside the Living Unit.

STAGE 4 – ASTRONAUTS' DESCENT

- Upon completion of the inflatable Living Unit by the remote Rover the communication system will instruct the Astronauts to transfer from the MTV to the Mars Descent Vehicle.
- The Descent Vehicle would follow a similar process to the Lander, however because all the weight was delivered by the Lander the Mars Descent Vehicle can utilise thrusters using limited fuel to land the astronauts safely.
- By using the transfer tube the astronauts can connect to the Rover which will then transfer them to the pre-pared inflatable Living Unit.
- This Mars Descent Vehicle will also be used as the Mars Ascent Vehicle during Stage 5 via recycling the hydrogen fuel from the Mars atmosphere.



Mars descent vehicle

How the Astronauts will be protected?

- Radiation
- Space Environment
- Mars Environment

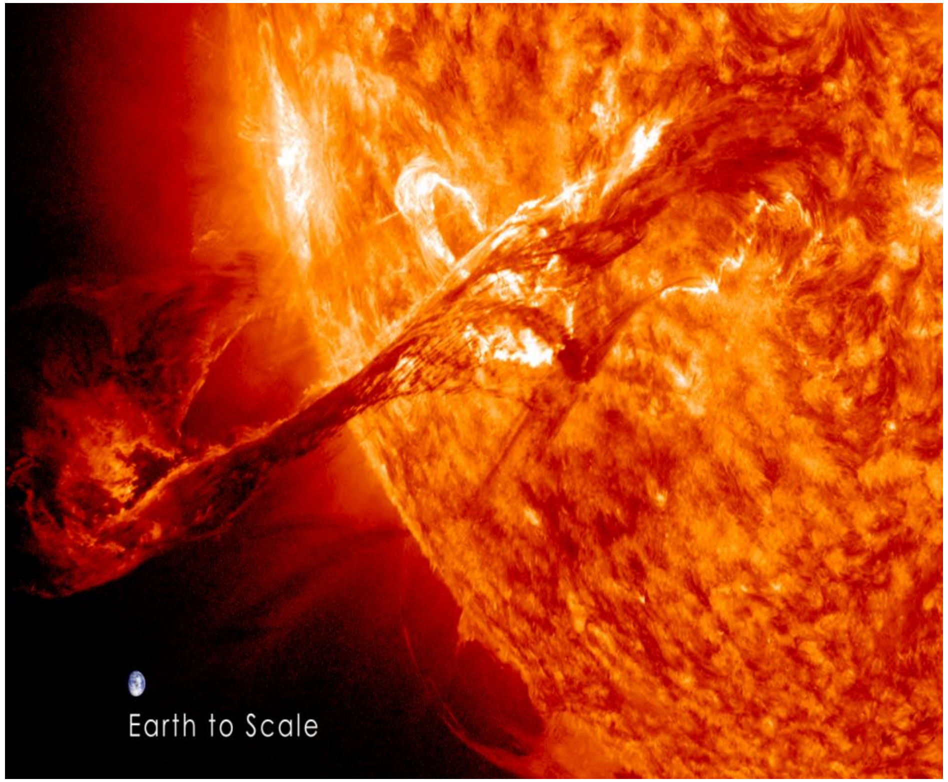
HUMAN PROTECTION

- Our largest hurdle in human protection for sending a manned mission to Mars is the prospect of deep space radiation.
- Deep space radiation is significantly different from radiation encountered on Earth, and it is unknown how the human body will respond to prolonged exposure. Earth, and to a lesser extent low Earth orbit, are protected by the Van Allen Belts, regions of trapped radiation held in place by the Earth’s magnetic field that shield the planet and its human inhabitants from space radiation and solar weather. Missions that travel beyond low Earth orbit do not enjoy the protection of the Belts.

WHERE DOES RADIATION COME FROM?

- As well as radiation from rocks, stars and food, Earth's biggest source of radiation is the Sun. The Sun emits all wavelengths in the electromagnetic spectrum. The majority is in the form of visible, infrared and ultraviolet radiation (UV).

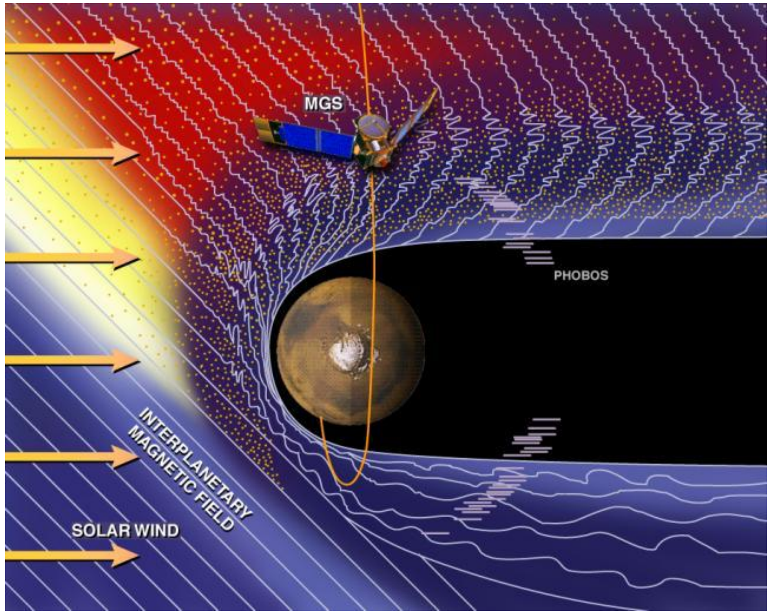
- Occasionally, giant explosions called solar flares and Coronal Mass Ejections (CME) occur on the surface of the Sun and release massive amounts of energy out into space in the form of x-rays, gamma rays, and streams of protons and electrons called solar particle events (SPE).   As you can see in the image, a CME captured by the robotic spacecraft, solar and heliospheric observatory (SOHO).



These CMEs can have serious consequences on astronauts and their equipment, even at locations that are far from the Sun.

RADIATION IN SPACE

- **Ultra violet light rays**
  - Potentially life-threatening
  - Shielded by covering up
  - Visors on space suits to reflect UV light from face while still being able to see
    - Gold foil to protect from infrared rays
    - Polycarbonate to protect from UV
  - Opaque layers of space suit to shield body
- **Gamma rays and X rays**
  - Mainly risk to machinery not astronauts
  - Hard to shield as lead is needed and lead is heavy
  - Not enough gamma and X-ray radiation to make using heavy lead worthwhile
  - Lead aprons used by radiologists can weigh 10-15kg
    - Lining entire space suit would weigh about 25-40kg
  - Material of suit reduces radiation
    - 14 layers of materials with decreasing Z numbers (atomic masses) from outside layer to inside layer
    - Proposed extra 2 layers to be added to protect from ionising radiation too
- **Subatomic particles**
  - Most common and most damaging
  - Mostly comes from the sun
  - Most aren't very penetrating
  - Majority can be stopped by the space suit
  - The little bit which isn't stopped is too energetic so not worth stopping (e.g. gamma rays as you'd need lead which is too heavy)



Unlike Earth, Mars lacks a thick atmosphere and magnetic field,

WHAT FACTORS DETERMINE THE AMOUNT OF RADIATION ASTRONAUTS RECEIVE?

- **Altitude above the Earth** — at higher altitudes the Earth's magnetic field is weaker, so there is less protection against ionizing particles, and spacecraft pass through the trapped radiation belts more often.
- **Solar cycle** — the Sun has an 11-year cycle, which culminates in a dramatic increase in the number and intensity of solar flares, especially during periods when there are numerous sunspots.
- **Individual's susceptibility** — researchers are still working to determine what makes one person more susceptible to the effects of space radiation than another person. This is an area of active investigation.

- Some of these are immediate term risks that can affect crew performance and the success of a mission, while others are long-term issues that affect the length and quality of crew members' lives.

FACTORS AFFECTING HEALTH RISKS

Altered Gravity Field

1. Vision Impairments and Intracranial Pressure (VIIP)
2. Renal Stone Formation
3. Sensorimotor Alterations
4. Bone Fracture
5. Reduced Muscle Mass, Strength, and Endurance
6. Reduce Aerobic Capacity
7. Host-Microorganism Interactions
8. Cardiac Rhythm Problems
9. Orthostatic Intolerance
10. Intervertebral Disc Damage[a]
11. Space Adaptation Back Pain
12. Urinary Retention
13. Pharmacokinetics[a, b]

Radiation

14. Space Radiation Exposure

Distance from Earth

15. Adverse Outcomes due to Inflight Medical Conditions
16. Uneffective or Unpredictable Effects of Medication Due to Storage

Hostile/Closed Environment Space Craft Design

17. Inadequate Food and Nutrition
18. Inadequate Human-System Interaction Design
19. Injury from Dynamic Loads (Occupant Protection)
20. Injury and Compromised Performance Due to EVA Operations
21. Celestial Dust Exposure
22. Altered Immune Response
23. Exploration Atmospheres
24. Sleep Loss, Circadian Desynchronization, and Work Overload
25. Toxic Exposure
26. Decompression Sickness
27. Hearing Loss Related to Spaceflight
28. Acute and Chronic Carbon Dioxide Exposure
29. Injury from Sunlight Exposure
30. Electrical Shock[c]

Isolation

31. Adverse Cognitive or Behavioral Conditions
32. Inadequate Team Performance

Human Health and Performance Risks by Space Environment Hazard

FACTORS AFFECTING HEALTH RISKS

Space Radiation Exposure In-Mission and Post-Mission Risk

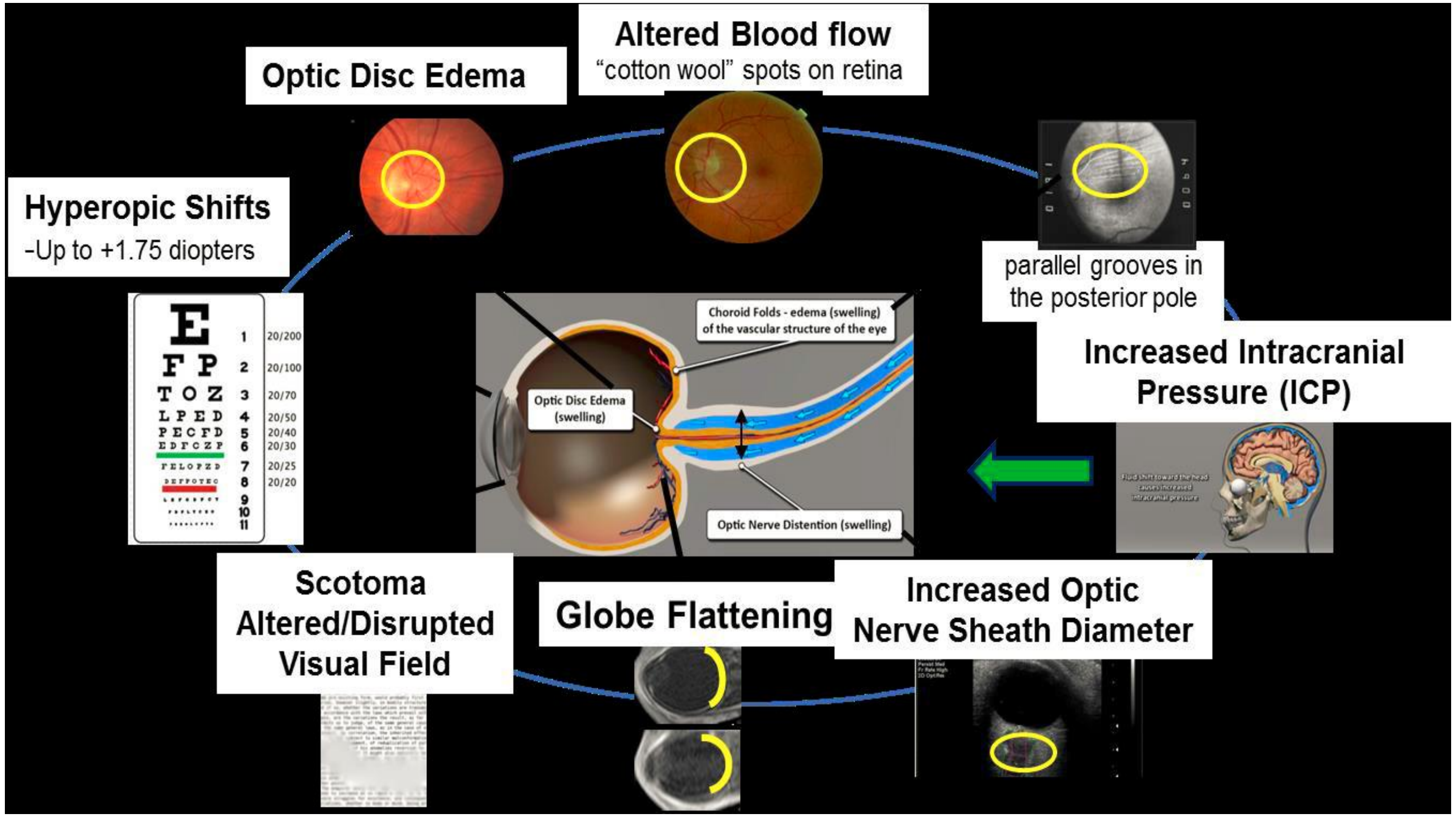
		Low Earth Orbit (6 months)	Low Earth Orbit (1 year)	Lunar Visit (1 year)	Asteroid (1 year)	Planetary (3 years)
Space Radiation Exposure	In-Mission Risk	Accepted	Accepted	Accepted	Accepted	Accepted
	Post-Mission Risk	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation

Source: Human System Risks Summary Charts, HMTA, January 2015.

Legend: High consequences Low to medium consequences Very low to low consequences

- NASA's current radiation standard limits astronauts to a lifetime 3 percent risk of exposure-induced death for cancer mortality. This means that were 100 astronauts exposed to the upper bounds of the radiation limits, 3 would die of cancer attributable to that exposure.
- NASA research estimates that life expectancy for astronauts with radiation-induced cancer would be reduced by an average of 12 to 16 years.
- As part of its mitigation strategy, NASA currently sets short-term exposure limits to minimize acute affects that could impair a crew's ability to complete a mission.
- Based on current knowledge, astronauts on a mission to Mars would exceed NASA's career radiation dosage limits. Therefore, the time of exposure for our astronauts is limited to a minimum.

VISION IMPAIRMENT AND INTRACRANIAL PRESSURE (VIIP)



- NASA believes that the microgravity environment of space leads to a shift in bodily fluids that creates intracranial pressure and that other factors such as resistive exercise, diet, medicines, and radiation may contribute to VIIP. The shift in fluids is also thought to lead to changes in vision and eye anatomy.

RADIATION IN SPACE

- A gray (Gy) is the amount of radiation absorbed by biological matter. To determine the biological effects of the radiation, the dose is multiplied by a ‘quality factor’ which depends on the type of ionizing radiation. This is called “dose equivalent” and is measured in Sievert (Sv). For electron and photon radiation (e.g. gamma), 1 Gy = 1 Sv.
- Curiosity rover received about 0.66 sieverts during 253 days of travelling to Mars
  - Streams of subatomic particles damage DNA
  - Can cause cancer and other diseases
- 0.1 mSv dose:
  - increased risk of death from radiation induced cancer about 1 in 1,000,000
- 100 mSv dose:
  - death of radiation induced cancer increased by 0.8%, two 100 mSv doses 1.6%, etc.
- 1,000 to 2,000 mSv dose:
  - 0 to 5% fatal
- 8,000 to 30,000 mSv dose:
  - 100 % fatal
- **≈450mSv in 100 days of exposure**

WAYS TO REDUCE EXPOSURE TO RADIATION

- **Use space trash/waste**
  - Trash produced after a day of living in the space craft made into tiles
    - Discarded water bottles, clothing scraps, duct tape and other waste on deep-space missions.
    - Compactor designed not to incinerate but to melt trash into discs
    - Compactor heats trash for 3 1/2 hours to between 300 and 350 degrees F, which should be hot enough to kill any microorganisms, and squeezes a pound of material into the compressed tile
    - Reduces the size at least 10 times the original.
    - A day's worth of trash makes an 8" diameter by about half an inch thickness
    - If there are enough plastic components then the tiles can be used for radiation protection (normally lots of plastic packaging) or just stored away (flat and small so easier to store)
    - Install around sleeping area or storm bunker
  - Bags of waste/food to line the walls
    - Solid and liquid human waste dehydrated and put into bags attached to the walls to shield space craft from radiation
    - Water recycled by extracting it from waste being put into bags so less water needed to be taken in the first place
    - Dehydrated unused food also lines walls but isn't dangerous as it only stops radiation but doesn't become a radioactive source so can be eaten

WAYS TO REDUCE EXPOSURE TO RADIATION

- **Water walls**
  - Polyethylene bags, initially filled with water, line walls
  - *“Water is better than metals for protection,”* says Marco Durante of the Technical University of Darmstadt in Germany because the nuclei stop the radiation so water (made of three small atoms) has more nuclei per volume than metal so is superior
  - Hydrogen-rich (like polyethylene, 1 carbon and 2 hydrogens) shielding needs to be couple of metres thick to completely block all radiation but 30 to 35 percent of the radiation can be blocked by shields just five to seven centimetres thick
  - Polyethylene bags that use osmosis to process clean drinking water from urine and faeces
  - Dual use of water walls (i.e. radiation shield and source of drinking water and storage) means it is preferable as the space that would have been used for the storing of water, food, sewage, can now be used for something else
  - Layers of bags make a 40cm thick defence against radiation
  - All bags initially filled with drinking water then as the bags are emptied then bags of waste replace them (osmosis filtering system in place so drinking water is produced)
  - Osmosis based filtering system much simpler than the automated life-support systems aboard the International Space Station (less likely to fail during ride to Mars)
  - But when tested in orbit they found to be 50 per cent less efficient in microgravity than in ground-based tests.

WAYS TO REDUCE EXPOSURE TO RADIATION

- **Use man made materials**
  - Gold foil all over walls of space craft
    - Thin sheets of gold foil, less than 0.15 millimetre thick
    - The lunar modules of the United States' Apollo flights were shrouded in foil
    - Gold reflects infrared radiation (above roughly .7 µm) as well as silver, copper and aluminium
      - Infrared heats technology
    - Reflects as much or more UV radiation (roughly .35 µm) than silver copper and aluminium while absorbing quite a bit of visible light
      - Won't create blinding reflective hotspots for astronauts
      - Heavy atomic weight lets it soak up quite a bit of that visible light before heating to any harmful temperature
    - Does not rust or tarnish in air the way copper or silver do
      - Less care and maintenance
    - Is more malleable and softer than aluminium when stretched

WAYS TO REDUCE EXPOSURE TO RADIATION

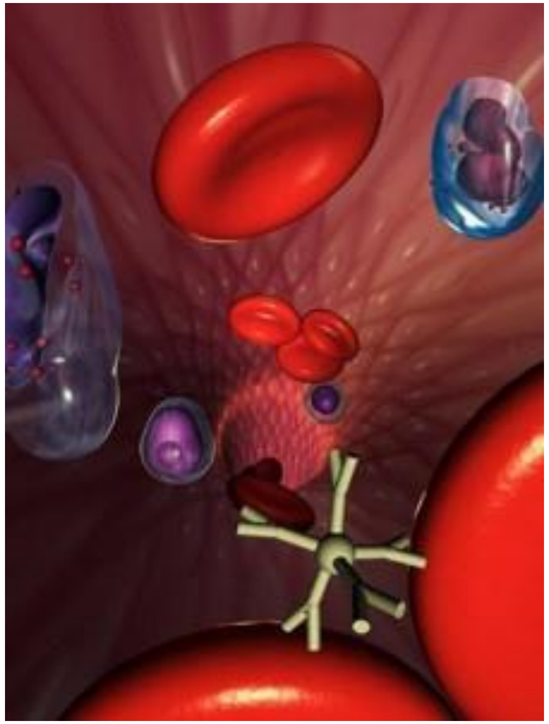
- **Gold foil is useful:**
  - It is very dense - the more dense a substance, the better it is at absorbing radiation
  - Great electrical conductor - use for internal and external electrical systems.
  - Provides protection before there is any waste produced into tiles

WAYS TO REDUCE EXPOSURE TO RADIATION

- **Demron**
  - Radiation shielding fabric
  - Weight-for-weight the material has slightly lower radiation protection than lead shielding
  - Flexible
  - Essentially particles of metal embedded in a polyethylene-based material
  - Roughly three to four times more expensive than a conventional lead apron
  - Can be treated like a normal fabric for cleaning, storage and disposal
  - Has demonstrated beta radiation and X-ray/gamma-ray shielding
  - Already in use in protective garments used in the nuclear industry and in DoD/Homeland Security products.

WAYS TO HELP ASTRONAUTS PROTECT THEMSELVES

- **Eat well**
  - Antioxidants
    - Antioxidants (e.g. Vitamin C and A) help by sopping up radiation-produced particles before they can do any harm
- **Machines within the body**
  - Microscopic vessels (nanoparticles/nanocapsules) that can venture into the human body and repair problems–one cell at a time
    - Injected into people's bloodstreams to treat conditions ranging from cancer to radiation damage
- **Interact with the cells in the body**
  - Instruct a damaged, abnormal cell to destroy itself (researching)
  - In cell cycles, cell divides and pauses occasionally, to check its genes for any kind of damage and to repair errors
    - Pharmaceuticals may be able to lengthen this part of the cycle; gives the cell more time to fix itself without prompting



WAYS TO HELP ASTRONAUTS PROTECT THEMSELVES

- **Machines more capable than astronauts**
  - Developing expert systems that can work effectively regardless of the training of the people who are operating them
  - Smart medical systems that can diagnose, and perhaps even treat, illnesses (e.g. external defibrillators); and telemedicine capabilities that will allow the ship's chief medical officer to consult with experts back on Earth (take photo of illness/injury e.g. rash and send to experts for advice)
  - Robot helpers with super-steady hands
    - Robotically assisted surgery
      - minimally invasive surgery will be important
      - large incisions: wounds may be slower to heal and fluids like blood harder to control
      - Robots make steadier, more even movements so smaller, finer incisions than humans
  - A device that produces medicines from stored substrates when needed
    - Long space expeditions exceed the life of many pharmaceuticals
    - Shelf life might be much less problematic if medicine made when needed
    - So-far hypothetical device
    - If a new antibiotic was invented after take-off
      - Can’t upload pills
      - Can upload software for new drugs

Da vinci surgical robot – intuitive surgical

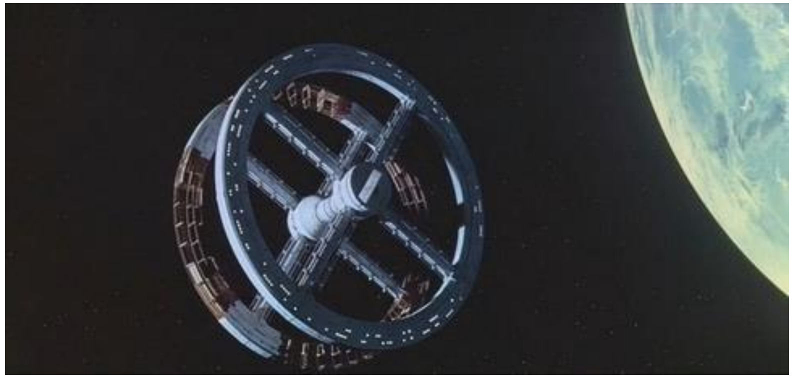
KEEPING ASTRONAUTS SAFE FROM ANTI-GRAVITY

- **One of Biggest problems: physiological changes caused by weightlessness**
  - your genes might be damaged and confused
  - Muscle atrophy and bone loss
  - loss of blood volume (tend to be light headed after landing on a planet like Mars or Earth and trying to get up)
  - Alters the sense of balance so that, for a while after astronauts return to gravity, they feel like the world is spinning whenever they move their heads.
  - “Proprioceptive" ability doesn't seem to work as well (ability to move your arm to where you want it to go)
  - slower wound healing
  - weaker immune system

- **Shorter journeys**
  - Bisphosphonates
    - Used on Earth to slow the rate of bone loss in osteoporosis
  - Astronauts on the International Space Station work out about two hours a day
    - Using:
      - Treadmills
      - exercise bikes
      - IRED (a device specially developed to allow astronauts to do resistive or strength training)

KEEPING ASTRONAUTS SAFE FROM ANTI-GRAVITY

- **For Mars**
- Countermeasures seem to work well enough for short stints in space so longer traveling to Mars needs new option: artificial gravity
  - Rotating spaceship
    - Both costly and complex
  - Human powered centrifuge
    - Cycling round a circle
    - Exercise track where an astronaut pedals a bike up and around a 360 degree circle
    - Creates more pull on feet than head so simulates earth's gravity



HUMAN PROTECTION - MARS

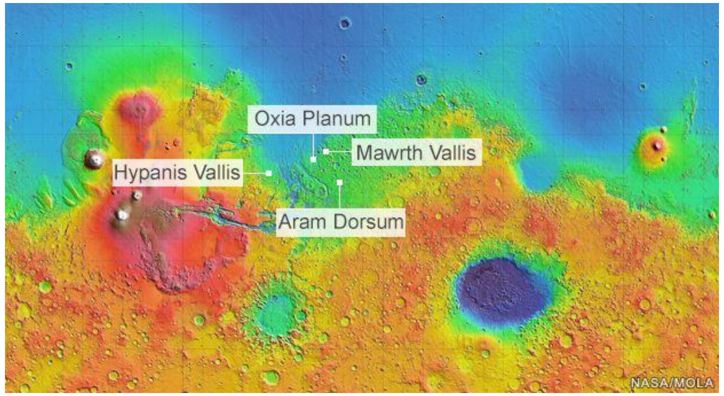
- Mars is similar to Earth in it has Polar ice caps, seasonal variability, Climate change and length of day – SOL
- But the following differences require Human protection:
- **Atmospheric Pressure**
  - Air pressure on MARS 7.5 milli-Bar v 1000 millibar on earth
  - Need a pressurised environment in habitat and canisters in suits
- **Climate changes**
  - Dust storms and high winds
  - Need detection systems and astronaut hook ups
- **Radiation & Temperature**
  - Radiation
  - Warmest +27 degrees C, coldest -143 degrees C
  - Need Suits to protect from Radiation and keep warm
- **Gravity**
  - 0.38% of earth, 100kg girl weighs 38kg on Mars
  - 2 days to acclimatised to Martian Gravity
- **Systems**
  - Communication system
  - Emergency detection system

Our Exploration

- The Objective and Benefits it offers
- The Time taken
- Suitable Landing Site
- Possible Disruptions

OUR EXPLORATION

- We propose a mission to mars to investigate whether the environment and atmosphere could allow for agricultural development in the hope of one day creating a sustainable community on Mars. Without a source of food and water, the chance for a sustainable community is negligible.
- Upon arrival the team will need to deploy a specialized rover at the chosen locations on Mars. This rover can be controlled by an astronaut from within to maximise accuracy of soil sampling and drilling down to springs. The rovers must also take samples of the air so that the composition may be studied and potential toxins can be noted. The rovers will also need a mechanism to collect Mar’s atmosphere If the rover breaks down at any point the astronaut arming the rover can then attempt to fix the rover to prevent the mission form failing These robots will drill into the earth to take soil and water samples and will also collect samples of Mar’s atmosphere from near the soil surface and a few metres above. These samples will be sent back to the spacecraft and sent back to Earth for analysis however the astronauts will need to monitor the samples during the time back to Earth.)



HOW WILL THE MISSION BE FURTHER CARRIED OUT ON EARTH?

- The team when back on Earth will then study the soil, water and air to determine the components that they are made up of so that they can be replicated on Earth. With the composition identified there may be a possibility of encountering elements that are not found on Earth and perhaps a chance of discovering microorganism life (however this is an incredibly slim possibility).
- This replication will enable biologists and botanies to attempt choose the most suitable plants and to try and grow them in Mar’s soil/ water and air back on Earth rather than on Mars. This plants will be grown in ‘Greenhouse Pods’ where the replicated Mars soil, water and atmosphere will be contained and the plant attempted to grow within it. This will prevent anything from escaping or reaching the plants which may disrupt the experiment. The Greenhouse Pods could also be a potential way of growing plants on Mars in a future Mission.
- If the plants are unable to grow in these conditions on Mars (for whatever reason encountered) then the team could ‘tailor’ the components within the soil, water or air in order to try and grow certain plants. Therefore, we could determine the correct conditions for potential plant growth on Mars that could be used for future crop growth by a sustainable Martian community.

HOW WILL THE MISSION BE FURTHER CARRIED OUT ON EARTH?

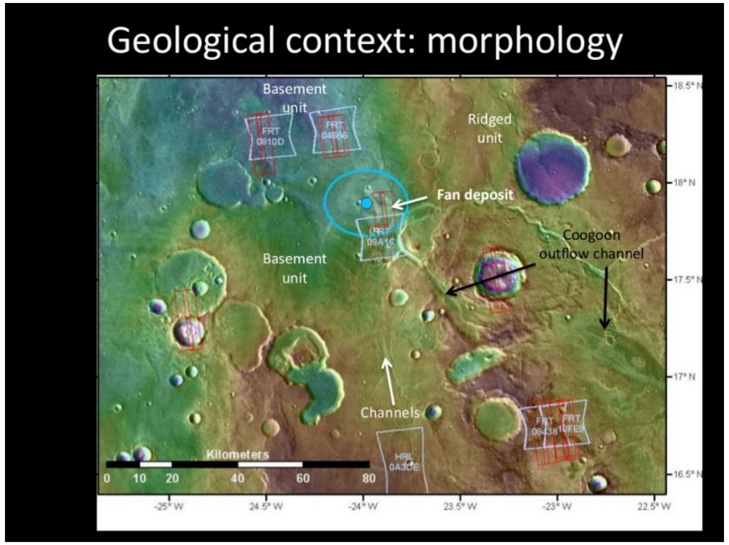
- This will help determine what the soil is lacking so that if it’s inadequate the team could create specialised fertilizers that provide the nutrients that the soil is deprived of. A range of plant samples will need to be used, including desert plants that require little water, to investigate which species cope the best with the new environment and if any contain desirable genes that help it thrive on Mars with the hopes of being able to genetically modify vegetables and fruits, giving them these characteristics in the future.
- The team will then be able to determine whether the water contains any microorganisms or toxins and whether it will be drinkable if filtered. If it can be drinkable, then a community on Mars would have a source of water.

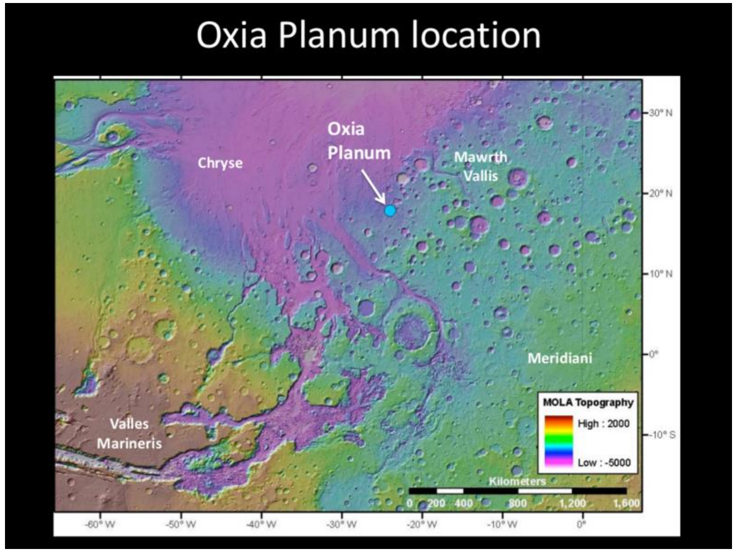
WHY DO WE NEED TO DEPLOY A TEAM?

- On January 3, 1999 the Mars Polar Lander, a 290-kilogram robotic spacecraft lander, was launched by NASA with the objective of gathering data about the climate however upon landing it failed to establish communication with Earth. The mission was deemed a failure.
- Had they had a team of professionals who understood the engineering of the polar lander it could have been repaired, done its job and it would have been deemed an international victory. This is one of the many reasons why having a team at hand secures this missions success.
- Having humans carry out the experiments means a reduction in the time gap between initiating an action for the rover and the rover actually completing the action as from earth, the response would take approximately 7 minutes which could result in loss of precision when collecting soil and drilling down into springs, therefore, it improves accuracy.
- If the results of this mission prove positive and plants can be grown in Mars atmosphere or modified atmosphere then it could develop in the future and larger, specially engineered dome like greenhouses much like the Eden project could be created to be deployed on Mars

LANDING SITE SELECTION

- The rover’s landing site is selected by identifying a geologic environment that would currently or has supported microbial life. Scientists prefer a site with both morphologic and mineralogical evidence for past water and a site with spectra that indicate hydrated minerals and clay minerals are preferred but not always possible due to engineering constraints and scientific goals. In March 2014 there were 7 landing sites being considered and by October 2014 the ESA had shortlisted these 7 to 4, which were all relatively close to the equator
- We selected Oxia Planum which is a plain located near the equator on Mars and there is a high chance that beneath the surface there is an expansive frozen cavity between the north pole and the equator. it has a smooth surface and has been chosen as a preferred landing location for the ExoMars rover. It contains one of the largest exposures of clay-bearing rocks which are around 3.9 billion years old. The site is rich in iron-magnesium clays, indicating that water once played a role here.
- Clay accumulation underneath the remnants of a fan or delta near the outlet of Coogoon Vallis may offer preservation for bio signatures against the planet's harsh radiation and oxidation environment.
- There are Several sources of water in Mars: On surface and underground in both ice and water form. We have a drill to cover the possibility of drilling down for ice/breaking up ice on surface. Soil sampling will collect water if in liquid form (The water would be present in tiny quantities between the grains of soil, rather than in droplet form).

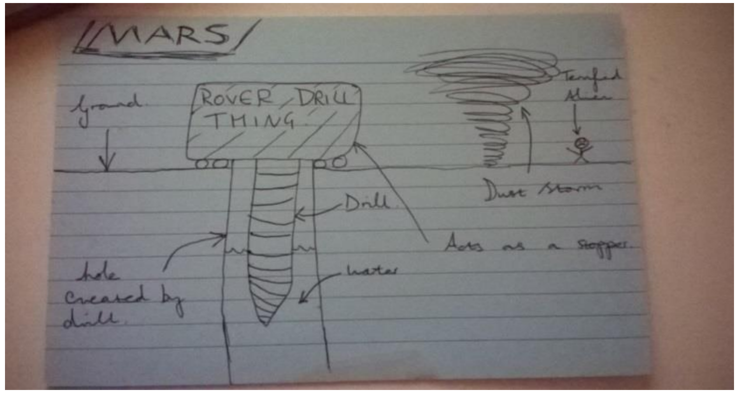




PROBLEMS WE'VE FACED AND OVERCOME

Dust Storms

- One of the main problems we faced on Mars is the **possibility of severe dust storms**. Despite the atmosphere on mars being much thinner than that on Earth, there are still substantial winds. These winds pick up the dust particles on the surface of Mars and form dust storms which travel at speeds of 33 to 66 miles per hour and cover an area for a few days. Consequently, this would prove difficult to attempt to grow plants on Mars in Greenhouse Pods (which was are initial Mission Statement) as the pods were very likely to be constantly covered in sand – buried and lost. It would disrupt the chances of plants growth and would be difficult to monitor
- Overall, we chose to analyse the soil and attempt to grow plant life on Earth rather than Mars to escape these problems (especially if it proves difficult to grow plant life), allowing for better analysis and monitoring of plant growth (scientists can monitor the plant grow more closely without the chance of radiation sickness).



PROBLEMS WE'VE FACED AND OVERCOME

- An issue we face is that the hole formed by drilling for water must be covered so that it's not filled with dust due to sandstorms once the mission is completed. This means we must have some way of covering it with a plastic or metal sheet or alternatively we could use the drill almost as a stopper that drives over the hole and plugs it to stop any sand from entering
- Another major problem to overcome is the erratic temperature on Mars. On Mars the average temperature is about -55°C, however it ranges from approximately -133° C during winter to 27° C during summer. It is quite likely that the water will be found as ice underground so it must be melted before use.
- Another point to consider is that if the astronauts need to go onto Mars the spacesuits must protect them from radiation poisoning and should also keep them warm to protect them from hypothermia when working. It is likely that even with a suit for protection, the astronauts will only be able to be on mars for a limited amount of time due to radiation.

WHY 30 DAYS ON MARS?

- A period of thirty days was chosen as the period of time spent on Mars. This was for a number of reasons:
- The Mars rover Curiosity has calculated an average radiation dose over the 180-day journey is equivalent of 24 CAT scans. In just getting to Mars, an explorer would be exposed to more than 15 times an annual radiation limit for a worker in a nuclear power plant.
- Radiation in space can lead to a great number of illnesses such as cancers due to the damage inflicted on your DNA.In just getting to Mars an astronaut will have suffered a fair bit of exposure to radiation.
- Therefore the shorter the period of time spent on Mars by the astronauts the better to reduce their exposure.
- This timeframe will however allow for disruptions caused by dust storms, equipment maintenance, refuelling the hydrogen tanks for the ascent.
- 30 days is also enough time for our astronauts to collect sufficient amounts of soil / water even if drilling is necessary. Human astronauts will also be able to operate the rover from Mars which removes the seven minute delay that would otherwise occur if the were operating from Earth.

RECREATING THE MARTIAN ENVIRONMENT BACK ON EARTH

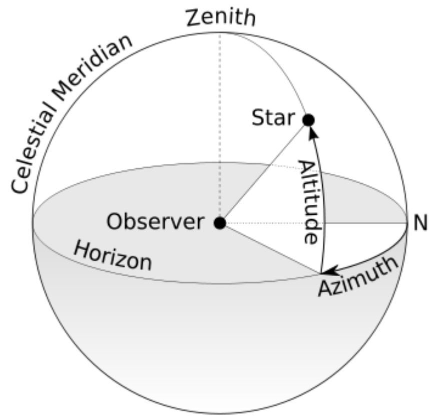
Why do it?

- Once safely back on earth, we intend to recreate the environment on mars in order to grow plants. We hope that by replicating Martian conditions we will gain knowledge and further understanding of the possibilities of growing crops on mars in the future. This is a factor that will be vital in future space exploration.
- Completing this part of the mission in labs on earth means that we can closely monitor the plants. Experts will be on a hand if anything goes wrong. This will greatly increase our chances of successfully growing crops in Martian conditions, compared to attempting this on Mars itself. We believe that it is a necessary step.

RECREATING THE MARTIAN ENVIRONMENT BACK ON EARTH

Is it possible?

- So is it actually possible? In 2014, a team of Spanish recreated Martian conditions, such a temperature, humidity, pressure and even dust, here on Earth, inside a special vacuum chamber. The vacuum chamber can also simulate sun illumination at different azimuths*, gas composition and UV-radiation. This machine is called MARTE – Spanish for Mars. It has been designed by a team of scientists from Centro de Astrobiología, INTA-CSIC, and Instituto de Ciencias de Materials de Madrid. The scientists believe that MARTE will give answers to many questions about the habitability of Mars.
- The simulation of conditions on Mars using vacuum chambers is not a new technique. A similar process was used by scientists at NASA to test the meteorological sensors used on the Curiosity rover.
- However the MARTE project is unique in simulating the effect of Martian dust -one of the primary problems for planetary exploration – to gain a better understanding of how instruments behave when covered in dust.
- We hope to use similar equipment and technology to recreate Martian conditions in order to grow our plants.



* **The azimuth is the angle between the north vector and the perpendicular projection of the star down onto the horizon.**

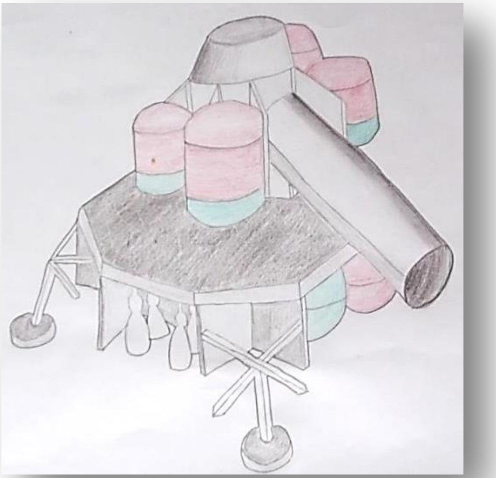
STAGE 5 - ASCENDING FROM MARS: MARS ASCENT VEHICLE - MAV

The most crucial part, the hardest challenge of the mission.

Crewed Mars Ascent Vehicle (MAV) designs fall into one of two broad categories:

1) a relatively large habitable variant that serves as both ascent vehicle and habitat, either on the surface or in orbit; or
2) a much smaller taxi variant used only for a few hours during the actual ascent. The taxi variant requires another Mars surface asset for habitation. Note that in some architectures, the Mars *ascent* vehicle might also be used as the crew's *descent* vehicle.

Ascent vehicles are generally regarded as the largest "gear ratio" item in a given architecture; in other words, every kilogram of an ascent vehicle needs more Earth-launched mass to do its job than most other architecture elements need. Even if ascent propellant can be manufactured on Mars, current technologies still require the ascent vehicle—and the propellant manufacturing plant—be launched from Earth, transported to and then descended onto Mars, all of which entails a considerable amount of transit and descent propulsion mass. The overall gear ratio depends on end-to-end mission architecture. Analysis performed by the National Aeronautics and Space Administration (NASA) estimates that the amount of propellant needed to boost a single kilogram of ascent vehicle to a 1-sol Mars orbit ranges between 3.5 kg (for an *ideal* rocket) to as much as 15 kg for a stage mass fraction of 0.73. For the purpose of this exercise, the ascent gear ratio was assumed to be at the lower end of the range, or 7:1 (seven kilograms of ascent propellant to boost every one kilogram of MAV inert mass).



Retractable tunnel from MAV to rover

STAGE 5 - ASCENDING FROM MARS: KEY DESIGN CONSIDERATIONS

- Launch from MARS is vastly more challenging than a lunar ascent as greater velocity required 4.2m/s versus 2.8m/s – PAYLOAD (WEIGHT) VERSUS THRUST CONSIDERATIONS
- Exploration architecture studies identified the Mars Ascent Vehicle (MAV) as one of the largest “gear ratio” items in a crewed Mars mission. Because every kilogram of mass ascended from the Martian surface requires seven kilograms or more of ascent propellant, it is desirable for the MAV to be as small and lightweight as possible. Analysis identified four key factors that drive MAV sizing:

1) Number of crew: more crew members require more equipment—and a larger cabin diameter to hold that equipment—with direct implications to structural, thermal, propulsion, and power subsystem mass.

2) Which suit is worn during ascent: Extravehicular Activity (EVA) type suits are physically larger and heavier than Intravehicular Activity (IVA) type suits and because they are less flexible, EVA suits require more elbow-room to maneuver in and out of. An empty EVA suit takes up about as much cabin volume as a crew member.

3) How much time crew spends in the MAV: less than about 12 hours and the MAV can be considered a “taxi” with few provisions for crew comfort. However, if the crew spends more than 12 consecutive hours in the MAV, it begins to look like a Habitat requiring more crew comfort items.

4) How crew get into/out of the MAV: ingress/egress method drives structural mass (for example, EVA hatch vs. pressurized tunnel vs. suit port) as well as consumables mass for lost cabin atmosphere, and has profound impacts on surface element architecture.

To minimize MAV cabin mass, the following is recommended: Limit MAV usage to 24 consecutive hours or less; discard EVA suits on the surface and ascend wearing IVA suits; Limit MAV functionality to ascent only, rather than dual-use ascent/habitat functions; and ingress/egress the MAV via a detachable tunnel to another pressurized surface asset.

STAGE 5 – ASCENDING FROM MARS: MARS ORBIT RENDEZVOUS

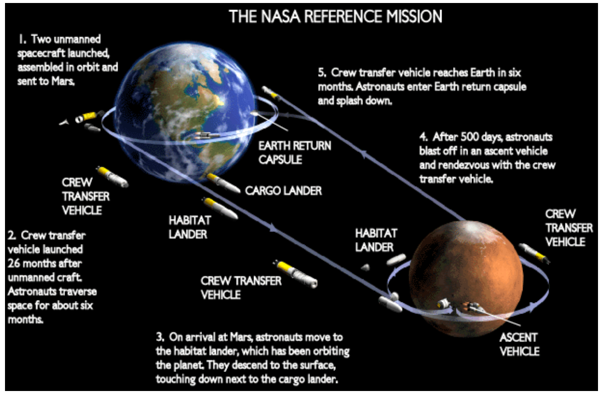
- MAV to re-join Transit Vehicle – MARS Orbit Rendezvous (MOR concept)
- **Mars orbit rendezvous** (**MOR**) is a space travel concept where two spacecraft meet up and/or dock in Mars orbit. For example, one vehicle takes off from Mars, such as a Martian ascent stage, and does a rendezvous in Mars orbit with another spacecraft. Applied to a Mars sample return or manned mission to Mars, it allows much less weight to be sent to the surface and back into orbit, because the fuel needed to travel back to Earth is not landed on the planet. It has also been proposed for unmanned Mars sample return plans
- Transit Vehicle will orbit every 7 hours
- Astronauts then transfer to Transfer habitat from the MAV for transit back to the ISS.

Why is our Mission realistic in terms of technologies available today or in development?

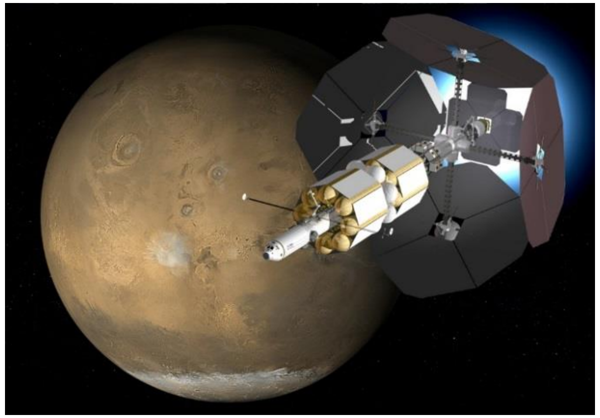
WHY IS OUR MISSION REALISTIC IN TERMS OF TECHNOLOGIES?

Mission Stage	Technology Utilised	Prior Mission Experience
Mission Strategy	120 day mission	NASA reference mission
Spacecraft, Assembly, Propulsion System	Propulsion system - Electric MAV Lander Rover Habitat	VASIMAR Previous Lunar vehicles Based on Mars One Previous Missions Simulated Johnson Space center, US
Human Protection	Support systems Suits / Detection systems Radiation protection methods Nutrition plans Preferred landing sites	ISS systems Previous Missions Preferred NASA sites
Launch	From ISS to Mars From Mars to orbiting MTV	Hohhmann Transfer orbit/opp dates MOR–Mars orbit rendezvous

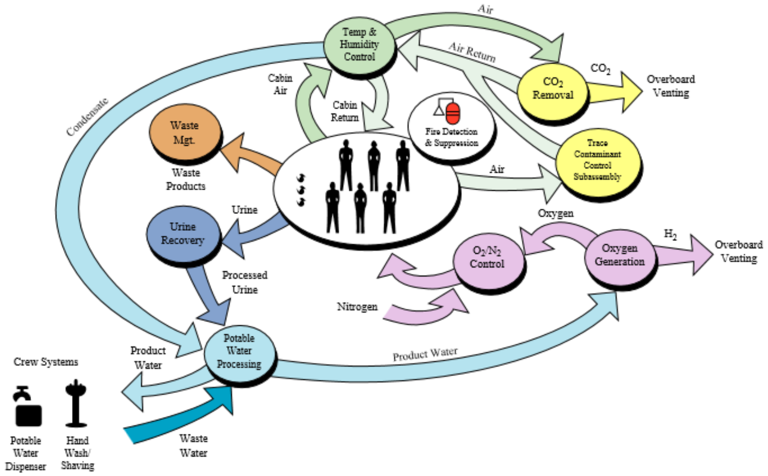
WHY IS OUR MISSION REALISTIC IN TERMS OF TECHNOLOGIES?



MISSION
Based around NASA reference Mission



PROPULSION
68 spacecraft have used SEP in Operation + The Martian



HUMAN PROTECTION
Utilising ISS ECLSS Technology

LAUNCH
Based on known Launch and MOR concepts

Optimisation of Cost and Schedule

How did we assess the cost and the schedule?

WHY DO WE NEED TO OPTIMISE THE SCHEDULE?

- Reducing the time spent in space will reduce the overall cost of the mission, as less money has to be spent on things such as food and fuel.
- More importantly, it will reduce the exposure of the astronauts to radiation. As this is a manned mission, radiation is a massive problem, so we need to try and spend the least amount of time in space as possible.

OPTIMISING THE SCHEDULE

- The easiest way to reduce the time spent in space is to leave the ISS when Earth and Mars are the closest they can be. This happens approximately every 2 years and 2 months.

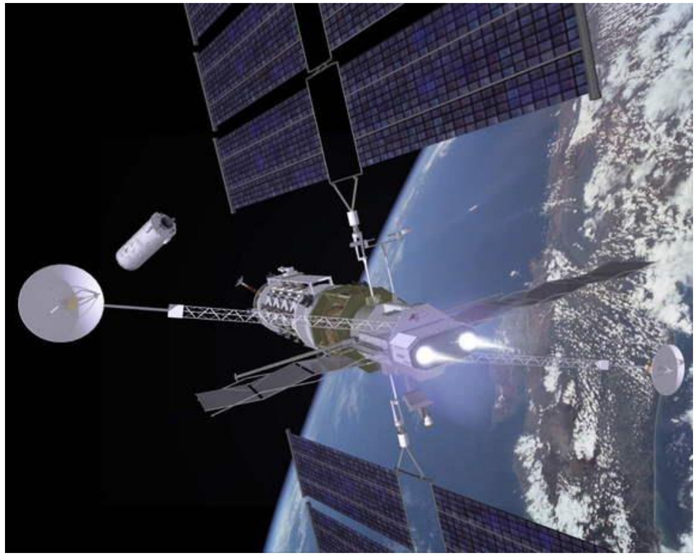
-2 Months	Million Km	**Closest**	Million Km
29.03.16	117	**29.05.16**	75
25.05.18	94	**25.07.18**	57
06.08.20	88	**06.10.20**	62
25.09.22	118	**25.11.22**	82
06.11.24	140	06.01.25	96
12.12.26	135	**12.02.27**	101

Projected launch date

- Expeditions often leave about two months before the 'smallest distance date' to allow some flexibility in order to accommodate weather. The Hohmann Transfer is used to move between the orbits of Earth and Mars, by travelling in an elliptical pattern.

OPTIMISING THE SCHEDULE

- Mars is always closer to Earth when it is closer to the sun (so in perihelion) and therefore there is sunshine to power the rover with. As we are working in the slightly longer Mars' days, means we work for more hours in a day, and so hopefully spend less time on the surface of Mars' collecting samples
- Using a faster engine = optimise schedule
- Alternative for chemical engines (relatively slow, and would mean that it would take over 200 days to travel to Mars)
- Electric and nuclear propulsion systems, each of which would reduce the travelling time to about 40 days.
- Chose electric = safer to use (than nuclear), and can generate fuel whilst on Mars. The current research is also more advanced than for nuclear.



OPTIMISING THE SCHEDULE

- Sidereal day – time taken for a planet to rotate on its axes
- Sidereal year – time taken for planet to return to its position regarding the sun (after a whole rotation)
- Synodic/solar day – time taken for sun to successively pass the meridian
- Sidereal period of Earth = 23h 56m 4.1s
- Sidereal period of Mars = 24h 37m 22.66s
- Synodic day of Earth = 24h 0m 0s
- Synodic day of Mars = 24h 39m 35.24s
- To translate to Mars time, we use synodic days (rather than sidereal days). The synodic day of Earth is 24 hours and 0 minutes, and the synodic day of Mars is just under 24 hours and 40 minutes. This means the days are approximately 2.7% longer. Previous projects on Mars have used a “24 hour Mars clock” which has slower time than on Earth.

COST OF OTHER MISSIONS

Apollo mission

- 1964-66: NASA preparing for first moon landing. Agency’s budget peaked, consuming roughly 4% of federal spending. The final total cost was between $20 and $25.4 billion in 1969 dollars (about $136 billion in 2007 dollars).
- 2009: NASA looked back at overall cost of Apollo program, and arrived at a figure of $170 billion in 2005 dollars (or around $200 billion in today’s money).
- We must also compare these costs to modern day space travel. expanding knowledge and understanding, and new technology mean that (close range) space travel is relatively much less expensive.

e.g. Companies like SpaceX charge $133 million to launch a spacecraft to the International Space Station.

Atlas V

- In 2013, the cost for an Atlas V 541 launch to GTO (including launch services, payload processing, launch vehicle integration mission, unique launch site ground support and tracking, data and telemetry services) was about $223 million.
- Since around 2005, Atlas V has not been cost-competitive for most commercial launches, where launch costs were about $100 million per satellite to GTO in 2013.
- Although price of space travel is falling, a manned mission to mars will have the equivalent effect on NASAs budget as the Apollo mission. Advanced and complex technology will be needed to shorten mission length and for astronaut protection.

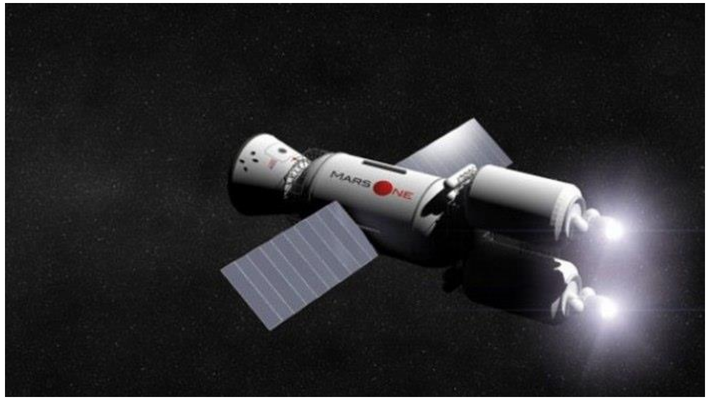
COST OF OTHER MISSIONS

Mars One (Manned)

- Mars One’s goal is to establish a human settlement on Mars.
- Mars One estimates the cost of putting the first four people on Mars at six billion US$. The six billion figure is the cost of all the hardware combined, plus the operational expenditures, plus margins. For every next manned mission, Mars One estimates the costs at four billion US$.

Our Mission

- We are looking to visit mars for a maximum of 30 synodic days, with only 40 days travelling time each way. Cost of our mission will be significantly lower than that of mars one.
- Therefore we estimate that our budget will be around $4 billion.



Mars one

COST OF EQUIPMENT

In space and on mars

- Spacecraft
- Fuel
- Rover
- Drill

Back on Earth

- Vacuum chamber – to recreate Martian atmosphere
- Analysis equipment

COST OPTIMISATION

- It is necessary to identify points where small changes in design can be made to optimise the cost of the mission.
- The biggest focus of cost optimisation when designing a rocket is the mass. The mass of the rocket must be the absolute minimum possible, as the heavier the total mass of the rocket, equipment and fuel, the more difficult it is to launch and be lifted into low earth orbit. The greater the mass, the more fuel will be needed throughout the duration of the mission to provide the necessary driving force.
- The majority of the mass of the rocket is fuel

Considerations for fuel and engine system

- The spaceship will be powered by an electric ionisation propulsion system. The technology VASIMR ships means that a much smaller volume of fuel will be needed, less mass etc.
- To save fuel we are not going to land the whole spacecraft on mars – most of the spacecraft will be left in orbit around mars. The more mass that you put down on mars, the more fuel will be needed to bring it back up. A small part of the spacecraft, including the rover (to which the drill will be attached) will land on mars. The spacecraft will be left in orbit at the same height as Phobos, one of Mars' moons. (see appendix)
- The rover and the drill are also not carried back up to take back to Earth, which reduces the mass (and so fuel) of the returning part of the spacecraft.
- The rover, similar to those in previous unmanned missions, will be powered by photovoltaic panels which will convert light from the sun into energy. This will allow the rover to move around without the need for fuel. Less fuel, less mass etc.

COST OPTIMISATION

Schedule and timings

- The technology in VASIMR ships also means that the spaceship will be able to reach mars in 40 days and we will be spending only 30 synodic days on mars. This hugely reduces the overall length of the mission and therefore has very positive effects on many aspects to do with cost optimisation;
- New technologies to protect astronauts from long term radiation exposure will not need to be developed as they are in space for a relatively short space of time.
- We will also need to take less food and less oxygen, so less mass, etc.

Waste and Radiation Protection

- Lining the walls in a material such as lead to protect the astronauts from outside solar radiation, would have a huge effect on the overall mass of the spaceship
- Our solution is to store food in the walls of the spaceship, then material and human waste as the mission progresses. Polyethene bags, initially filled with water and later filled with urine will also line the walls. This will help in preventing harmful radiation entering the spaceship, and free up space in the spaceship. As a result the spaceship will be much lighter, so less fuel will be needed etc.
- Gold foiling will also cover the walls of the spaceship to reflect infrared and ultraviolet radiation. This material is also relatively light.
- We intend to take a trash compactor to crush food packaging and other rubbish so that it can easily be placed in the walls by the astronauts. Although this will add to the mass of the spaceship, its usefulness will greatly outweigh the inconvenience of the extra mass and space needed.
- We will recycle water so less liquid needs to be taken.

REFERENCES

- www.mars-nasa.gov
- www.nasa.gov
- www.space.com
- www.marsopposition.com
- www.quora.com
- www.mars-one.com
- www.mydarksky.org
- www.wfs.org
- www.universetoday.com
- www.bambam31.com
- www.uapres.Arizona.com
- www.Wikipedia.com
- http://sci.esa.int/mars-express/31031-phobos/
- http://sci.esa.int/mars-express/50837-deimos/
- https://www.nasa.gov/pdf/284273main_Radiation_HS_Mod1.pdf
- http://www.universetoday.com/14979/mars-radiation/
- https://oig.nasa.gov/audits/reports/FY16/IG-16-003.pdf
- https://oig.nasa.gov/audits/reports/FY16/IG-16-003.pdf
- https://www.quora.com/With-our-current-technology-would-it-be-possible-to-send-a-team-of-people-to-Mars-and-back
- http://www.windows2universe.org/
- http://astro.unl.edu/naap/motion3/sidereal_synodic.html
- http://cseligman.com/text/sky/rotationvsday.htm
- http://iss.astroviewer.net/
- http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/Where_is_the_International_Space_Station
- http://www.weather.com/science/news/does-mars-have-seasons-20130910
- http://www.universetoday.com/14719/does-mars-have-seasons/
- http://www.nasa.gov/mission_pages/station/expeditions/past.html