Havant Sixth-Form College Mission To Mars Plan

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Mission objective / unique benefit

Coherent Objective:

Logically, the first part of the process in designing the mission is defining and justifying the objective!

The scientific merits of doing so are not lean at-all, as-well as the side-effects of such a project including science & technology investment, international co-operation and an economic boost.

- We intend to analyze the prospects of **future colonization** through surface tests
- We intend to monitor the growth of plants in martian conditions as a key factor of colonization, including the soil. We will be carrying a sealed laboratory inside the spaceship for this purpose that will be destroyed with Hydrogen Peroxide before leaving so as to abide to the Deep Space Treaty of 1967.
- Our use of a fusion reactor should path the way for future deep-space missions, opening up previously unavailable opportunities and timescales.

What will we do on the surface?

Mars has little to no atmosphere. It has long since vanished due to its lack of electromagnetic field, and the solar winds.

Its atmosphere was formerly rich with nitrogen and other gases much like that of Earth's. However, much of the planet's nitrogen was absorbed and locked into the soil by constant volcanic eruptions and tectonic plate movement.

As we know nitrogen is an essential component for plant growth and it also contributes to the greenhouse effect. With this is in mind we plan to bring with us to Mars equipment necessary to start a controlled nitrogen cycle. This provides us with several opportunities; we can measure the changes in the Martian atmosphere in controlled laboratory conditions, we can reliably grow crops for food, and bring equipment that may be reused for future missions.

What will we do on the surface? (cont.)

With atmospheric loss and volume of green matter in mind we would be able to somewhat accurately estimate the value of time that it would take in order for a given volume of Martian atmosphere to be converted to a level deemed safe for humans to live in. Depending on this value we could begin to further discuss the likelihood of human colonisation.

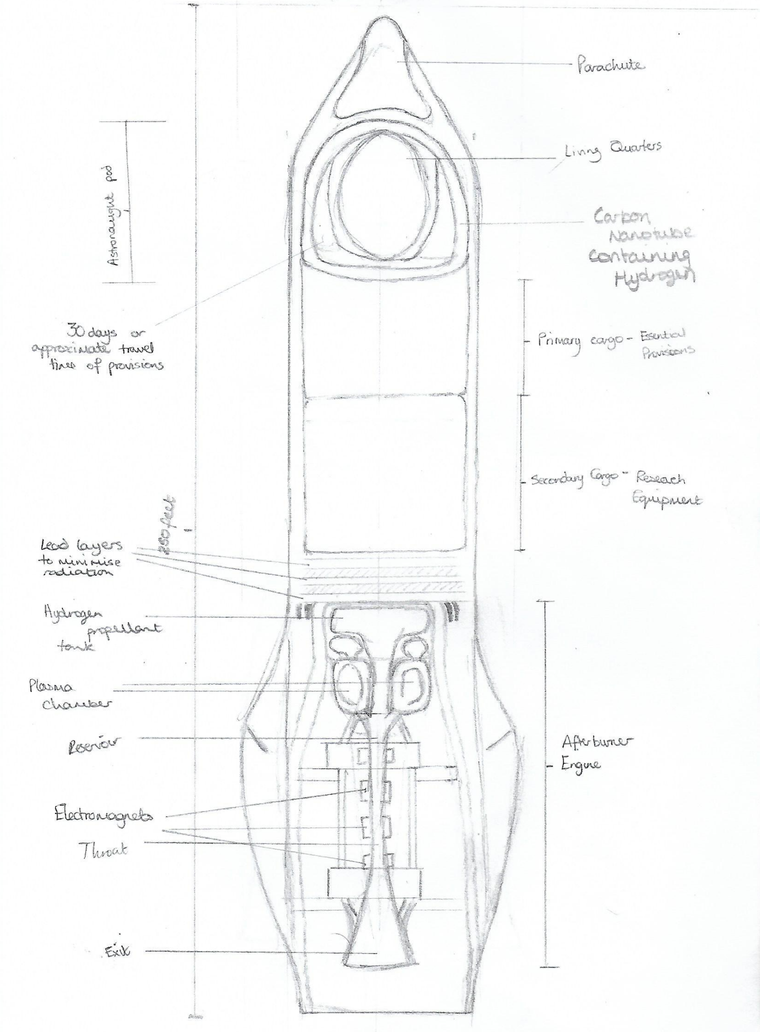
Additionally we would be able to observe the effects on plants of a low gravity environment over a long period of time. This will be a critical factor in estimating the value of bio-forming the planet. We can measure this on the ISS, but only estimate Mars' exact effects.

Propulsion / design

Spacecraft Design

The spacecraft design was centred around several criteria:

- Ample protection for astronauts
- Able to maneuver in a vacuum
- We intend it to house the first nuclear fusion based engine
- Equipment necessary to carry out experiments on the surface of Mars
- Food/water/storage space



The Rocket

The rocket in question is going to stand approximately 250 feet tall and weigh around 700 tonnes. Around the base of the rocket and in other necessary places will be corrugated lattices of material so as to increase friction, when landing, but not when entering the atmosphere. The material in question must be lightweight so as to make the rocket easier to put into space and accelerate, therefore we are intent on the use of carbon nanotubes as this structure also doubles for radiation protection.

Rocket Propulsion - Nuclear Fusion

We are planning on using a system in which a powerful magnetic field causes large metal rings to implode around the plasma, compressing it to a fusion state. The converging rings merge to form a shell that ignites the fusion, but only for a few microseconds. Even though the compression time is very short, enough energy is released from the fusion reactions to quickly heat and ionize the shell. This super-heated, ionized metal is ejected out of the rocket nozzle at a high velocity. This process is repeated every minute or so, propelling the spacecraft.

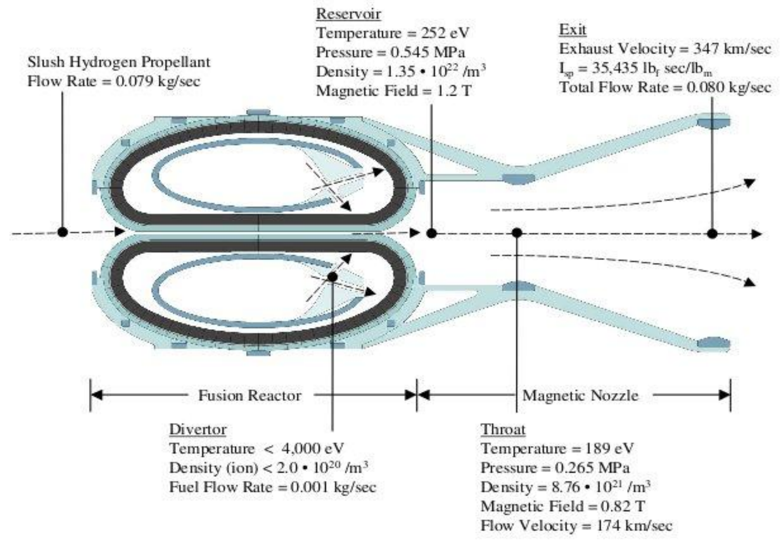
In the video below, the plasma (purple) is injected while lithium metal rings (green) rapidly collapse around the plasma, creating fusion.

https://www.youtube.com/watch?v=xrk1SdKiILE

Using this method the rocket could reach 10% of the speed of light.

However, a pure fusion engine just uses the hot spent fusion products as the reaction mass. An afterburner fusion engine has a second plasma chamber *(the afterburner)* constantly filled with some cold propellant *(generally hydrogen or water, but you can use anything that the spend fusion plasma can vaporize)*. The hot spent fusion products are vented into the afterburner, heating up the cold propellant. The average temperature goes down *(decreasing the exhaust velocity)* while the propellant mass flow goes up *(increasing the thrust)*.

The propellant mass flow increases naturally because instead of just sending the fusion products out the exhaust nozzle, you are sending out the fusion products plus the cold propellant. The contents of the afterburner are sent out the exhaust nozzle and Newton's Third Law creates thrust. This could decrease our flight time.



Rocket Propulsion - Nuclear Fusion Cont.

A nuclear fusion powered rocket isn’t as far away as it sounds. The main problem with nuclear fusion being faced, such as in the envisioned European fusion reactor power plant, is that plasma leaks, in addition to costing, in that a power plant must be cost less to keep running than money it can draw in. This problem is unique to a fusion power plant, because in a rocket, we want plasma to leak to power the engine! We’ve been leaking plasma for years, by way of the nuclear fusion bomb!

Overall mission strategy

Duration of Journey

Every 26 months, Mars and Earth are at their closest configuration, called “opposition”, where Mars can be as close as 55,000,000 km from Earth. In theory, the closest that the planets converge would be when Mars is at its closest point to the sun (perihelion) and Earth is at its farthest point (aphelion). In that situation, the planets would be 33.9 million miles (54.6 million kilometers) from each other. But that has never happened in recorded history. The closest known approach was 34.8 million miles (56 million km) in 2003. Mars travels at 24.130 km/s around the sun so this speed would need to be matched when the rocket approaches. A rocket powered by nuclear fusion could reach Mars in 30 days, according to a project led by the University of Washington and the MSNW. (A commercial space propulsion company.)

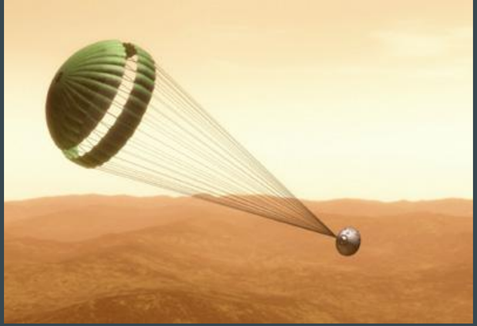
Deceleration & Landing

Mars orbits the Sun at a speed of 24.130 km/s. To enter Mars' orbit the rocket will need to decelerate from 10% the speed of light (29979.2458 km/s) to less than 24.130 km/s. To do this we will slowly reverse the direction of the ship and use our engines to project our rocket in the opposite direction.

To land we could use **Aerobraking. This** is a space flight maneuver that reduces the high point of an elliptical orbit (apoapsis) by flying the vehicle through the atmosphere at the low point of the orbit (periapsis). The resulting drag slows the spacecraft. Aerobraking is used when a spacecraft requires a low orbit after arriving at a body with an atmosphere, and it requires less fuel than does the direct use of a rocket engine. However, Mars' atmosphere is very thin, with pressure ranging from 0.4 – 0.87 kPa – which is equivalent to about 1% of Earth's at sea level, and so other methods will also need to be used.

Deceleration & Landing (cont.)

We will also be using a parachute which will be made out of two durable, lightweight fabrics: polyester and nylon. The parachute will have a triple bridle (the tethers that connect the parachute to the backshell) which will be made out of Kevlar, the same material used in bulletproof vests.



Landing Site

There are three basic criteria for picking a Mars manned landing site — a spot that’s sustainable in terms of water, energy generation and building materials. One that’s scientifically interesting for a lengthy mission. And, most importantly, one that is safe to land. The 5 possible landing sites are:

1) Martian lava tubes and caves.
2) Arabia Terra
3) Martian “glaciers” at Hellas Basin in Mars’ mid-latitudes.
4) Deep canyon of Valles Marineris.
5) Outer edge of Mars’ 3 km-thick North polar ice cap.

We have chosen to land on the outer edge of Mars’ 3 km-thick North polar ice cap.

Pros and Cons of our Landing Site

Pros: Water is close by. It’s very flat for landing; and since Mars’ solar orbit is larger than Earth’s, its northern summer would have nearly six months of continuous daylight, Hynek says. This would allow direct-to-Earth communications most of the time, in contrast to non-polar sites which would have to rely on links through orbiters.

Mars’ North Pole is also 6 km lower in elevation than its South Pole, so there would be more time to slow the craft and correct its position, to ensure the first Mars astronauts have a safe landing.

Cons: If staying year-round, you’d probably want to be more equatorial.

Living conditions

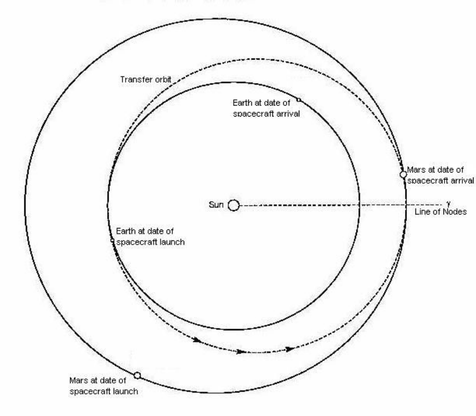
When our astronauts land on Mars away from their man vessel, they will have to construct habitable living conditions. In order to do this they will need to make a series of livable “pods” similar to that pictured below. They will also need to set up solar panels for energy. and a lab with which to work in.

Living conditions (cont.)

In order for these “pods” to be constructed we will take a similar approach to how the ISS was assembled. IE we will add slowly to it over time. The astronauts will start by producing an area in which they grow crops for consumption as well as setting up solar panels in order to generate sustainable energy. This will be important or else they run the risk of running out of food in the long run. They will then move onto living quarters, IE a place to sleep, and finally a small leisure area will be added. The lab will be set up last and this module will be separate of the living quarters as the atmosphere will not be breathable in the zone (so that we will be able to measure changes in the atmosphere caused by plants as mentioned previously).

Return Journey

The acceleration due to gravity on Mars is 3.711 ms^{-2} and the escape velocity is less than half than that on Earth (only 5 km/s) so it will be much easier to lift off than if we were on Earth, this is more than ideal as we will have to use comparatively small amounts of fuel in order to again re enter deep space travel in order to rendezvous with Earth. We will leave Mars after 26 months (when Earth and Mars are at their closest point again). This will give us approximately 25 months on Mars to complete our experiments. Upon leaving Mars we will sterilise the area which we worked in, in order to abide by the deep space treaty.



Human protection

Human Protection: Radiation

The main concerns regarding radiation exposure in space travel revolve about the increased risk of developing cancer. Along with this other damage can caused to the human body specifically surrounding the central nervous system and the respiratory system (the onsets of cardiovascular disease and ischemic heart disease are a common issue). Generally low-Earth orbit ships are substantially protected by the Earth's magnetic field, so these are not problems we would regularly have to deal with. However during deep space travel there will be nothing to protect our astronauts from deadly high-charge, high-energy nuclei sent from distant supernovae or galactic cosmic rays made of high energy protons.

Human Protection: Radiation (cont.)

Current NASA radiation standard limits an astronaut to a 3% chance of exposure induced death. However a manned mission to Mars imposes anywhere from a 5% chance to a 10% chance of death. On top of this the Van Allen belts (giant clouds of high energy particles trapped by Earth's own magnetic field) are also an issue, so too is Solar particle radiation. the Sun regularly ejects mass amounts of radiation and “solar wind” comprised of high energy particles during coronal mass ejections. This is a problem because due to the immense difficulty of predicting the plasmadynamics of the Sun, these ejections are near to impossible to predict.

Also when our astronauts are on Mars, due to its absence of an electromagnetic field, they will constantly be subject to radiation. On the surface they can expect to be subject to around 30 microsieverts per hour (at this rate it would take over 60- years for ESA career limits to be exceeded), and although this level is low it must still be considered.

Radiation: solutions

The most obvious and best solution to reduce radiation exposure is to decrease travel time; to travel fast and get to Mars quickly. This approach however does not solve all of our problems as it provides no long term protection and even when travelling at the fastest speed humans have given an object (New Horizons at 21 Km per second) it would take approximately 124 days to reach Mars, during which time a potential absorption of 240 millisieverts can be expected (this is roughly equivalent to 3400 chest x-rays). With these numbers in mind, when considering the use of our nuclear engine and a total travel time of 30 days, a solar body would expect to receive ~58 millisieverts, however this would not be the case for our astronauts as our spaceship will provide for extra protection in the form of carbon nanotubes.

Radiation: solutions

A more permanent solution is required, one that provides a measureable level of protection. A thick metal lining on the outside of our ship? No. that would be heavy and metal is actually quite poor at shielding from GCR's. When a GCR hits a metallic atom, it can shatter the atom's nucleus (similar to how fission works). Secondary radiation produced in this way can be worse than the initial GCR radiation. Luckily, the best shields against GCR's are atoms of the least mass. Hydrogen (the most abundant atom in the universe) is the best material for absorbing GCR's due to its incredibly dense nucleus core. Essentially when collisions between GCR's and hydrogen atoms occur, little secondary radiation is produced. A 50 to 100 cm layer of liquid hydrogen surrounding the ship would hence be a tremendous shield. Its only disadvantage is the incredible level of mass that it would add to our spacecraft due to its need for cooling.

Radiation: solutions

A more hypothetical solution would be to employ the use of a lattice of carbon nanotubes. Such a structure is able to store hydrogen in very high densities, but without the need for extremely cold conditions (as was the case with liquid hydrogen). It would still provide substantial protection from GCR's, thus this solution offers the greatest resolve to our problem. the material would also be ultra-lightweight (which is ideal as less fuel would be required to move the spacecraft) and it serves its ultimate purpose of protecting our astronauts.

This idea could then be taken one step further, we could also lattice the structure with atoms of other elements that are exceptional at absorbing radiation such as Boron for neutrons or Aluminium for electrons.

Human protection: Gravity

Life in microgravity brings with it many problems for living organisms. Loss of bone and muscle mass, the reduction in efficiency and in the size of the heart and body-wide alterations initiated by changes in the nervous system.

The skeleton’s job on Earth is to store nutrients, provide support and to protect the organs. In space however these functions change in only a few days. Owing that the weight of any body in space falls to ~0N, many bones that aid in movement are no longer subject to stress. Over time this causes calcium to be broken down and passed into the bloodstream as the excess calcium is considered as redundant. This mass decrease in bone density is known as Disuse Osteoporosis.

This is an issue because a) our astronauts will be in space for a very long time and b) they will need to be in good health to survive and carry out experiments on Mars.

Gravity: solutions

One solution to this problem is to produce artificial gravity. This can be done by spinning the vessel at such a speed that the centrifugal forces act to pull everything to the hull of the ship. In a ship designed in this the astronaut would walk around perpendicular to the “wall” he was stuck to and parallel to the “floor.”

The ship would have to be very large, because if the ship were too small the speed of the rotations required to produce the effect would be unfeasible, and the difference in forces experienced by the astronaut’s head and feet would be so great that blood would be forced downwards from the brain causing extreme nausea and lightheadedness.

This brings even more issues, because engineering what is essentially a vehicle this large and complex is completely unknown, and the components of the spaceship and reactor would also undergo the same forces as the astronaut, requiring consideration.

Gravity: solutions

As it is unfeasible to recreate “real” gravity, the best way to offset the effects of weightless conditions is simply to keep the time spent in travel to a minimum, as we envision an unprecedented one month journey times across the 55,000,000 km journey to Mars, made possible through the emerging field of nuclear fusion.

The other part of the solution is to simulate the effects of gravity on the body, as may be possible through a vibrating plate that produces G forces on the body similar to gravity. NASA is currently researching the utility of this in space. There are risks associated with these machines, mostly that they may exaggerate existing injuries, but this is a non-issue as astronauts selected for space travel are always of the highest possible health.

Cost and scheduling

We will base our costing around the supplies that are delivered and used aboard the ISS. We will be doing this as pricing our own space programme is an extremely difficult task due to the fact that we are basing the mission on some technologies that are not yet in frequent use. We will be using the Stellarator engine in order to estimate the cost of our engine as it is the closest real-life approximation.

Cost

Assuming that our spaceship starts in orbit we can ignore the costs associated with launching from Earth. This is good as the amount of fuel used during the launch of a space mission usually accounts for nearly one half of the total fuel used. This is also good as we are unsure of the mass of our vessel. We can however approximate the cost and weight of the supplies that we will need to bring with us.

It currently costs approximately £13800 to place 1 kg of material into orbit. A typical load of 3500kg of food, water clothes and other living essentials will last for around 4 months. Assuming we will be away from Earth for 3 years, we will need 9 of these payloads, for a total cost of £434,700,000

Cost (cont.)

A typical spacesuit costs in at £8.3 million and our mission will consist of 6 astronauts. Most missions have a backup team as-well, and assuming that the cost of photograph suits is negligible, this comes to a total of £99,600,000.

A lab to work in on the surface can be expected to cost as much as £10,000,000

R&D costs for a workable fusion engine should actually be rather low, given that working stellarators have been produced for ~£700k. Costs for staff have been ignored given that we intend to obtain the workbase from existing space programme staff.

This brings an estimated total of £1,244,300,000, which is less than Apollo 11’s figure accounted for inflation. (1.75 billion.) The comparatively low price-tag will no doubt be a seller to investors in the current economy. (There will doubtlessly be international interest in the development of a workable fusion reactor engine.)

Schedule

Leave Earth orbit

Deep space travel to Mars ← 1 month

Time on Mars ← 25 months

- -construct crop area, 2 months
- -construct living areas, 2 months
- -construct leisure area, 1 month
- -construct lab area, 2 months

Return journey ← 1 month