'Why is it so much more difficult to attempt a manned mission to Mars compared to a mission to the moon?'

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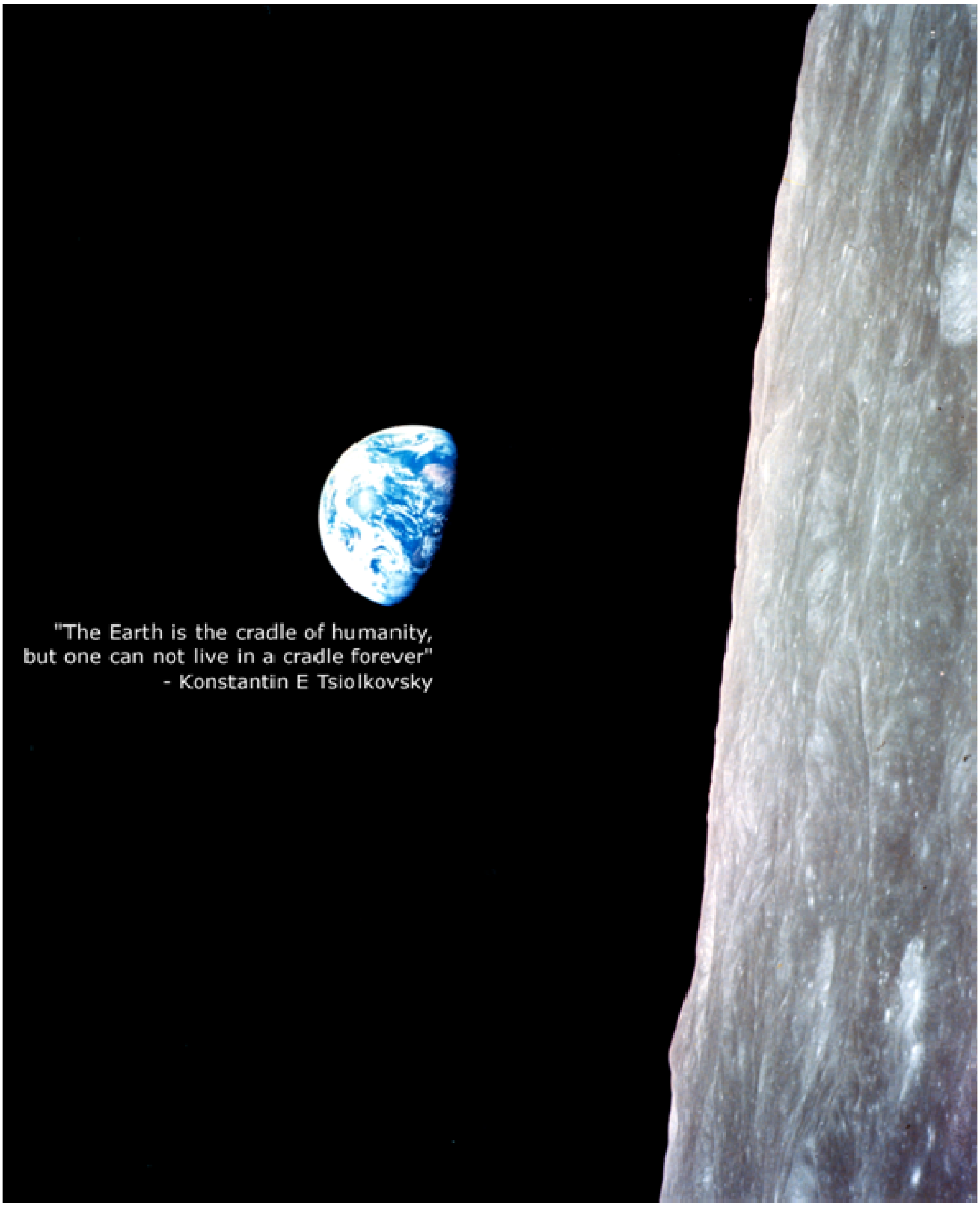

Mars, manned spaceflight, moon, difficulties,

Extended project, Wellsway, space

In 1969 man first graced the surface of the moon, but almost forty years on we have yet to set foot on Mars. Why is this? This essay finds that there are problems with reaching Mars, a much further target than the moon, and the effects that this has on the crew both physiologically and psychologically. It also finds that Mars itself is a much more demanding destination to exist on, as well as to leave. Last but not least, it examines the current political and economic climate compared to the space race, and finds that the single largest difficulty in a mission could be getting it off the design board. Is such a thing possible? This essay finds that it probably is, but that such a mission is a way off yet.

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''Why is it so much more difficult to attempt a manned mission to Mars compared to a mission to the Moon?'

Introduction

In this essay, I will attempt to overview the potential difficulties of a manned mission to Mars compared to a lunar mission, and review the ways in which such difficulties may be overcome. In order to do this, first an overview of the Apollo lunar missions will be conducted, and then each aspect of the program referred back to as a potential mission to Mars is examined.
I will be defining a 'manned missions to Mars' as any mission which descends to the surface of Mars while carrying a payload of one or more humans, with the intent of returning said crewmen. Also, throughout the essay I will be referring to crew*men*, as is stereotypical of exploration. The debate as to the inclusion of women on a prospective Martian mission is covered under the psychological effects section.

The topic of spaceflight, and in particular the sheer audacity of human spaceflight has always fascinated me, although whether this is because it is bravery or inspired lunacy I have yet to decide. A once in a lifetime trip as part of a team to the American space centres in 2006 cemented my passion for the subject and I sincerely hope that even in a small sense this essay conveys some of my interest and, more importantly, the reasons for my curiosity.

The Apollo Missions

The Apollo lunar missions (1961-75) (Anon 2008) were arguably the finest technological achievement of mankind. The program consisted of 9 manned missions beyond the Earth's orbit and several others within the confines of the Earth's gravity. 6 of the missions ended in successful landings, namely Apollos 11, 12, 14, 15, 16 and 17, (Smith 2008) with only one ending in failure- the ill-fated Apollo 13. They utilised the gigantic Saturn V launch vehicle- the most powerful machine in history, which carried a payload of a lunar lander along with an orbiter (the craft which circled the moon while the landing took place) three crewmen and an array of scientific instruments, although in later missions more advanced equipment was carried, for instance the lunar rover (essentially a buggy). Each mission followed the same basic template; spending so many days to reach the moon, separating the lander from the orbiter, descending to the surface and conducting whatever experiments need to be conducted, then ascending from the lunar surface to rejoin the orbiter and return to Earth. Amid political turmoil, budget cuts and a shift of vision, it was decided that the manned lunar missions were to be ended in 1970 (Anon 2008), but by the time the program was terminated; mankind had taken one small step into a new era of its development.

Succeeding in placing a human footprint on the moon was a colossal feat and pushed the technology of the time to the very limit, to such an extent that the accomplishment has not been repeated since. As such, the comparison between any manned mission to Mars and the Apollo missions is an appropriate one to make, with similarly large difficulties, for the time, to be overcome for success to be obtained.

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Let's take a look at an overview of the Apollo missions-

Typical length of mission:	10 days
Distance travelled per mission:	1-1.7 million km
Lunar characteristics:	Gravity= 1.622m/s^2 (Ostrega 2004) Surface composition= fine dust, rocky debris Atmosphere/Weather= non-existent
Cost:	$135 billion (estimated) (at today's exchange rates)

Each of these categories plainly involved huge effort from both NASA officials and the US taxpayer, but pale in comparison to the technological, material and economic difficulties to be overcome in a manned mission to Mars. Each of these sections of the Apollo program shall now come under more detailed review, and then a thorough comparison with the prospect of a Martian mission made.

Length of Mission

Buzz Aldrin once wrote that 'walking on the Moon was a piece of cake. It was easy. But getting to the moon was anything but easy.' (Sparrow 2007), and indeed the most difficult part of virtually any manned mission has proven to be the duration of the mission and any adverse effects it has upon on the crew. This section will, as such, constitute a significant part of the essay and will have to be divided into several sub-sections.

Apollo

First, a review of the length of the lunar missions. As previously outlined, the 'typical' manned mission to the moon would take in the order of 10 days, with the shortest mission (excepting the prematurely aborted Apollo 13) being Apollo 11 at 8 days, 3 hours; and the longest being Apollo 17 at 12 days, 13 hours (Anon 2008). There were two main factors which contributed to this particular length- the distance travelled and the form of propulsion used (in other words, what type of rocket, and which fuel). The Apollo spacecraft used the Saturn V's first and second stages with their colossal engines to escape the Earth's atmosphere and then used only the third stage to put them on course with the moon, some 384, 800 km away (Ridpath 1985). For more details on multi-stage rockets, please see Appendix B. To give an idea of this astronomical distance, a typical car travelling at 60mph non-stop and in a straight line (not accounting for service stops) would take around 167 days to reach the moon! For details of the calculation used here, please see Appendix A.

The Saturn V's third stage, thankfully, packed considerably more punch than a two-seater coupe because of its engine- a J2 specification rocket using liquid hydrogen and liquid oxygen, the fuel being in liquid form for balancing launch weight and volume. This provided a thrust of 1,001kN (Anon 2008), and took the spacecraft up to 39,420kph (or 10.95 kilometres per second) (Anon 2008), meaning that the journey took a paltry three days. Upon reaching the moon, the fourth and final stage of the Saturn V, containing the Command Module (CM), the Service Module (SM) and the Lunar Module (LM) split into two, with the CM and SM remaining in an orbit around the moon (with one astronaut aboard) while the LM descended to the moon with two crewmen, returning several hours later. The entire procedure of landing lengthened as the program progressed, but took roughly three days (Makara 2004) from lunar orbit insertion to transearth injection - in other words the time from the craft being placed in a lunar orbit to the point where the engines are fired to take the craft back to Earth. The time to return to Earth was about two and a half days, with a burst from the Service Module's engine powering the spacecraft out of lunar orbit.

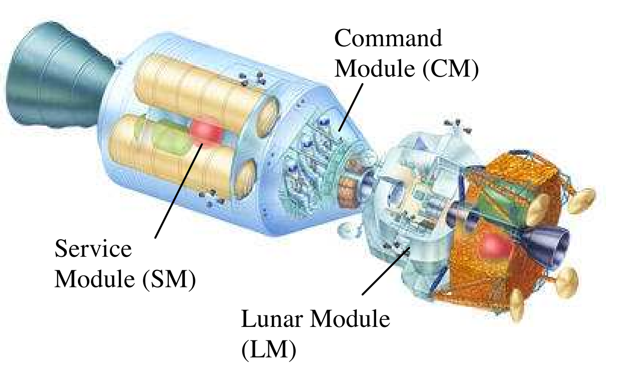

Figure 1: The Apollo Spacecraft

There have been no documented long term physiological effects on the Apollo astronauts (although exposure to lunar dust in the LM apparently caused brief hay fever and irritation), or negative psychological implications- in fact most lunar astronauts felt a feeling of deep compassion towards the Earth and a drive towards environmentalism.

Mars

First and foremost, Mars is significantly further away than the moon. As mentioned previously, the moon orbits the Earth at a relatively constant distance of around 384,800km. Mars, at its closest point to the Earth (its perigee), is some 78,000,000km away and up to 378,000,000 km away at the furthest point (the apogee) from Earth (Anon 2006). For this essay we shall assume that a prospective mission sensibly chooses to make the most of Mars' perigee (a reasonable safe assumption, as this happens every 26 months).

Even with this use of Mars' orbit, the distance travelled to reach the destination is still over 200 times greater than a lunar mission. To use the example of our interplanetary car, the journey would take, again at 60mph and in a straight line, somewhere in the region of 93 years to complete (see Appendix A). Or in other words, this distance is roughly equal to going around the Earth's equator almost 2,000 times (Dunbar 2007). This poses a significant problem to potential astronauts, and so a different form of engine to a turbo-charged V8 must be found.

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Propulsion

If an unmodified Apollo spacecraft, travelling at 39,420kph, were used to get to Mars at its perigee then the journey would take roughly 82 days (see Appendix A). This may seem like a long time as it stands, with a mission taking the better part of a year to complete, however there is a problem with this estimate.

The Apollo spacecraft carried enough supplies – food, water and air – to support three people for just under two weeks. If the craft had to support three people for, say, a year, then over a hundred times greater mass of supplies would have to be carried, although air can be recycled and purified to an extent. Also, the astronauts aboard the Apollo spacecraft had only 6.1m^3 of habitable volume in the command module (Kerbs 2008) and 4.5m^3 aboard the lunar module (Braeunig 2004). This combined is roughly the load volume of a Ford Transit van (Anon 2004), a volume that only the most sadistic of mission controllers could expect 3 men to contend with for almost a year. For a longer mission, a considerably larger volume would have to be provided for astronauts.

This poses a problem because such changes increase the mass of the spacecraft, thus reducing the speed gained from each thruster. This is because of Newton’s second law-

$$\text{Force Applied} = \text{Mass of the Object} \times \text{Acceleration produced}$$

Or, in its more pertinent form-

$$\text{Acceleration Produced} = \frac{\text{Force Applied}}{\text{Mass of the Object}}$$

In other words, the acceleration produced when a force acts on an object is dependent on how massive the object is- a small object will be accelerated at a greater rate than a larger object if the same force is applied. To use an example, if an astronaut in zero gravity pushes, say, a pen with their hand then the pen moves away at a reasonable rate. If on the other hand they push a 100kg bag with the same force, the bag will move away at a much slower rate.

In context, this means that for a larger spacecraft to achieve the same rate of acceleration that Apollo experienced, more powerful engines will be needed. The two movements to which this is important are - the trans-Mars injection (TMI), the movement which places a spacecraft on a trajectory with Mars, and the initial launch procedure. Entire essays could be written (and indeed have been written) on both of these topics, and so a short summary is provided here.

The only viable option for getting a spacecraft into orbit is a chemical rocket (in other words a conventional rocket such as the Saturn V) using a liquid hydrogen/oxygen mix. No new technology would be needed – the American lunar program developed launch technologies capable of putting 125mT (Rapp 08) into orbit (i.e. 125 mega tons; 125,000 tons, roughly the weight of 330 Boeing 747s (Anon 1999)), while their Saturn

V launcher, fully fuelled, came in at a relatively puny 3mT (Sparrow 2007). Having said this, such a craft would have to be on a scale unprecedented in modern rocketry. The potential, therefore, is there, but it remains to be seen exactly just how much mass is needed to be lifted. It is very difficult to estimate this figure, as the amount of supplies necessary will depend on the engines used for the TMI, and the time taken to perform this manoeuvre will depend on the mass of the supplies taken… etc. And when it takes 12,000kg of supplies per year (Couper & Henbest 2001), per person in space, then even a small discrepancy in the figures used could throw estimates wildly out.

We can, however, take a look at the potential for engines for the TMI.

While there are dozens of myriad propulsion techniques, for the purposes of this essay I will focus on three main areas – traditional chemical rockets, nuclear propulsion and ion drives. I have chosen to focus on these three types because chemical rockets are 'traditional' engines, ion drives have been successfully used in recent missions, while nuclear engines have never been tested but have been subject of considerable study. Other engine types such as antimatter drives, warp drives and solar sails have yet to come out of the conceptual stage (Clark 2000).

Chemical rockets have been the only engines used in manned spaceflight so far, and they have advanced considerably since the days of Apollo. The proposed J2X specification rocket, the descendent of the J2 used in Apollo, has a thrust in vacuum of 1,307kN (Kidder & Dick 2007), fully 30% more powerful than the original J2s. However, any thrust gained over the past forty years of technological advancement would be counteracted by the vastly increased mass of an extended mission, meaning that the time taken to reach Mars would roughly be the same as in unmodified Apollo craft if not slightly longer. It is this problem that has led many rocket scientists, being as they are the paragons of scientific society, to suggest the unorthodox step of nuclear rockets.

One of the techniques suggested is the nuclear thermal rocket - containing a nuclear fission reaction (such as those used in nuclear power plants, with uranium-235 or plutonium-239) within the rocket, and then use the energy created from this to heat a propellant such as hydrogen. This is then ejected through a nozzle in the same way as in a chemical rocket, providing a thrust (Bromley 2000). An advantage of this approach is that it has a very high power to mass ratio- just 1 gram of uranium could provide roughly a megawatt of useful power for a day (in other words, 1 gram of uranium alone could power a 100W light bulb for 10,000 days). So we are keeping the mass of the fuel needed low while still ensuring we have considerable thrust, meaning that the acceleration produced by such an engine would be much greater than a comparably sized chemical rocket. However, the downside of using a nuclear reactor is that some radioactive elements will be most likely present in the propellant emitted, potentially causing nuclear fallout planetwide if the engine is used too close to the Earth. Also, the nuclear reactor itself would need to have extensive shielding and safety mechanisms built in, increasing the mass of the vehicle and, in part, negating the advantage over chemical fuels. Also, there is a very small chance of nuclear meltdown, putting the astronauts' lives at risk.

An alternative to nuclear thermal rockets, while staying in the nuclear vein, would be nuclear pulse propulsion. This works on the principle of using nuclear explosions as thrust. While this may seem a little left field (and in fact, suicidal) it does make physical sense- if we place an especially tough object on top of a large explosive device and detonate it, the object would fly into the air. In exactly the same way, if we detonate a device behind a spacecraft, provided the craft has adequate protection, the craft would shoot forwards due to the force of the explosion providing thrust on the back of the spacecraft. Obviously, creating a craft capable of surviving such abuse would be the largest difficulty of such an approach, but several projects have analysed the procedure- Project Orion and Project Daedalus in particular have drawn much attention. Project Daedalus in fact predicted that a speed 12% of the speed of light (i.e. 36,000 kilometres per second) would be attainable in the long run, using small nuclear explosions at a rate of 250 per second (Matloff 2008). These projects however became shelved due to concerns for fallout, and cold war fears of placing weapons of mass destruction in space. In fact, the Outer Space Treaty of 1967 (Anon 2008) made it illegal to place nuclear warheads into space and so this approach is, as of the moment, in breach of international law.

The last approach is the Star Trek-esque topic of ion drives. To demystify the term, all atoms are neutrally charged (i.e. they are neither positive nor negative). An ion then is simply an atom with charge. Ion drives apply a large voltage across a chamber containing a gas, which causes the gas to become electrically charged; the ions of gas are then repelled by a plate that is similarly charged, causing the ions to be ejected out of the back of the craft. This ejection then exerts a force on the craft, causing it to move forwards. This technology has been demonstrated successfully on a number of missions recently, including NASA’s Deep Space 1 and ESA’s SMART-1, where the ion drive has proven more than capable of transporting cargo long distance (Sparrow 2007). While the ion drive is highly efficient and has a high power to mass ratio, the disadvantage is that it causes the spacecraft to accelerate at a very slow rate. However, the engine burns for months at a time rather than minutes, and so the craft can be accelerated to huge velocities. In fact one of the most promising designs, the Variable Specific Impulse Magnetoplasma Rocket (VASIMR), which uses radio waves to ionise a propellant and then emit it through changing magnetic fields (Anon 2008), is currently being researched by NASA and would be capable of over 400N of thrust (Nyrath 2008). This may pale in comparison to chemical and nuclear engine types, but would burn for thousands of times longer than other engines. This, if the technology can be successfully demonstrated, would cut the journey time considerably but until we know precisely how much thrust VASIMR would be capable of we cannot now a potential journey time.

Personally, I believe that nuclear engines need to be refined and tested extensively before they could be used on a mission to Mars. As such, I believe that using a chemical rocket to escape the Earth and then an ion drive such as VASIMR for the TMI would be the most efficient (and safest) way to conduct the mission. Also, if such a propulsion technique could be designed to incorporate resources found on Mars (see the section on destination characteristics) then overall mission mass could be reduced.

To summarise, the distance to Mars makes it more difficult because it is considerably further from Earth. In order to combat this, a considerably larger spacecraft and different propulsion techniques will be needed. These could take years to perfect and be in usable form, while the larger spacecraft and new technology would be even more expensive than the $135 billion Apollo program.

Psychological and Physiological Effects

Physiological Effects

Accepting Darwin's theory of evolution as true, the human body evolved on Earth, and so our biology has become dependent on the presence of gravity. If no gravity were present, then our skeletal structure would become almost defunct, our muscles would not have to work so hard to accomplish any movement, and our heart would not have to pump so hard to deliver blood to the body. When any significant length of time is spent in space, for instance aboard the Mir space station or the International Space Station, these problems are well documented and, upon return to Earth, can prove extremely detrimental to the health of astronauts. No permanent damage such as cell damage, gene mutations or chronic stress is done though, and any alterations to muscles, bones and biological systems are, ultimately, reversible although potentially extremely painful.

However, the longest time any one person has spent in zero gravity is Dr. Valeriy Polyakov with 437 days aboard Mir in the mid-1990s (Phelan 2008), and as previously discussed, a typical mission to Mars will most likely take in the region of 1,000 days. Although Dr. Polyakov made a point of walking away from his capsule (and was in fact jogging within 24 hours of returning to Earth), in order to maintain a physical state capable of survival on Earth a strict exercise regime of two to three hours daily was required (Gale 2004). While this is plausible on an extended mission, there are still downsides to the approach- Dr. Polyakov still experienced some wasting of muscle tissue and bone structure, and extrapolated over an even greater period this could still amount to serious physical damage. This, combined with the issue of spending a considerable length of time on the Martian surface, under the influence of 0.38 Earth gravity, has led to many scientists proposing an alternate method; creating artificial gravity.

Figure 2: A 'Gravitron' amusement ride

In order to explain how this is possible, an understanding of basic circular motion mechanics must be achieved. Most of us will be familiar with the classic fairground ride shown in Figure 2, where the prospective thrill-seekers are strapped into the inside of the circle's circumference and pinned into place as the ride begins to spin.

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The reason for this, regrettably, requires another equation-

$$\text{acceleration experienced} = \frac{\text{velocity of point}^2}{\text{radius of circle}}$$

Or, in its other form-

$$\text{acceleration experienced} = (\text{rate at which circle spins})^2 \text{ x radius of circle}$$

So the faster the circle spins, the greater the acceleration experienced by a point on its circumference. This acceleration is felt because of centripetal force- the force exerted by the circle on any body in its interior that makes it follow a curved path. To better understand this, imagine a point on the inside of a circle as it rotates. While its speed may remain constant, its *velocity* does not. Velocity is, put simply, speed but with a direction tagged on, and so as a point rotates in a circle its direction of motion is continuously changing. This change of direction comes about because the centripetal force is in effect gradually pushing the point’s direction to bring it in to line with the motion of the circle. Without this force, anything on the inside of the circle would simply fly off. With it, an object on the circle’s interior feels acceleration away from the centre of the circle and stays in place.

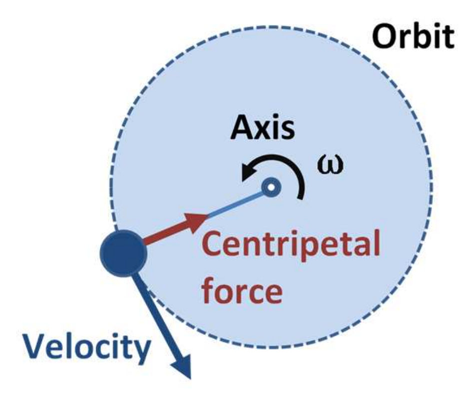

Figure 3 : Centripetal force description

This is relevant because gravity itself is acceleration. On Earth, when an object is dropped it accelerates towards the ground at a constant rate of 9.81ms^{-2}. This means that one second after being dropped an object will be travelling at 9.81ms^{-1}, at 19.62 ms^{-1} after two seconds and so on. We therefore define Earth gravity as a constant acceleration of 9.81 ms^{-2}. As gravity is acceleration, it can be generated by a rotating body such as the ‘Gravitron’. If we wanted to experience 9.81ms^{-2} of acceleration in a large drum of radius, say, 10m, we would then need to rotate the drum at a certain speed. The exact calculation used can be found in Appendix C but the result comes out as 0.99 rad s^{-1}, or in less physic-sy words, we would need to make the drum rotate such that it made one full rotation every 6.3 seconds.

To return to a mission to Mars, artificial gravity could be created either by spinning a habitation unit around a central support or truss, or counter weighting it with another mass. In either case, provided that the maths is done correctly, gravity would be felt on the outermost edge of the rotating body. Therefore, the ‘wall’ furthest from the centre of rotation would become the ‘floor’. Inside, the occupants would not be aware of this rotation and would feel as we do on Earth, just as we are not aware of the planet spinning. Also, as there is no other major gravitational force present, the astronauts would not have to be strapped in to the edge, as in the 'Gravitron', and so would be free to walk around. While it may seem to defy common sense, if a spacecraft shaped like a cylinder were made to spin about its central axis then gravity could be felt on a belt all around the edge of the craft. An excellent example of this can be found in the masterful film 2001: A Space Odyssey, if visualising this proves difficult! (See figure 4 for a cruder example).

Regardless of whether any artificial gravity is used on the journey to and from Mars, any time spent on the surface (and, given the amount of effort taken to get there, it will be a considerable length of time: most likely weeks or months) will still be detrimental to the wellbeing of astronauts. Exactly what damage will be incurred is, as of the moment, uncertain, although the typical problems of zero- or microgravity exposure such as loss of bone structure, weakening of muscles and a lack of blood to the lower body are predicted. The problem with such an issue is that the only way to be certain is to experience one third Earth gravity for a significant length of time. The need to adjust to this level of gravity could also prove problematic on a mission; especially if astronauts have to adapt from long term zero gravity exposure to the serious g forces of entry into the Martian atmosphere, to one third Earth gravity on the surface. This prospect of adapting to Mars gravity could potentially be overcome if artificial gravity were to be used, with the acceleration felt in the habitation unit originally starting at around 9.81ms^{-2} and then decreasing gradually by reducing the angular velocity of the unit as the spacecraft neared Mars, although no plans to do as such have come to this researcher's attention.

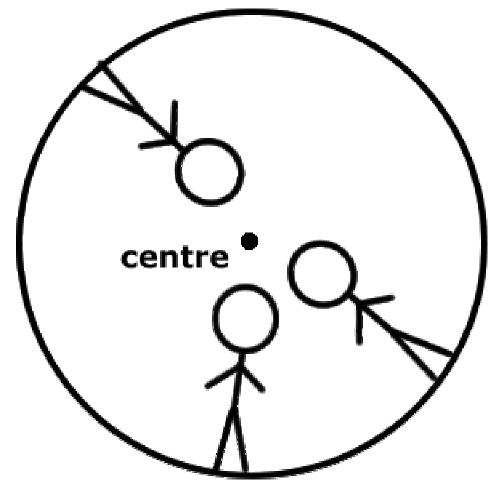

Figure 4: Artificial gravity. When the circle is spun around the centre gravity is felt on all 'sides'/'floors'

Quite apart from the threats of microgravity, potential astronauts face another, potentially deadly obstacle on the way to Mars: the threat of solar radiation.

In order to appreciate this, we must consider what we call 'the sun'. To most people the sun is simply a light in the sky, a source of light and heat. This is partially true, but the full truth is that the sun is a stupendously colossal ball of rapidly combusting hydrogen, fusing together to form helium and generating truly unimaginable quantities of energy. This energy is partly converted into radiated particles of staggering energy. These particles are the basis of solar radiation- the solar wind.

Here on the Earth we are protected from the worst of the solar wind by the Earth's magnetosphere, a magnetic field generated by the Earth's iron core that deflects the worst of the radiation. This field extends to around 60,000km away facing the sun (Microsoft Encarta 2008) and an almost infinite tail facing away from the sun. This means that all life forms on Earth, and all low-Earth orbiting spacecraft, are protected by our magnetic 'force field'. Apollo astronauts were out of the protected zone for a matter of days, and so suffered no long term damage whatsoever. However, a mission to Mars will be exposed to the full brunt of the solar wind for potentially three years or more, with some experts predicting a dosage of radiation similar to that experienced by the heroic Chernobyl fire-fighters; up to 13.4 Gy (United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2006) (meaning that they would absorb 13.4 joules of energy for every kilogram of living matter in their body (Anon 2008)).

The effect of such an extended radiation exposure is, as yet, unknown, as it is understandably difficult to find willing test subjects. This partially limits our ability to best counter the problem, although it is a safe assumption to make that techniques used here on Earth to counter radiation could be used to protect space farers. One technique that has been suggested is to use a mission’s water supply as a radiation shield, wrapping a water tank around a part of the habitation module that could protect the crew in times of peak solar activity and thus peak radiation exposure. The use of water, as opposed to more traditional materials such as lead or aluminium, works because solar radiation is mostly relatively heavy particles, and so when they hit heavier elements such as aluminium or lead they can produce secondary radioactive particles that may be extremely damaging (Couper & Henbest 2001). Water, as a light molecule, reduces the risk of secondary radiation being produced.

As previously mentioned though, this protected portion of the space craft would only be used during periods of greater solar activity. However, for the period of the mission spent on the Martian surface, another protected area will be needed for astronauts, most likely separate from the water storage tank. This will most likely significantly add to the mass needed to be transported to the surface.

It has been suggested that piling the regolith (see section on Martian geology) on top of any landing craft could be used as a form of radiation shield, although understandably this would only be compatible with certain designs of craft.

As a footnote to the section on physiological effects, we must consider that a crew headed to Mars will need to remain healthy and uninjured for the course of the trip if the experience on the surface is to be worthwhile. As such, it is almost a certainty that one of the seats on the spacecraft will be occupied by a doctor, whose roles would have to range from rudimentary checkups to dentistry and, potentially, zero gravity surgery. With him or her would have to be a medical kit for every eventuality under the sun, as there would be no potential to simply turn the craft around should one of the crew members fall ill.

Most likely, finding a capable doctor willing to take part could be one of the greatest challenges facing a prospective mission.

Psychological Effects

When people think of the effects of spaceflight they typically think of the debilitating results of zero gravity, or the punishing re-entry forces experienced when returning to Earth. One aspect that is often overlooked is the psychological health of astronauts, from the claustrophobia of living in such an enclosed space to the social tensions that will inevitably rise up over time. Or, as Jack Stuster, senior scientist at

Anacapa Science Inc. puts it- ‘Imagine travelling around England in a motor home with five other people for three years and you can’t go outside.’ (Couper & Henbest 2001)

For a mission to Mars, an appropriate comparison to make would be that of a long term naval voyage, where the morale of the entire crew often is solely hung together by the leader. Just as Scott and Columbus kept their crews going the commander of a Martian mission would have to be an inspirational character. The main problem facing the mentality of the crew is often cited as being the extreme isolation and the loneliness this entails, as one would expect, although according to Michael Collins, the pilot of Apollo 11, this is often overstated: ‘I was described as the loneliest man ever in the universe, ever, or something like that. Which was a load of baloney – I had mission control yakking in my ear half the time. I kinda liked it.’ (*In the Shadow of the Moon* 2007)

However, much as Michael Collins claims, it is extremely like that a trip taking years rather than weeks will have a negative impact on the crew’s mentality. This has been demonstrated by several long term studies into either isolation or zero-gravity. For instance in 1986 the Soviet Union started a 370 day test into blood pooling in the upper body (Phelan 2008) (as a result of microgravity, see previous section) which went wrong from the outset. The small crews of two, three and five began to bicker with one another almost instantaneously, and the most vocal of the five-man group had to be moved. This would not be possible on a Martian mission, and crew selection would have to extremely careful with numerous mentality tests. Although currently astronauts do undergo psychological tests, there are none of the type as seen in the film *The Right Stuff*, as most seem to expect! Incidentally, one of the members of the 1986 test claimed to have fallen in love with one of the attending nurses, and several divorced their wives at the test’s conclusion. This would likely be another emotional strain on astronaut’s minds.

In addition to inter-personal friction, another issue that has yet to be answered is that of the gender of the crew. This is very much a matter that can be interpreted in different ways depending on your viewpoint (and gender!) and so I have attempted to include as many people’s stances as possible.

No woman ever participated in a lunar landing, and traditionally the role of exploration is seen as being a ‘man’s calling’. However, in a modern world in which women are finally becoming more and more empowered both socially and in the workplace, the issue of women being on a Martian crew is now being considered. The effects of extended microgravity exposure on women is little understood however, and given that physiology differs quite considerably between genders, many feel that it would be unwise to take the risk of sending women when their health could be at considerable risk. Also, Dr Valeriy Polyakov controversially claims that women should be excluded because they would be ‘an unnecessary emotional and hormonal disturbance’. This was in fact proven true in 1999-2000, when a female Canadian astronaut participating in an isolation experiment accused one of her Russian (male) colleagues of sexual harassment, and although the experiment continued the researchers felt considerably embarrassed. In fact, the only mixed-sex mission that worked well was Shannon Lucid’s six month stay aboard Mir in 1996.

That said however, there is now considerable evidence that women may be more suited to space exploration than men. Jill Richardson of the (British) National Space Centre was quoted in The Guardian as saying that women ‘[are] smaller, lighter, more efficient, require fewer calories, produce less waste and, probably because of their oestrogen, are less prone than men to heart problems brought on by the flight.’ (Parry 2005). In fact, it would appear that the male dominance of space travel has largely been down to (in this researcher’s opinion) bigoted individuals in power. For instance, cosmonaut commander Alexey Leonov said in 1975 that ‘After training, [a female cosmonaut] will be 28 or 29, and if she is a good woman she will have a family by then’ (Oberg 2005). Additionally, the training of the first batch of US astronauts contained women until the navy’s top brass (men one and all) cancelled the testing, appalled at the concept of women in space. Personally, however, I sadly believe that it is unlikely for such a status quo to be removed overnight, and indeed the physiological problems that authority figures point to as justification have yet to be satisfactorily solved.
For these reasons, most likely it will again be an all male crew aboard the ship to Mars.

Again, to summarise, the increased length of mission has adverse effects on both the body and the mind. It wastes muscle and reduces bone density, and steps must be taken to reduce such a decline, such as artificial gravity. Astronauts would also need protection from solar radiation, and all medicinal needs or supplies would have to be planned for. Additionally, crewmembers mental health must be preserved both so far from home, and in such close proximity to other people for extended periods of time. None of these were problems for the Apollo astronauts and so the mission profile has become much more difficult.

Destination Characteristics

The Earth’s moon is, relatively speaking, a small body. In fact, it has a mass of less than one eightieth (Williams 2006) of the Earth, itself a small astronomical body. As a result, it has only 1.622ms^{-2} gravity, which is roughly one sixth of the Earth’s. This was very helpful to the Apollo missions, as it made it very easy to propel spacecraft from the surface of the moon, as there was very little gravitational force to overcome. In fact, the escape velocity from the moon is only 2.38ms^{-1}, as compared to the Earth’s 11.2ms^{-1}. In other words, in order to escape the gravitational pull of the moon, you only need to go upwards at one fifth of the speed need to escape the Earth.

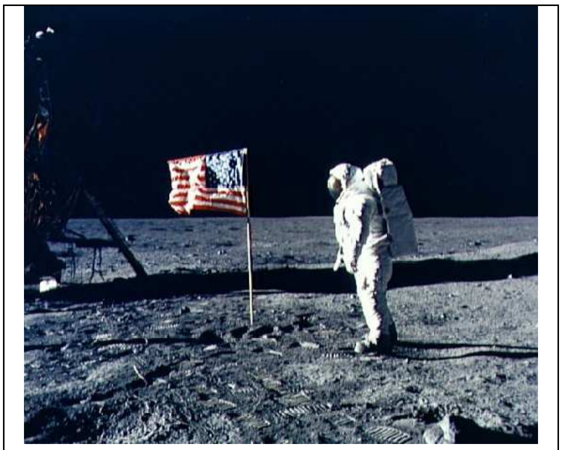

Figure 4: The lunar surface

''Why is it so much more difficult to attempt a manned mission to Mars compared to a mission to the Moon?'

The majority of the lunar missions landed on lunar 'maria' (NASA 1997) (the Latin for 'seas', but are in fact basaltic plains formed by volcanic eruptions), which were largely flat with occasional boulder fields. Apart from these though, the terrain was the 'regolith', which is unconsolidated loose grains not dissimilar to cat litter. This made the task of landing relatively easy.

Mars

Mars is different from the moon in many respects. Firstly, it has a mass closer to one tenth of that of the Earth and as a result has a gravity of around $3.71 ms^{-2}$, along with an escape velocity of $5.03 ms^{-1}$ (NASA 2007). While this may not sound like a serious issue, effectively doubling the escape velocity means that four times as much launching power must be brought to the surface (this is because of the need to conserve energy- as kinetic energy is proportional to $velocity^2$ then twice the velocity means 2^2 times the kinetic energy, and therefore 2^2 times the amount of fuel needed). So in other words, a much larger and more powerful spacecraft (and consequently a much more massive one) needs to be safely landed on a site where it can safely take off. As a result of this, it has been suggested that in situ (on site) resources be used to make take off possible. The Sabatier reaction (Anon 2008), for instance, which turns hydrogen and carbon dioxide into methane and water, has been proposed as a means of fuelling a rocket with methane. If this approach was used, then the only fuel that would be needed to brought in would be the light-weight hydrogen, as the carbon dioxide could be taken from the primitive Martian atmosphere (see below), with the water produced being electrolysed to produce more hydrogen (that could be fed back in to the reaction) and oxygen.

The only alternative to an approach such as this would be effectively landing a low to medium powered rocket, in addition to any habitation or equipment, onto the surface in a state ready to be launched at any point. When required to be launched, the entire procedure, other than the astronauts depressing the large red button, would have to be automatic with no chance to correct anything from ground control should something occur. If something unexpected were to happen during the landing on Mars (an event which is reasonably likely, as Apollo 11 almost crash landed into a boulder field) then this rocket would have to be repositioned and re-prepared for launch by a handful of people who will most likely have no professional association with rocket design. As this is a fairly undesirable situation, most prospective mission profiles include either a limited payload to be delivered to the surface, reducing the need for a very large launch vehicle, or utilise on site resources.

The surface of Mars varies from place to place much as that of the Earth does, and so for the purposes of this section of the essay I will focus on the two most likely locations of a landing. The first of these is the Planum Boreum (Anon 2008), which is essentially the northern polar cap of Mars. The north of the planet is primarily smooth due to volcanic activity, but closer to the pole there is a permanent ice cap of water ice and dry ice (carbon dioxide in solid form). As such, a landing close to the edge of the ice cap could finally determine the composition of this with minimal difficulty at landing, as the composition of the planes around the pole is mostly dune-like in nature and thus easy to prepare for on Earth. The disadvantages of a landing at such a location include the possibility of both avalanches and cyclonic storms (most commonly known on Earth as hurricanes), both of which have been observed at the pole. Also, if a landing site is chosen in a dune area then a precise landing point would have to be calculated during the descent, as the dunes would continuously change location. In addition, the low temperatures of the winter months closer to the pole may be unsuitable for a prolonged surface mission.

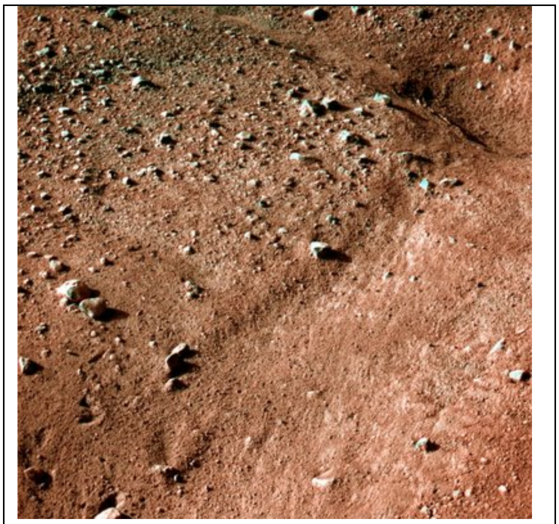

Figure 5: An example of the northern plain of Mars (false colour)

The second potential location for a landing site is the area surrounding the southern pole, the Planum Australe (Anon 2008). Less is known about this area, although it is known to play host to long, cold winters and short, mild summers, making a longer term stay viable. There is a permanent ice cap made mostly of water ice and a seasonal cap of dry ice, which disappears when temperatures increase in the Martian summer. A manned mission could again determine the composition of the ice cap, but also the origins of the unique features known as Martian ‘spiders’ (see figure 6), which are believed to be caused by carbon dioxide thaws. Of course, further observations and probes would be needed before a manned mission could be considered, but further disadvantages would include the nature of the terrain- the area surrounding the ice cap is permafrost, and thus any landing would effectively be taking place on a material as hard as concrete. Also, it is believed that during the summer months when the carbon dioxide evaporates (or more precisely, sublimes; turning straight from solid to gas) it can become trapped under water ice and

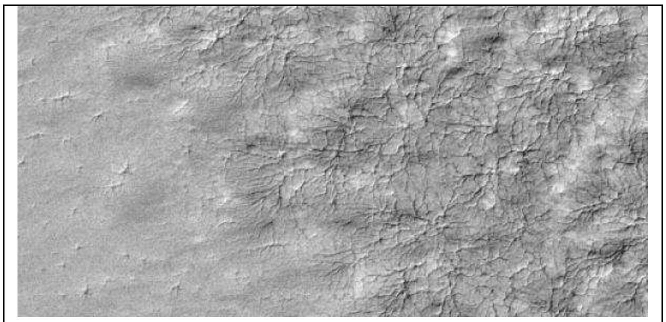

Figure 6: Martian ‘spiders’ (from above)

eventually burst up in a geyser form. Obviously, this danger would have to be considered if landing near the ice cap.

Another considerable difference between the moon and Mars is that Mars actually has an atmosphere (the vast majority of which is made of carbon dioxide, but with traces of nitrogen and argon) (Anon 2008), and thus experiences a climate. The presence of an atmosphere means that, unlike on the moon, air resistance will be encountered when descending to the surface. While this means that a shallower angle of descent and a heat shield will have to be used, such as when for returning to Earth, parachutes could be used to slow the spacecraft down. The effect of parachutes will be slight compared to that of when used on Earth- Mars has a typical atmospheric pressure of 7-8 millibars, while on Earth pressure rarely drops below 900mb, meaning there is less potential for air resistance and thus upthrust - but have been successfully demonstrated on the Mars Exploration Missions in conjunction with retrorockets (downward turned rockets that fire to reduce rate of descent) and surrounding airbags. Of course, the use of airbags on a large landing craft would be difficult and so a combination of several large parachutes and powerful retrorockets would have to be used.

The climate of Mars would also be another obstacle to overcome. Although Mars’ climate is significantly different from that on Earth, as the planet is in effect one big desert, cyclonic storms, snow and dust devils have all been observed on the surface. In addition to these phenomena, colossal (and indeed sometimes planet-wide) dust storms have been seen on an alarmingly frequent basis, when huge portions of the planet’s surface are swathed in a dust cloud. If a manned mission were on the surface when such a storm occurred, the effects could be deadly- the storms would most likely render communication with Earth extremely difficult, and an external foray would be akin to walking in a desert during a hurricane – wind speeds have been estimated to be up to 100 mph (Phillips 2001). When also considering that one global storm in 2001 lasted for several Earth months and raised surface temperatures by up to 30°C, such an event would put an end to any prospective mission. We must bear in mind, however, that our understanding of such events is simply based on external observation and therefore my sources are not to be treated as canon. As such, a greater understanding of the Martian climate is absolutely necessary before humans could even contemplate setting foot on the surface.

To provide a summary, Mars provides a much more demanding destination than the moon. Its increased gravity makes it more difficult to leave the surface, meaning that a more powerful rocket would have to be landed to start the return journey. Also, the Martian weather means that a landing party could have to contend with anything from hurricanes to snow to extreme warming, something that did not happen on the moon. Its atmosphere means that in situ resources can be utilised, unlike the moon, but also that a more complex descent would be needed.

‘‘Why is it so much more difficult to attempt a manned mission to Mars compared to a mission to the Moon?’

The majority of this section of the essay was based on a lecture given by Dr John Mason on the 7th of March 2008. All acknowledgements, unless otherwise stated, are to him.

Political and Economic Factors

During the course of the Apollo Program, the United States was competing with the Soviet Union in the depths of the cold war, and it was this rivalry that fuelled the space race. Indeed, the two superpowers were by far and a way the most powerful nations on Earth, with almost limitless resources at their disposal.

In the intervening time however, the political landscape has massively changed: the cold war has ended, the Soviet Union reformed back to its member states, the superpowers gone. No one nation on Earth now has the resources available to the two superpowers at their peak, and this may prove to be the single largest problem of a manned Martian mission.

If we take a look at the economic data, it is clear to see that the USA was in a position of unparalleled economic strength in 1970, the time of the Apollo program: its international net reserves grew by far the largest figure in the world at $2.5 billion, compared to the second largest value, that of South Africa with $500 million. (World Bank 1970) In 2005 (the most recent data), international reserves grew by $14 billion; the sixth largest in the world (with Japan at the top with an increase of $208 billion) (World Bank 2005), clearly showing the USA’s slip from the very pinnacle of the world’s economy. This data has been used because other data sets available such as gross national and gross domestic product, while equally valid, show personal wealth rather than the economic position of the government, as we are interested in here. Most specifically, it shows the US government’s fall in economic confidence, something absolutely necessary for a program with the scale of Apollo.

With no one nation willing (or indeed able) to foot the bill for such an ambitious project, international cooperation is necessary for a landing to take place. As of July 2008, only the American, Chinese and Russian (Anon 2008) space agencies are pursuing manned spaceflight programs, although the European Space Agency (ESA) has an extensive astronaut core and frequently provides mission specialists for space shuttle launches. Cooperation between some or all of these agencies then would have to take place for a mission to go ahead. Each agency has its own speciality- NASA has obviously sent people out of the Earth’s orbit before, while Russia has more experience with long term spaceflight. China, on the other hand, is currently undergoing a period of unprecedented economic and scientific growth, and so, provided such growth continues, could provide huge sums of cash and manpower to an international effort. Such international cooperation is easier said than done however, as although the USA and Russia have cooperated extensively on the International Space Station, the Chinese space agency was absent from the roster of participating nations. While Sino-American relations have improved markedly over the past few years, the BBC describes that there is ‘plenty of room for continued misunderstanding and tension between the two countries’ (BBC 1999), and if this cannot be resolved within the upcoming few years it is likely that the USA and Russia (with the possibility of Europe) will have to go it alone to Mars. Whether or not this is in fact possible remains to be seen, but I am personally hopeful that cooperation is (eventually) possible- for instance, it was widely believed in the 1970s that the Cold War would never end, but now Russia and the USA have cordial relations on a day to day basis. Hopefully humanity will overcome politics.

To briefly summarise, the global political and economic climate currently means that no one nation is equipped or prepared to fund a project as large as a Martian mission, and international cooperation is doubtful. This means that it is less likely for a mission to occur, possibly being the single greatest difficulty.

Conclusion

Question: Is it possible to do a manned mission to Mars?
Answer: Yes.

Question: Will this happen within the next decade?
Answer: No.

While predicting the future is an often impossible task, this observer feels that it would be impossible to fully complete a successful manned mission, from the drawing board to lift off within the next ten years. Having said that, the technological challenges that face mission designers are not insurmountable and I feel that a manned mission is quite likely to take place within the next fifty years. As with all such things however, this estimate cannot take into account the changing political and economic landscape, the two of which are likely to become the largest factors in a prospective mission. We must remember that we only went from the Wright brothers to Apollo in 60 years because the political and economic climate allowed for rapid advance and competition. It is an arguably similar leap to go from the moon to Mars, and so we must simply hope that such an environment persists into the mid-21st century.

A word of warning however. Civilisation as we know it stands on a knife-edge; ever deadlier weapons threaten to extinguish the light of humanity, crises of health and capita eat away at the foundations of nations, and our climate is on the brink of descending into its death-throes. We must ask ourselves if the time is in fact right to visit other planets, whether it is worth the expense, or whether we should discover and save our own Earth before discovering another.
Ultimately, humanity must spread its wings to the stars. It is our choice of whether we keep two feet on terra firma, or allow the flower of our species to have its seeds dispersed to the heavens and the universe.

Appendix A

Calculations

1. Car from Earth to Moon

   To establish speed in kph: $60 \times \frac{8}{5} = 96$

   To calculate time taken: $\frac{\text{Distance (km)}}{\text{Speed (kph)}}$: $\frac{384800}{96} = 4008.3$ hours

   In days: $\frac{4008.3}{24} = 167$ days

2. Car from Earth to Mars

   To calculate time taken: $\frac{78000000}{96} = 812500$ hours

   In days: $\frac{812500}{24} = 33854$ days

   In years: $\frac{33854}{365.25} = 92.7$ years

3. Apollo craft to Mars

   To calculate time taken: $\frac{78000000}{39420} = 1978.7$ hours

   In days: $\frac{1978.7}{24} = 82.4$ days

Appendix B

Rocketry Stages

The intent of this appendix is to straighten out any confusion as to the sections – 'stages' – of rockets that may have arisen in the course of the essay.

A simple rocket such as the infamous V-2 of the Second World War could be considered as a firework, with fuel combusting inside the fuselage and being expelled out of the base to provide thrust (Figure 1). However, most rockets constructed after the Soviet Union's R7 ICBM (used to launch Sputnik) used more than one stage to achieve orbit. In simplistic terms, a multistage rocket is several simple rockets stacked on top of one another (see figure 2), with the first stage (the bottommost) firing first until running out of fuel and then falling away to allow the stage above to ignite. This process may continue for four or five stages.

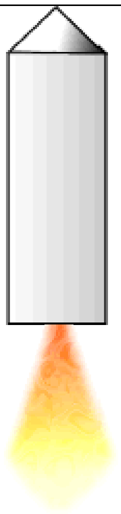	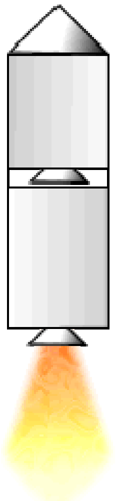
Figure 1 – a simple rocket	Figure 2 – a multistage rocket

Generally, the more stages that a rocket has, the greater its operational reach. To use the towering Saturn V as a contextual example (and I can testify personally that they are extremely towering!), the first two stages powered the astronauts out of the Earth's atmosphere while the third stage fired briefly to reach a low Earth orbit and then again, after orbiting the Earth several times, to put the craft on course with the moon. The fourth stage was then left to carry the astronauts there. Each stage had progressively less trust than the one before it, as the rocket had to stand up on the ground and larger fuel tanks higher up the rocket could fatally unbalance it.

Appendix C

The rate of rotation can be measured as a value of rad s^{-1}, with rad s^{-1} being short for the number of radians turned through per second.

The radian is a method of measuring angles without using degrees- instead of there being 360° in a circle, there are 2π radians. Therefore, if our drum rotates at a rate of 2π rad s^{-1} then it makes one full rotation every second.

Returning to our example, to achieve $9.81ms^{-2}$ of acceleration- (ω = angular velocity, or rate of rotation)

$$9.81 = \omega^2 \times 10$$

$$\omega^2 = \frac{9.81}{10}$$

$$\omega = 0.99 \text{ rad s}^{-1} \text{ (2 s.f.)}$$

Or in other words, we would need to make the drum rotate such that it made one full rotation every 6.3 seconds.

Appendix D

A note on sources used in this essay

Wherever it has been possible I have attempted to track down technical data from the American, Russian (and Soviet) and European space agencies in order to make this essay as valid as possible. In particular, NASA's webpages have been used for technical specifications. This is because they are where the information itself has originated from, and is therefore most likely to be accurate (although sometimes bogged down in administrative bureaucratic web design).

Where this has not been the case and I have used public domain websites such as Wikipedia, I have endeavoured to track down where these sites have obtained their data from in order to check the reliability of the information. In some cases, for instance looking up a rough definition of a phenomenon or location, this has not been necessary and so I have assumed that the website did know what it was talking about. While these websites are doubtlessly less reliable (and in many cases, harder to understand) I feel that for the purpose I set them to, these faults did not impede the essay.

Also, I used publications such as 'Spaceflight' by Dorling Kindersley and 'Space Exploration 2008' for dates and technical information. I have treated the information written as accurate, although in some cases (especially 'Spaceflight' and 'The Hamlyn Encyclopaedia of Space') the publications were intended for a non-scientific audience and thus I have shied away from using these sources for specific technical data, or high level concepts. I have, however, used sections of their text as inspiration for sections of the essay that deal with basic concepts (e.g. escape velocity), as the writing style and purpose is similar.

In addition to webpages and publications, I also had the privilege of attending a lecture on Mars by Dr John W. Mason, and have also received information and guidance from Dr Stella Bradbury of Leeds University in order to receive expert help on topics that are difficult to come across on the internet. Again, I have taken the information given as correct, as the professors are quite likely to know their subject and so I have not double checked this information. If some information proves to be erroneous, it is almost certainly down to my interpretation and presentation.

I have also used books on the subject of spaceflight and on Mars, which are noted in the bibliography.

Discrepancies in my sources

For the most part, my sourced data has been technical data and so was constant in all of the mediums used. However, for the 'economic factors' section of the essay I came across a problem in showing the United States' economic dominance during the space race. When analysing the gross national product (GNP) and gross domestic product (GDP) across the two time periods, I expected to see the USA in a much stronger position during the 1960s compared to now, as demonstrated by higher values (all values provided by the

World Bank were given at today’s exchange rates) or being larger than other nations’ values by a more significant margin. In fact, the figures suggested that the USA is in a stronger position now than it was during the space race. What I realised however was that GNP and GDP showed personal wealth, rather than the economic strength and confidence of the government. To communicate this I looked first for the export/import balance over the two periods, but this data was unavailable and so I used changes in net reserves, as can be seen in the final essay. I used this data because the more money that a government puts into reserve, the more economically confident that government is that such money is not needed in investments. Incidentally, I treated this Therefore, the USA putting more into net reserves during the Apollo Program shows that the government was more economically confident than it is now, demonstrating why the Apollo Program happened when it did and not now.

Another notable occasion when sources contradicted one another in my research was the topic of female astronauts, and differing opinions held on the issues. The common scientific consensus was that women should not be included on a Martian mission partly due to the belief that they would cause emotional friction, but mostly because the effects of extended microgravity on female physiology are largely unknown. While these two reasons in themselves seem reasonable, an article on the subject (at http://www.smh.com.au/news/world/another-giant-leap-8230/2005/07/05/1120329448366.html) argues that the lack of inclusion of women in space efforts lie in a deeper source- the chauvinism of male individuals in power. While I have ultimately left it up to the reader to decide, I find such an argument difficult to ignore- the evidence put forward by the article that bigoted views have impeded equality in space is compelling. That said, the counterpoint that physiological effects on women are unknown, I believe, takes precedence over any past foolishness at NASA and the cosmonaut agency- if we don’t know what danger we are placing astronauts in then we should not be placing them in it at all.

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