

MISSION TO MARS

PROJECT BASED LEARNING



Mission to Mars: Project Based Learning

Getting to Mars

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Getting to Mars

By: Elisabeth Ambrose

Escape velocity



Launch of the Mars Pathfinder Mission. NASA/JPL.

The first problem facing a potential trip to Mars is leaving Earth. Specifically, this problem deals with the enormous amount of energy necessary to break free from the Earth's gravitational field and start traveling towards Mars, or anywhere else in the Solar System. To find out what energy, and therefore speed, is necessary to escape Earth's gravity, let us consider the energy of a rocket at Earth's surface:

$$E = \frac{1}{2} m_{\text{rocket}} v_{\text{initial}}^2 - \frac{GM_{\text{earth}} m_{\text{rocket}}}{R_{\text{earth}}}$$

Energy is the sum of kinetic and potential energies. Here, v_{initial} is the initial velocity, m_{rocket} is the mass of the rocket, and M_{earth} and R_{earth} are the mass of the Earth and the radius of the Earth. Now, because the energy of the rocket is constant as it travels upward, we can equate the energy of the rocket at the surface to the energy of the rocket at its maximum altitude:

$$\frac{1}{2} m_{\text{rocket}} v_{\text{initial}}^2 - \frac{GM_{\text{earth}} m_{\text{rocket}}}{R_{\text{earth}}} = \frac{1}{2} m v_{\text{final}}^2 - \frac{GM_{\text{earth}} m_{\text{rocket}}}{r_{\text{maximum}}}$$

Here, v_{final} is the final velocity and r_{maximum} is the maximum height. However, at its maximum height, $v_{\text{final}} = 0$, so the equation becomes

$$\frac{1}{2} m_{\text{rocket}} v_{\text{initial}}^2 - \frac{GM_{\text{earth}} m_{\text{rocket}}}{R_{\text{earth}}} = - \frac{GM_{\text{earth}} m_{\text{rocket}}}{r_{\text{maximum}}}$$

Solving for v_i , we have

$$v_{\text{initial}}^2 = 2GM_{\text{earth}}(1/R_{\text{earth}} - 1/r_{\text{maximum}}).$$

Setting $r_{\text{maximum}} = \infty$, which is the condition for gravitational escape, v_{initial} becomes v_{escape} and we have

$$v_{\text{escape}} = \sqrt{2GM_{\text{earth}}/R_{\text{earth}}}.$$

The same logic can be applied to any planet, so the equation for escape velocity can be generalized to

$$v_{\text{escape}} = \sqrt{2GM/R}.$$

Thus, the escape velocity from any planet depends on the mass of the planet and the radius of the planet. For example, let us assume that we have a spacecraft on Earth that we are trying to send into space. $M_{\text{earth}} = 5.98 \times 10^{24}$ kg, and $R_{\text{earth}} = 6.37 \times 10^6$ m, so we get:

$$v_{\text{escape}} = \sqrt{2GM/R}$$

$$v_{\text{escape}} = \sqrt{(2(6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2)(5.98 \times 10^{24} \text{ kg})/(6.37 \times 10^6 \text{ m}))}$$

$$v_{\text{escape}} = 1.12 \times 10^4 \text{ m/s, or about 11 km/s.}$$

Now, let us assume astronauts have successfully completed their mission on Mars and need to calculate the escape velocity on Mars so they can travel back to Earth. $M_{\text{mars}} = 6.42 \times 10^{23}$ kg, and $R_{\text{mars}} = 3.397 \times 10^6$ m, so we get:

$$v_{\text{escape}} = \sqrt{2GM/R}$$

$$v_{\text{escape}} = \sqrt{(2(6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2)(6.42 \times 10^{23} \text{ kg})/(3.397 \times 10^6 \text{ m}))}$$

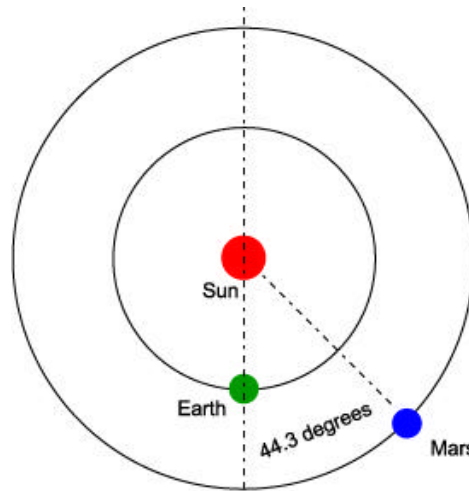
$$v_{\text{escape}} = 5.0 \times 10^3 \text{ m/s, or about 5 km/s.}$$

Routes and travel time

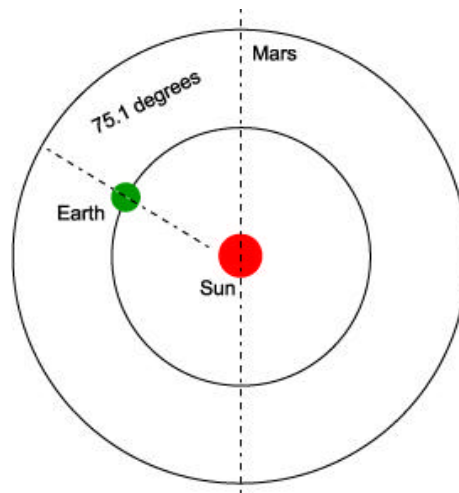
There are many different possible routes to take when sending a spacecraft to Mars. As each trip covers a different distance, each takes different amounts of time and fuel.

Perhaps the most familiar type of route involves sending the spacecraft out when Mars is about 45 degrees ahead of Earth in its orbit. This happens once

every 26 months. The spacecraft powers outward and catches up with Mars in about 260 days. For the return trip, which also takes 260 days, the spacecraft simply leaves Mars when Earth is slightly ahead in its orbit, and spirals into Earth's orbit, catching up with the planet. In this scenario, a team arriving on Mars would be able to spend 460 days there. The entire trip would take about two and a half years. This type of route is known as a conjunction class route because the spacecraft arrives on Mars or Earth when that planet is in conjunction with where the other planet was when the spacecraft left.



The Sun, Earth, Mars configuration upon launch from Earth.



The Sun, Earth, Mars configuration upon arrival at Mars.

A different type of route is known as an opposition class route, which is similar in style to conjunction class routes. It is called opposition class because Earth and Mars make their closest approach sometime during the trip. A spacecraft would have to leave

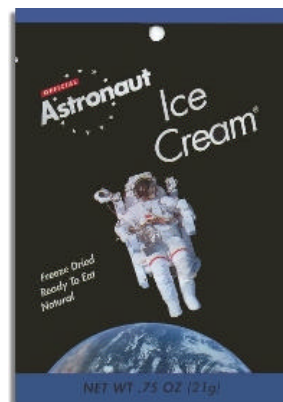
Earth when Mars was significantly ahead in its orbit, and the trip would take 220 days. During the return trip, the spacecraft would spiral inside Earth's orbit and catch up to the planet from the back. The return trip would take 290 days. To time the orbits correctly, there would only be 30 days available to stay on the surface of Mars.

Lower thrust rockets can also travel to Mars using less direct means. These types of spacecraft spiral out of Earth's gravitational field, and arrive at Mars in 85 days. Part of the ship detaches to drop off the astronauts and their gear, and the return module continues to fly by the planet. The return module will rendezvous with Mars again in 131 days, allowing the astronauts to catch their ride home.

There are many other proposed ways to get astronauts to and from the red planet. For example, one scenario

envisions astronauts launching from Earth and landing on one of Mars' moons. The astronauts could then set up a base of operation from which they could make many trips to the surface of the planet. In another proposal, a space station that acts as a permanent ferry could be put in orbit between the two planets. Smaller spacecraft could then taxi astronauts between Earth and the space station and between the space station and Mars. This situation would allow many more frequent trips for many more travelers back and forth between the planets.

Supplies: food, water, oxygen.



Freeze dried ice cream.

Every person on board a spacecraft bound for any Solar System body needs to have access to a minimum amount of food, water, and other supplies. Some of these items, such as air and water, can be filtered and recycled, while others, such as food, cannot. For one day on the spacecraft, one person typically needs 1 kg of oxygen, 0.5 kg of dry food and 1 kg of whole food, 4 kg of drinking water, and 26 kg of wash water. Of these staples, 80% of the oxygen, 80% of the drinking water, and 90% of the wash water can be recycled. None of the food can be recycled. For a one way flight lasting 200 days, this translates to 3,440 kg of supplies needed. Once on the surface of Mars, oxygen and water can be manufactured by the astronauts. Food is therefore the only supply to bring to the surface, and for a 600 day stay for four

people, 1,200 kg of dry food and 2,400 kg of whole food will be needed.

Psychological needs/concerns

Taking a trip to Mars would be unlike anything ever experienced by humans before. As they travel away at thousands of kilometers per hour in a tiny capsule, the Earth would get smaller and smaller until it was just a tiny dot. The feeling of empty space all around would be almost crushing, leaving no doubt of the tiny insignificance of the speck of a spacecraft. And how would people handle living together, cramped in a tiny space with no escape for three years? Communication with Earth would take longer and longer, eventually causing there to be 20 minute delays between messages. If problems aboard the spacecraft emerged, there would be little or no help available from Earth. The threat of death would be woven into everything the astronauts did. A tiny hull

breach by a small meteorite or a flare from the Sun would pose fatal hazards that the crew could not prepare for or fix. What would be the psychological effects of such a journey?

It is possible to get a glimpse of what life might be like on such a journey by looking at similar environments here on Earth. Environments such as that on board a submarine, the International Space Station, or a remote scientific camp in Antarctica mimic the psychological problems that might be present during a trip to Mars. Examples of these psychological problems could include concerns about a limited amount of resources, the unchanging social group, social isolation, limited communication with the outside world, a self-contained ecosystem, the constant sense of danger, physical confinement, lack of privacy, lack of separation between work and non-work, limited

opportunity for variety and change, limited sensory deprivation, and dependence on machine-dominated environment.

As a specific example, travelers to Antarctica are very cut off from the outside world, just as astronauts bound for Mars would be. Neither would be able to contact their loved ones whenever they wished, and both would be so far removed from the recognizable world that no trace of it would remain. Also, people in Antarctica must be very careful with their equipment, food, and supplies in order to stay alive in the bitterly cold, harsh conditions. Astronauts bound for Mars would share these types of concerns. However, people living in Antarctica would have plenty of air to breathe and plenty of water to drink. They would not have to bring these supplies with them or be concerned that they might run out. They

would also have plenty of space – if one member of an Antarctica team got annoyed with another, he or she would have the whole continent to walk away and be separate for a while. Astronauts, however, would be very confined with no escape from each other, and they would be very worried about the supply of air and water.

On the International Space Station, astronauts deal with limited supplies of air, water, and food every day. They also live in very small quarters and must be able to cooperate in order to survive. These conditions would be very similar to those experienced by astronauts bound for Mars. However, if astronauts aboard the ISS ever got homesick or frightened, they merely have radio down to Earth to speak with their families or friends, or to look out the window to see that Earth is just a short flight away. In the event of a

major disaster that threatened the lives of those aboard, emergency escape vehicles are available to shuttle the men and women back to their home planets. However, aboard spacecraft bound for Mars, no such quick communication or emergency ride home would exist. As the ship got farther and farther away from the Earth, radio messages would take longer and longer to reach them. Also, the Earth itself would shrink to the size of a tiny dot, similar to the other stars. No one in human history has ever been so far from our home planet, and the psychological effects of seeing Earth nearly disappear into the darkness of space are much unknown.

Perhaps the best analogue relating to travel to Mars would be that of a person in a submarine. Living on a submarine for an extended period of time would certainly be similar to living in a spaceship going to Mars. In both

situations, the people on board would be living in very cramped, tight quarters, and they would be forced to get along to survive. They would be breathing filtered air and drinking filtered water. All necessary food and personal supplies would have to be brought on board the ship before it departed. In addition, communication with the outside world would be limited and delayed, resulting in only sporadic contact with the crew's loved ones and friends at home. Perhaps most similar would be the dependence on machines for life and safety and the imminent threat of death if those machines fail. Just as all aboard the submarine would be killed in the event of a hull breach, or a fire, so would all be killed in a spaceship bound for Mars. However, it is important to note that if a crew member became very ill or if an emergency happened that was not immediate, the submarine (unlike the

spacecraft) could always return to the surface in a relatively short time to secure help.

In order to alleviate some of these potential problems that might arise during a mission to Mars, studies are being done to determine the types and numbers of people that would best handle the enormous stress and that best get along in these types of environments. Technology is also being developed to help determine when an astronaut is in psychological distress, and to develop strategies for dealing with the distress that do not involve returning to the Earth. For example, computers can now discern the emotional inflection in a person's voice to look for signs of emotional trouble. If the computer does find that someone is in need of help, it is programmed to suggest ways to alleviate the problem, such as recommending

extra rest, extra food, or possibly
medications.

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