

# Interplanetary Space Travel- A Proposed Mars Mission

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## Abstract

The Earth is dying; its resources are disappearing, and its habitats are failing. It is now necessary to transform the wonder with which mankind looks at the stars into ambition. This ambition's focus is on the red planet of Mars, for the purpose of researching and colonizing the planet with the closest environment to our own. This difficult yet necessary project requires large amounts of money, materials, time, and foresight.

Realistic "blueprints" were created in SolidWorks, a design program, in order to calculate an estimated cost of the mission, as well as define the functionality of all the components of the mission, including a spacecraft and Mars base. Advanced mathematics were used in order to calculate things such as the orbits needed to successfully reach Mars, the amount of spin required for an artificial gravity room, and the time a Martian mission would take.

The successes and failures of previous Mars missions allowed for this mission to be sculpted in such a manner that would build on past successes and learn from past mistakes.

## Introduction

Mankind has tried repeatedly to reach Mars. Of the thirty-seven launch attempts only eighteen have succeeded. That is more than a fifty percent failure rate. This fact goes to show the difficulty and danger in sending a manned mission to Mars. The high failure rate is due to variety of factors ranging from engine failure, in the Soviet Marsnik 1, to navigation errors, in

America's Mars Climate Orbiter. However, there have been numerous successes that inspire further exploration. For example, the Mars Pathfinder mission sent back over 16,500 pictures of the Martian surface ([http://en.wikipedia.org/wiki/Mars\\_Pathfinder#Facts](http://en.wikipedia.org/wiki/Mars_Pathfinder#Facts)). Many scientists believe that Mars is capable of supporting life because there is evidence of past liquid water. The possibility for life is the ultimate driving factor in exploring Mars. Therefore, the fundamental goal of Martian exploration is to sustain humans on the Red Planet.

The primary problem confronting a mission to Mars is keeping the astronauts and equipment safe. First, the astronauts will have to be safe while in transit between Earth and Mars. There are many hazards in space from solar radiation, micrometeorites, and weightlessness. Solar radiation permeates through space and can potentially endanger the health of the crew and the functioning of electronic equipment. Although Micrometeorites do not have much mass, they travel at several miles per a second and thus, possess enough kinetic energy to cause serious bodily injury to astronauts and structural damage to the spacecraft. The transit to Mars will take several months and the prolonged exposure to a zero gravity environment would have a detrimental effect on the astronauts. They would lose significant amounts of muscle mass and have lower bone densities. This change would inhibit the astronauts from being able to function optimally on the mission. These problems need to be addressed adequately before any mission is sent to Mars. In very general terms, the first two problems can be solved by adding extra shielding around the spacecraft to protect the people and equipment inside. The third challenge can be addressed by creating artificial gravity. This would be accomplished by using a chamber that spins. The centrifugal force exerted on those inside would simulate the force of gravity.

Cost reduction, a classical engineering problem, is another major issue concerning any mission to Mars. The cost of a mission to Mars includes more than just the cost of sending a spacecraft. Money must also be spent on further research and development of relevant technologies. Also, the training of a group of astronauts to journey to Mars will cost a significant amount. In addition to these factors, to design and build a completely new type of spaceship will cost a significant amount as well.

It is estimated that a program of this type and size would cost more than even the Apollo missions to the moon. The Apollo missions were accomplished with a cost of \$20 billion. A mission to Mars would probably cost a total of \$100 billion, about the cost of the International Space Station. Although this is a huge sum of money, the burden can be reduced by spreading the cost over a period of fifteen years. Currently NASA's annual budget is about \$16 billion ([http://www.nasa.gov/pdf/142458mainFY07\\_budget\\_full.pdf](http://www.nasa.gov/pdf/142458mainFY07_budget_full.pdf)). During the fifteen years this money can be redirected to the mission to Mars and be able to sufficiently cover the costs.

Once on Mars the crew would begin to accomplish their mission objectives, which would contribute to the ultimate goal of sustaining humans on Mars. The mission objectives include constructing a preliminary base, searching for resources on Mars, and studying the planet and the effects of living on Mars for prolonged period of time. These mission objectives would be the first steps in accomplishing the final goal of a permanent human establishment on Mars.

Man should explore Mars, because it is in his nature to be curious and find new places. Ancient humans spread throughout the world from a small area in East Africa. Now it is necessary for mankind to take the next step in exploration by going to Mars. Although the costs and challenges will be immense, a mission to Mars will help further the human race.

## **Background**

One of the most important lesson history has taught us is that in order to succeed, we must learn from our past mistakes. Keeping this in mind, a great deal of research was done concerning previous Mars missions. The most useful information comes from some of the more recent Mars missions.

The Mars Exploration Rovers, Spirit and Opportunity, provided the best examples for which to follow. Both were launched in 2003. When they reached Mars, a parachute system was deployed, as well as an air cushion to ensure a safe travel through the Mars atmosphere onto the surface. This methodology inspired the system used to drop the equipment from Goliath. The Base and the Rover are to be dropped from the spacecraft while it is still in orbit above Mars. They will then travel through the

atmosphere and gently land on the Martian surface.

Other missions, such as the Mars 4 and 7 launched by the USSR, flew past Mars and entered a solar orbit. This shows how precise the calculations need to be to enter a Mars orbit. Out of the 36 international missions to Mars, only 13 have successfully completed their mission. That is a thirty six percent success rate. Clearly, correctly calculating the figures necessary to make a trip to Mars is extremely difficult, even for an unmanned spacecraft. Goliath, being manned, will have many more challenges to overcome

These four missions provided the best data to learn from. Their mistakes and successes gave an excellent example of how to operate certain components of a Mars mission.

## **Engineering Design**

### **R&D: \$40 Billion**

Development of the propulsion system for Goliath will most likely be based on the newly designed technology of Bimodal Nuclear Thermal Rockets (BMTR). The BMTR works by using a nuclear reactor. This form of propulsion is safe, having small radioactive leakage, and does not involve any uncontrollable nuclear reactions. This is basically a high powered version of the already tested ion engine which was used to propel a DEEP SPACE satellite to an asteroid. Power for the ship will be provided by the same nuclear reactor as the one used for BMTR. This reactor will be based on the work done on the SP-100 reactor in the 1990's. The features in this type of reactor have been used successfully in the construction of reactors for nuclear submarines. This reactor will produce 2 Megawatts of electricity, and it will also be compact and extremely safe. Technological work is necessary to convert onboard hydrogen into propellant and water. These technologies will be incorporated into the lander in order to take advantage of the materials already available on Mars. This will significantly reduce the weight of the spaceship. Work also needs to be done to research the effects of a low to no gravity environment on the astronaut's bodies. Also, scientists need to research the materials which can be manufactured to protect the astronauts from radiation as they leave the safety of the Earth's magnetic field. Promising work is being done in the research of

polyethylene which actually shields better than the aluminum used in APOLLO. In this way, as astronauts leave Earth, polyethylene would shield them from any of the Sun's harmful rays. Exposure to such rays could result in serious health problems in the future for the astronauts.

It is necessary that we use as much of our available technology as possible to reduce costs in the mission. Materials that are used on the Space Shuttle will be used on Goliath as well (such as the outer cover and the heat resistant shield). This will save the research team from having to spend money to discover a new shell material; considering that a large sum of money is being spent researching the highly sophisticated propulsion system. Research is where most of the money is spent to help solve some of the problems involved with a mission. However, if existing technology is used, it is possible to save billions of dollars.

### **CONSTRUCTION: \$30 Billion**

Construction of the parts of this spaceship will be able to be done with technology that is currently in existence. It will involve many major aerospace and electronic companies in the United States because Goliath is such a large undertaking. The immense size of the ship itself will be a daunting task alone (not to mention all of the new technology that will also be implemented during construction). There is no way that one company could take on this task alone. It will require the cooperation of many companies in order to efficiently and safely construct this vehicle. Builders must insure the highest quality of every piece of Goliath to guarantee reliability throughout its long life in space. Also, since the Goliath is reusable, its parts must be extremely durable. Once constructed, the parts will be transported to the launch and preparation site. They will each be carefully inspected by two separate groups of inspectors to ensure product quality.

### **ASSEMBLY: \$30 Billion**

A large part of the cost will be the launch of the parts into low Earth orbit where they will be assembled with the assistance of the International Space Station. Getting the large parts into space will be the most difficult task for engineers. However, the new ARES class of rockets already designed by NASA makes launches of large loads somewhat more practical

than those of the Space Shuttle. The ARES rocket itself is capable of launching loads of up to 125 tons into a Low Earth Orbit (LEO). By comparison, the maximum liftoff weight of the space shuttle is 120 tons. Also, the cost of each launch of the ARES rocket will be less than a shuttle launch. Therefore, not only will NASA be able to assemble the Goliath relatively quickly, it will also be able to do it cheaper than if it had done so with the shuttle. Once in space, the robot arm on the ISS will be able to manipulate the larger parts of the Goliath, and its sensors will be able to keep tabs on the project, making sure that all the parts are in the correct place. Factoring in costs for transportation to the launch site from the various parts of the globe, the assembly phase of this program should cost around \$30 billion.

### **The Ship and the Base**

The success of a Mars mission lies solely on the shoulders of the equipment involved. The four objects mentioned are the most vital in this mission.

The Spacecraft contains some of the most important traits vital to the mission. All of its components were designed to meet specific requirements. Starting from back to front, the first important section of the ship is the artificial gravity simulator room. The room is 49 feet in diameter and 80 feet wide. It contains all the living quarters and things essential to the survival of the astronauts. Within this room the astronauts will live for the trip to and from Mars. The way in which this room creates gravity lies in its design. It quickly spins within the ship at a rate of .1821 revolutions per second. This rate of spin creates artificial gravity and is therefore a suitable place for the astronauts to live. Next to this room is the cargo bay. This is a large space, roughly 80 feet wide and 100 feet long. The main function of this room is to hold the base stations. The bottom opens to allow the equipment to be dropped onto the surface and Mars, and likewise the top can be opened by two large doors to load the equipment. Also held within the cargo bay are the Mars rover and a large crane used for loading and unloading of heavy equipment. Next to the cargo bay is the cockpit area. Contained within are the control panels of the spacecraft. These control the ship as it flies through space as well as provide readings concerning the condition of the ship. Backing up a bit, there are two large rocket

boosters clasped to the left and right sides of the ship. Both of these boosters are designed to provide plenty of thrust to get through space. Since the ship is going to be constructed in space in small sections, the boosters don't have to be large enough to get past the Earth's atmosphere, and therefore money is saved in both the amount of materials used as well as the amount of fuel required. The next important piece of equipment is the Lander.

The Mars Lander is 'attached' to the front of the spacecraft. It is within this miniature ship that the six astronauts staying on Mars will depart the main craft and head for the Martian surface. The Lander consists of two floors. The top floor is a simple storage space, providing room for all the equipment too delicate to be dropped from the spacecraft. The bottom floor is split into three different sections. One section on the far side of the Lander acts as an entrance and exit point from the Lander. It has two very thick doors on either side, one leading out of the Lander, the other leading into the middle section. These doors are designed this way in order to provide an airtight lock. This allows the astronauts to enter and exit the Lander without exposing themselves or the other sections of the ship to the harshness of Mars's surface without first draining or filling the room with oxygen and pressure. The center most section of the ship is a cockpit very similar to that on the spacecraft. It contains control panels for steering and condition readings. The third section of the Lander wraps around the wall opposite the airlock room. These rooms act as temporary dormitories for the astronauts until the base is established.

In order to properly navigate the Martian surface, the astronauts will require some sort of vessel to get around. This is where the Mars rover fits in. The Rover is similar to a jeep, in that it acts as an efficient means of traveling through rough terrains with little difficulty. It has four wheel drive, with each wheel having a thick, solid rubber tire. On the Rover are four chairs, in rows of two. In front of the first row are controls to maneuver the Rover, and behind the second row is trunk space. This is used to hold the equipment for studying the surface of Mars, as well as a large built in drill. This drill will be used to probe the surface of Mars, allowing the astronauts to take samples back to the base. The entire Rover is powered by large, rechargeable batteries.

The Mars Base Design initiated from the idea of creating a livable condition for mankind. To facilitate this plan, five important

sectors were developed: a greenhouse, a laboratory, living quarters, a water sanitation area, and a fuel compartment. With that came the notion of creating the best possible way to accommodate the five individual parts. The end product of the design was a circle divided into the 5 sections providing a more sufficient surface area.

The first section, the greenhouse, is located at the center of each circular Planetary Observation Dome (POD). The green house is heated by the solar energy captured during the two weeks spans of sunlight on the planet. This solar energy is captured through several solar panel fixtures. These panels are placed just below the plastic dome covering, allowing for better sunlight absorption.

The greenhouses will contain several plants, each of which will be used to provide oxygen to begin the process of creating an earth like atmosphere. In order to establish this outcome, different plant seeds will be brought on the mission. Each POD has a security system programmed to immediately activate airlock seals to protect all other PODs when a leak is detected from any malfunction. If contamination does breach these seals, the POD will be immediately ejected.

The laboratory section of the POD is solely based for the conduction of experiments. Included in these experiments is the testing of the life expectancy of living organism such as plants. The resulting effects of Mars' atmosphere on the plants will allow the astronauts to determine what plants will be strong enough to create an oxygenated atmosphere.

The living quarters of the PODs has been designed for multi-purpose services. Included in these services are the sleeping area, the dining and cooking area, a recreation area, and finally an entertainment area. The living quarters in general are designed as a convertible section that can be converted into the listed areas above. To create a sleeping area, the astronauts will simply have to pull out their individual beds from the walls, however, the cooking and sanitation areas are permanent fixtures. Similar to the system of pulling out the beds from the walls, the entertainment and recreational areas will also be invertible. The reason for the invertible parts is due to limited yet sufficient space provided in each section.

Included in each POD is a water purification center. This particular section is divided into three sub-sections. The first section is filled with water used for waste disposals such

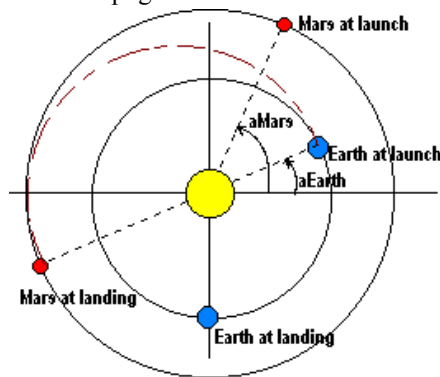
as in bathrooms and toilets. The second is for consuming purposes, and the third is for agricultural purposes. Water from each section will be recycled for repetitive uses. Water that can no longer be used is automatically transferred to the agricultural and waste disposal section. The purest water will be used for consumption and laboratory purposes.

The last part of the POD is a section mainly for fuel. The fuel produced in this section is needed for the spaceship as well as the base. The fuel also serves as a backup in case of a fault in the solar panels. The fuel is a combination of liquid hydrogen and liquid oxygen however while in the fuel reservoir the two are separated and must be kept at extremely cold temperatures. The liquid oxygen must be kept at a  $-297^{\circ}\text{F}$  and the liquid hydrogen at  $-423^{\circ}\text{F}$ .

These five sections together create a complete and functioning base for the incoming astronauts.

## THE JOURNEY

Goliath will be constructed in orbit around Earth and this will reduce the change in velocity required to reach Mars. In order to calculate the necessary launch speed, travel time, and angular difference it is simpler to treat the orbits of Earth and Mars as coplanar and circular. The most efficient method of getting to Mars is by using a Hohmann transfer orbit. This method puts the spacecraft in a heliocentric elliptical orbit. The elliptical orbit is tangent to Earth's orbit at its perigee and tangent to Mars' orbit at its apogee.



The spacecraft will pass through  $180^{\circ}$  or  $\pi$  radians with respect to the Sun. Before we continue with any calculations we need to define some variables.

$M_s$  = mass of the sun =  $1.989 \times 10^{30}$  kg  
 $G$  = Gravitational constant =  $6.67 \times 10^{-11}$   $\text{m}^2\text{N}/\text{kg}^2$   
 $d_{\text{Earth}}$  = Earth to Sun distance =  $1.496 \times 10^{11}$  m  
 $d_{\text{Mars}}$  = Mars to Sun distance =  $2.279 \times 10^{11}$  m  
 $a$  = semimajor axis

First we will calculate the launch speed necessary for this trajectory. We know that energy is conserved in an elliptical orbit. Thus,  
 $E = K + U$

$$E = mv^2/2 - GM_s m/r = -GM_s m/2a$$

Where  $m$  = mass of the spacecraft and  $r$  = distance from the sun.

The semimajor axis is equal to half of the sum of the apogee and perigee. Thus,

$$a = (d_{\text{Earth}} + d_{\text{Mars}})/2$$

Solving for  $v$ :

$$v = \sqrt{2GM_s(1/r - 1/(d_{\text{Earth}} + d_{\text{Mars}}))}$$

at launch  $r = d_{\text{Earth}}$ . Thus,

$$v_{\text{launch}} = \sqrt{2GM_s(1/d_{\text{Earth}} - 1/(d_{\text{Earth}} + d_{\text{Mars}}))}$$

$$v_{\text{launch}} = \sqrt{2GM_s(d_{\text{Mars}})/((d_{\text{Earth}})(d_{\text{Earth}} + d_{\text{Mars}}))}$$

That is the speed that Goliath must leave the Earth at (relative to the Sun) in order to enter into its trajectory. When the spacecraft is in orbit around Earth it has velocity relative to the Sun that is equal to Earth's velocity to the Sun. The distance of the spacecraft to the sun is  $d_{\text{Earth}}$  and the semimajor axis is also  $d_{\text{Earth}}$  because the Earth has a circular orbit. Thus, the energy of the spacecraft (relative to the Sun) when it is in geocentric orbit is:

$$E = mv^2/2 - GM_s m/d_{\text{Earth}} = -GM_s m/2d_{\text{Earth}}$$

Solve for  $v$ :

$$v_{\text{Earth orbit}} = \sqrt{GM_s/d_{\text{Earth}}}$$

With the launch velocity and the velocity when orbiting earth, we can calculate the change in velocity that is required.

$$\Delta v = v_{\text{launch}} - v_{\text{Earth orbit}}$$

$$\Delta v = \sqrt{2GM_s(d_{\text{Mars}})/((d_{\text{Earth}})(d_{\text{Earth}} + d_{\text{Mars}}))} - \sqrt{GM_s/d_{\text{Earth}}}$$

Substituting in for the real values:

$$\Delta v = 2942.951 \text{ m/s}$$

This is the extra velocity that Goliath's rockets will have to impart on the spacecraft for it to enter the trajectory to Mars.

Next we will calculate the travel time of the spacecraft from Earth to Mars. Kepler's Third Law states that:

$$T^2 = (4\pi^2/GM_s) a^3$$

Where  $T$  = time of one orbit and  $a$  = semimajor axis. Goliath's trajectory goes through  $180^{\circ}$  and therefore we need to find  $T/2$  to find the travel time.

$$t_{\text{travel}} = T/2$$

$$= \sqrt{4\pi^2 a^3/GM_s} / 2$$

$$= \sqrt{\pi^2 a^3/GM_s}$$

$$= \pi \sqrt{((d_{\text{Earth}} + d_{\text{Mars}})/2)^3 / GM_s}$$

Substituting in for the real values:

$$t_{\text{travel}} = 22,366,601 \text{ s or approximately 259 days}$$

With the travel time we can now calculate the angular difference between Earth and Mars at the time of launch. Mars will have to be advanced in relation to Earth because Earth's angular velocity is greater than Mars'. Goliath passes through  $180^\circ$  or  $\pi$  radians. Thus, the angular difference will be equal to  $\pi$  minus the angular displacement of Mars during this time period. Define the following terms:

$a_{\text{Earth}}$  = Earth's angle with respect to the x-axis at the time of launch

$a_{\text{Mars}}$  = Mars' angle with respect to the x-axis at the time of launch

$t_{\text{Mars}}$  = time it takes for Mars to orbit the Sun

The angular displacement of Mars during this time will be its angular velocity multiplied by travel time. The angular velocity is constant since Mars has a circular orbit and equal to  $2\pi/t_{\text{Mars}}$  (since Mars travels  $2\pi$  radians in a time of  $t_{\text{Mars}}$ ). Thus,

$$a_{\text{Earth}} - a_{\text{Mars}} = \pi - (2\pi/t_{\text{Mars}})t_{\text{travel}}$$

From <http://en.wikipedia.org/wiki/Mars>,

$$t_{\text{Mars}} = 59,353,344 \text{ s}$$

Substituting in for real values:

$$a_{\text{Earth}} - a_{\text{Mars}} = .7738 \text{ radians approximately } 44.34^\circ$$

Earth and Mars must have an angular difference of .7738 radians or approximately  $44.34^\circ$  at the time of launch. In order to calculate a launch date with this particular configuration we must first select an initial reference date. On March 27, 1997 Earth and Mars were .0975 radians apart. We can solve for a launch date using the following angular mechanics equation:

$$\theta = \theta_{\text{initial}} + \omega t + \frac{1}{2} \alpha t^2$$

Angular acceleration is zero because Earth and Mars are assumed to have circular orbits with a constant velocity. The initial angle on March 27, 1997,  $a_{\text{initial}}$ , is .0975 radians. Time is the time between March 27, 1997 and the launch date. The theta on the left hand side is the launch angle,  $a_{\text{launch}}$ , .7738 radians. The angular velocity is the difference between the angular velocities of Earth and Mars. Define the following terms as such:

$$t_{\text{Earth}} = \text{one Earth year} = 31,558,464 \text{ s}$$

$$t_{\text{Mars}} = \text{one Martian year} = 59,353,344 \text{ s}$$

$$a_{\text{initial}} = .0975 \text{ radians}$$

$$a_{\text{launch}} = .7738 \text{ radians}$$

The angular velocity of Earth is  $2\pi/t_{\text{Earth}}$  because it is angular displacement divided by time. The angular velocity for Mars

is  $2\pi/t_{\text{Mars}}$ . Now we have the following equation:

$$a_{\text{launch}} = a_{\text{initial}} + ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

$$.7728 \text{ rad} = .0975 \text{ rad} + ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

$$.6763 \text{ rad} = ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

Solving for t would result in the earliest launch date after March 27, 1997. However, constructing the spacecraft will take about fifteen years. As a result we need to modify the equation to the following:

$$.6763 \text{ rad} + 2\pi k = ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

Where k is an integer. Let  $k = 12$ .

Solve for t.

$$t = 815,935,107 \text{ s}$$

This would give a prospective launch date of February 3, 2022. With a travel time of 259 days the prospective landing date would be October 20, 2022. Once the spacecraft reaches Mars, it will use its rockets to put itself into orbit around Mars.

The return trip from Mars to Earth will use a Hohmann transfer orbit. The spacecraft will enter an elliptical orbit around the Sun with an apogee at Mars and a perigee at Earth. Earlier when we calculated the launch speed, we derived the following formula for the velocity of an object in orbit around the Sun:

$$v = \sqrt{2GM_s(1/r - 1/(d_{\text{Earth}} + d_{\text{Mars}}))}$$

When the spacecraft is in orbit around Mars,  $r = d_{\text{Mars}}$ . Thus,

$$v_{\text{return}} = \sqrt{2GM_s(1/d_{\text{Mars}} - 1/(d_{\text{Earth}} + d_{\text{Mars}}))}$$

$$v_{\text{return}} = \sqrt{2GM_s(d_{\text{Earth}})/((d_{\text{Mars}})(d_{\text{Earth}} + d_{\text{Mars}}))}$$

Earlier we used a formula to calculate the spacecraft's velocity (relative to the Sun) when it was in orbit around the Earth. We can modify this formula to find the spacecraft's velocity (relative to the Sun) when it is in orbit around Mars.

$$v_{\text{Mars orbit}} = \sqrt{GM_s/d_{\text{Mars}}}$$

Now we can calculate the change in velocity required:

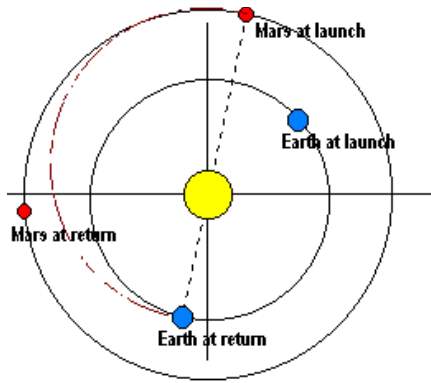
$$\Delta v = v_{\text{return}} - v_{\text{Mars orbit}}$$

$$\Delta v = \sqrt{2GM_s(d_{\text{Earth}})/((d_{\text{Mars}})(d_{\text{Earth}} + d_{\text{Mars}}))} - \sqrt{GM_s/d_{\text{Mars}}}$$

Substituting results in:

$$\Delta v = -2647.45 \text{ m/s}$$

The spacecraft's engines will have to slow down the ship by firing opposite to the direction of Mars' orbit around the Sun.



The return trip is geometrically congruent as the Earth to Mars trip, because it is on the same elliptical orbit. Also, the angle covered is  $180^\circ$  again; thus, the return trip will equal half the period of the elliptical orbit. This is the same as the Earth to Mars trip. As calculated earlier:

$$t_{\text{return}} = 22,366,601 \text{ s or approximately 259 days}$$

Now we can calculate the angular difference needed for the return flight. Mars will need to be advanced in relation to Earth because it has a slower angular velocity than Earth. Define the following terms as follows:

$$\theta_{\text{Mars}} = \text{Mars' angle with respect to the x-axis at the time of launch}$$

$$\theta_{\text{Earth}} = \text{Earth's angle with respect to the x-axis at the time of launch}$$

The spacecraft after launch will have an angular displacement of  $\pi$  radians. Earth will have an angular displacement equal to the product of its angular velocity and the time the spacecraft travels. Earth's angular velocity is equal to  $2\pi$  divided by one Earth year. The following formula will allow us to calculate the angular difference:

$$\theta_{\text{Mars}} - \theta_{\text{Earth}} = (2\pi/t_{\text{Earth}})t_{\text{return}} - \pi$$

$$\theta_{\text{Mars}} - \theta_{\text{Earth}} = 1.3115 \text{ radians or } 75.14^\circ$$

Mars need to be ahead of Earth by this angle. Now we need to determine the launch date for the return trip. We can use the same formula that we used to determine the first launch date except we need to change the launch angle from .7738 radians to 1.3115 radians. March 27, 1997 will be used as a reference date again. The following formula that we derived earlier will be used:

$$a_{\text{launch}} = a_{\text{initial}} + ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

$$1.3115 \text{ rad} = .0975 \text{ rad} + ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

$$1.214 \text{ rad} = ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

Again we need to modify the equation for the time difference between our mission schedule and reference date.

$$1.214 \text{ rad} + 2\pi k = ((2\pi/t_{\text{Earth}}) - (2\pi/t_{\text{Mars}}))t$$

Where  $k$  is an integer. Let  $k = 13$ . Solve for  $t$ .

$$t = 889,092,315 \text{ s}$$

This yields May 30, 2025 as the prospective launch date for the return trip. This means that the astronauts will have about two and half years on Mars. Adding the 259 day travel time yields a prospective landing date on Earth of February 11, 2026. Overall the mission will take about four years.

## Future

Evidently, Goliath is a monstrous ship that will cost billions to construct. There is no way that the US Government has enough money to construct multiple ships of this size and repair them after each mission. So, engineers must deduce a plan to make the ship financially feasible. The only way to do this is to make sure that, after the first mission, Goliath will be cheap to send back to Mars.

Goliath was designed with many alternative goals in mind. Not only will this be the first ship to make the trip to Mars, but it will also be the first ship with the capability to complete many missions with little maintenance. How is this possible? Goliath will be constructed in space so that it can avoid any damage that could be caused during a launch from the Earth's surface. Once it is built, it will never enter the Earth's atmosphere and will never be subjected to any strains that such an environment would possess. After returning from Mars, the ship will remain in orbit. The astronauts will descend in the landing pod while Goliath is controlled by computers on Earth. As a result, Goliath need only be inspected for damage caused by micrometeorites or other collisions during travel to the Red Planet. This inspection will be done in space, as will the repairs of such damage. However, it is the hope of the team that the space elevator will have been constructed by this time. This is the most economically practical solution to the inspection and repair process. If not, astronauts from the ISS (International Space Station) or a separate launch would have to be used to carry out this procedure; therefore, keeping a ship in orbit would not save much money. Solar panels would also come in handy on Goliath to refuel the ship's energy supply as it waits for a new mission. Batteries would have to

be replaced rarely as a result, and this would cater to the financial aspect of future missions as well. Fuel and the Lander will be two of the few things that would need to be transported to Goliath. As said before, the use of the space elevator would assist this process greatly. However, with the technology that we have today, another, smaller mission would have to be launched to bring these things to Goliath. The money saved on repairing Goliath could be spent on the construction of this delivery ship.

The Lander, however, will need to be replaced or restructured after each mission. This craft will undergo the most stress of any part of Goliath because it will be descending to the surfaces of Mars and the Earth. Although replacing or revamping the Lander will be relatively expensive, it is a necessary outlay to insure the safety of the astronauts.

The other way to make future missions less expensive is to leave tools and materials on the surface of the Red Planet after the first trip. This would save money in multiple ways: the tools would not have to be replaced; the ship would be lighter on the return trip, saving fuel; the number of total missions necessary to construct the base would decrease due to extra space left on the ship where the tools used to be.

Goliath is designed so that it will take multiple trips to complete a single mission. For this first trip to Mars, a base will begin being constructed. After the initial structures are completed, more expeditions will be necessary to complete the colony type structure on the surface. Since Goliath can be used many times, it is capable of making many such trips that become cheaper and cheaper each time. The engineering of the ship provides the mission program with a future as bright as the sun.

Not only is the ship qualified for use far into the future, but the discoveries that are made on Mars will greatly benefit human civilization on Earth. Through the base project, it is possible that an entire colony can be constructed on the surface of Mars. In this way, if anything were to happen on Earth that would cause a mass loss of life, there would be a place for the human race to escape extinction. Also, many scientific experiments will be carried out on the surface of Mars. We will learn how to grow plants and terraform the environment of the Red Planet to look more like Earth. Hopefully, after this is accomplished, the first set of missions will open the door to more advanced programs. Mars will slowly become more Earthlike, and travel to the planet will become ever cheaper. Having another

planet on which to live will provide solutions to many of the major problems that overcrowding causes on Earth. If other sources of fuel are found on Mars' surface, these could be used to help solve energy crises throughout the world. By the end of the century, people may be able to live on the Red Planet and be mainly supported by its resources.

## Conclusion

It is obvious how much work would have to go into designing and planning a mission to the Red Planet, let alone the construction of the materials and the enactment of such a proposal. It will take an enormous amount of man power to thoroughly solve every problem that the astronauts could encounter on their journey. Evidently, the basic mission plan could take years to complete as there are thousands of things that the team has to take into account. From the size and shape of every piece of the new rocket to the practicality of the cost of construction, any organization that takes on this task will definitely have their share of difficulties.

Not only is getting astronauts to the Martian surface a daunting task in itself, but maintaining their health on the four-year journey is another thing that needs to be taken into consideration. The astronauts' health will greatly deteriorate while they are in space. If they are not cared for, they will be carried off the ship in wheelchairs when they return home.

Once the ship reaches the Martian surface, exploration needs to supplement various scientific experiments that could benefit us on Earth. This will require another team of men to design a plan for these experiments and predict what their results are going to show.

However, although the aforementioned are extremely difficult tasks, the design and construction of a ship and base this size is an absolutely enormous assignment. With a ship the size of Goliath, the amount of work that would go into the design process is an incomprehensible amount. As a team, we barely touched the tip of the iceberg in the design of the ship. Just the basic design of the ship, the lander, the Mars Base, and the rover took the team over twenty hours. These designs would need to be further refined and modeled until engineers believe they are perfect. Before actually reaching the final design, it could take years of changing and switching things around. It is unbelievable

that any single group of people could complete this mission without any outside help.

Millions would have to collaborate from around the globe to make this mission possible. Not only does the mission plan require that other countries assist Goliath once it is in space, but the manufacturing abilities of places outside the United States would need to be utilized to reduce the costs of this project. The amount of work we put into this project is immeasurable. It is amazing how far we've come in our understanding of this trip to Mars. It is even more amazing how far we have to go.

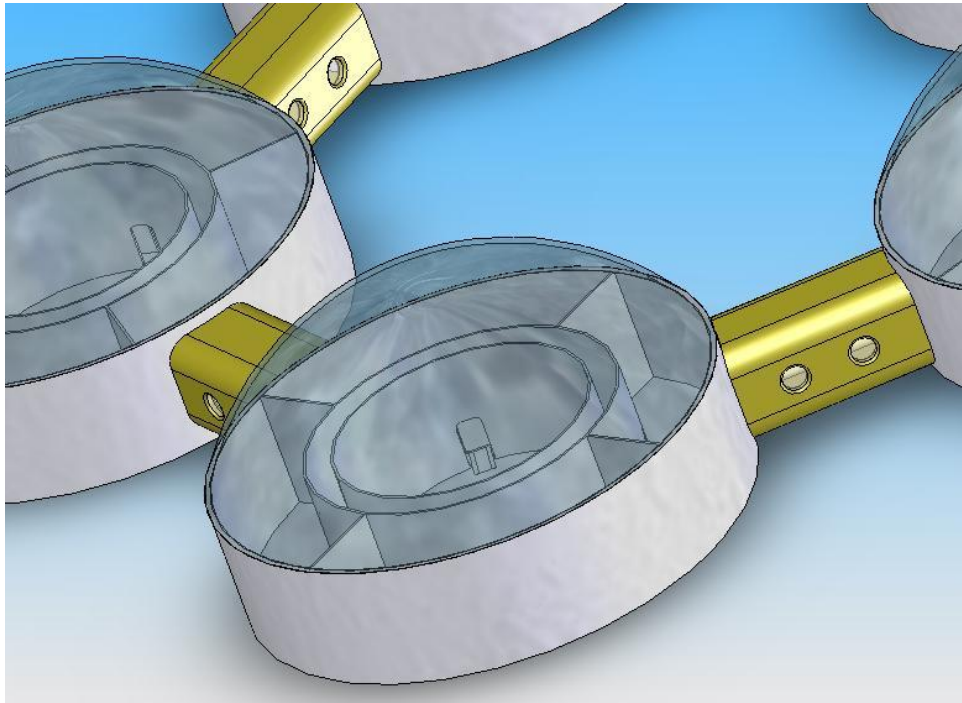
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Working on this project took a considerable amount of time and effort. Our group would not have been able to achieve the success it has had if not been for a few key people. First, we would like to thank Anthony Welch and Governor's School. Anthony did an excellent job organizing a fun and fulfilling program, and without him we would have never been here to be afforded an opportunity like this. We would also like to thank our project advisor, Justin Meiswinkle. The aid he gave with respect

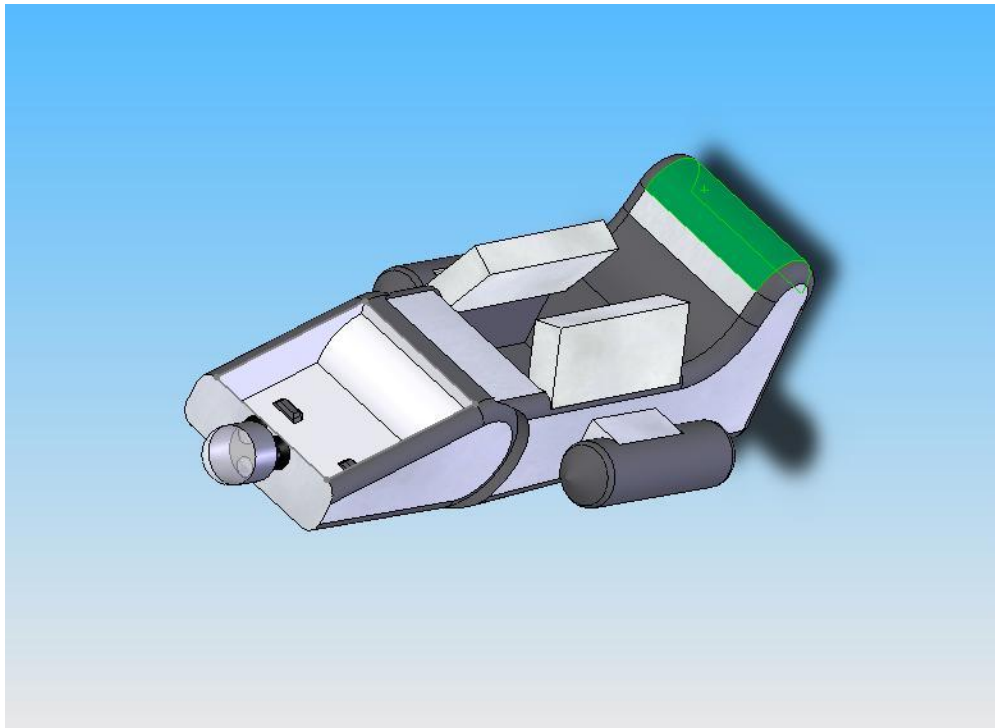
to using SolidWorks, calculating everything we would need, and his general support helped bring this project together from start to finish. Finally, we would like to thank our counselor advisor Sean Borkowski. His guidance kept us on track and insured the project was completed on time.

One last time, we would like to thank everyone mentioned for all their hard work. It has been greatly appreciated.

Appendix A:  
Solidworks rendering of the base



Solidworks rendering of the ship



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