# http://i.telegraph.co.uk/multimedia/archive/02445/mars_2445397b.jpgColonization of Mars

# Why is Mars our best choice?

Mars is the focus of much speculation and scientific study about possible human colonization. Its surface conditions and the presence of water on Mars make it arguably the most hospitable of the planets in the Solar System, other than Earth. Mars requires less energy per unit mass (delta-v) to reach from Earth than any planet except Venus. However, at minimum energy use, a trip to Mars requires 6–7 months in space using current chemical spacecraft propulsion methods.

Earth is similar to its “sister planet” Venus in bulk composition, size and surface gravity, but Mars’s similarities to Earth are more compelling when considering colonization. These include: The Martian day (or sol) is very close in duration to Earth’s. A solar day on Mars is 24 hours, 39 minutes and 35.244 seconds. Mars has a surface area that is 28.4% of Earth’s, only slightly less than the amount of dry land on Earth (which is 29.2% of Earth’s surface). Mars has half the radius of Earth and only one-tenth the mass. This means that it has a smaller volume (~15%) and lower average density than Earth. Mars has an axial tilt of 25.19°, similar to Earth’s 23.44°. As a result, Mars has seasons much like Earth, though they last nearly twice as long because the Martian year is about 1.88 Earth years. The Martian North Pole currently points at Cygnus, not Ursa Minor like Earth’s. Recent observations by NASA’s Mars Reconnaissance Orbiter, ESA’s Mars Express and NASA’s Phoenix Lander confirm the presence of water ice on Mars.

* Atmospheric pressure comparison
* Mars average 0.6 kilopascals (0.087 psi)
* Mount Everest summit 33.7 kilopascals (4.89 psi)
* Earth sea level 101.3 kilopascals (14.69 psi)



# How Mars differs from Earth.

Although there are some extremophile organisms that survive in hostile conditions on Earth, including simulations that approximate Mars, plants and animals generally cannot survive the ambient conditions present on the surface of Mars. The surface gravity of Mars is 38% that of Earth. Mars is much colder than Earth, with a mean surface temperature between 186 and 268 K (−87 °C, −124.6 °F and −5 °C, 23 °F). The lowest temperature ever recorded on Earth was 180 K (−93.2 °C, −135.76 °F) in Antarctica. Surface water on Mars may occur transiently, but only under certain conditions. Because Mars is approximately 52% farther from the Sun, the amount of solar energy entering its upper atmosphere per unit area (the solar constant) is only around 43.3% of what reaches the Earth’s upper atmosphere. However, due to the much thinner atmosphere, a higher fraction of the solar energy reaches the surface. The maximum solar irradiance on Mars is about 590 W/m² compared to about 1000 W/m² at the Earth’s surface. Also, year-round dust storms on Mars may block sunlight for weeks at a time. Mars’s orbit is more eccentric than Earth’s, increasing temperature and solar constant variations. Due to the lack of a magnetosphere, solar particle events and cosmic rays can easily reach the Martian surface. The atmospheric pressure on Mars is far below the Armstrong limit at which people can survive without pressure suits. Habitable structures on Mars would need to be constructed with pressure vessels similar to spacecraft, capable of containing a pressure between 30 and 100 kPa. The Martian atmosphere is 95% carbon dioxide, 3% nitrogen, 1.6% argon, and traces of other gases including oxygen totaling less than 0.4%. Martian air has a partial pressure of CO2 of 0.71 kPa, compared to 0.031 kPa on Earth. CO2 poisoning (hypercapnia) in humans begins at about 0.10 kPa. Even for plants, CO2 much above 0.15 kPa is toxic. This means Martian air is toxic to both plants and animals even at the reduced total pressure. The thin atmosphere does not filter out ultraviolet sunlight.

Conditions for human habitation on Mars. Conditions on the surface of Mars are closer to the conditions on Earth in terms of temperature, atmospheric pressure than on any other planet or moon, except for the cloud tops of Venus. However, the surface is not hospitable to humans or most known life forms due to greatly reduced air pressure, and an atmosphere with only 0.1% oxygen. In 2012, it was reported that some lichen and cyanobacteria survived and showed remarkable adaptation capacity for photosynthesis after 34 days in simulated Martian conditions in the Mars Simulation Laboratory (MSL) maintained by the German Aerospace Center (DLR). Some scientists think that cyanobacteria could play a role in the development of self-sustainable manned outposts on Mars. They propose that cyanobacteria could be used directly for various applications, including the production of food, fuel and oxygen, but also indirectly: products from their culture could support the growth of other organisms, opening the way to a wide range of life-support biological processes based on Martian resources. Humans have explored parts of Earth that match some conditions on Mars. Based on NASA rover data, temperatures on Mars (at low latitudes) are similar to those in Antarctica. The atmospheric pressure at the highest altitudes reached by manned balloon ascents (35 km (114,000 feet) in 1961, 38 km in 2012) is similar to that on the surface of Mars. Human survival on Mars would require complex life-support measures and living in artificial environments. There is much discussion regarding the possibility of terraforming (the hypothetical process by which Mars’s climate and surface would be deliberately changed to make large areas of the environment hospitable) to allow a wide variety of life forms, including humans, to survive unaided on Mars’s surface, including the technologies needed to do so.

# Radiation

Mars has no global magnetic field comparable to Earth’s geomagnetic field. Combined with a thin atmosphere, this permits a significant amount of ionizing radiation to reach the Martian surface. The Mars Odyssey spacecraft carries an instrument, the Mars Radiation Environment Experiment (MARIE), to measure the dangers to humans. MARIE found that radiation levels in orbit above Mars are 2.5 times higher than at the International Space Station. Average doses were about 22 millirads per day (220 micrograys per day or 0.08 grays per year.) A three-year exposure to such levels would be close to the safety limits currently adopted by NASA. Levels at the Martian surface would be somewhat lower and might vary significantly at different locations depending on altitude and local magnetic fields. Building living quarters underground (possibly in lava tubes that are already present) would significantly lower the colonists’ exposure to radiation. Occasional solar proton events (SPEs) produce much higher doses. Much remains to be learned about space radiation. In 2003, NASA’s Lyndon B. Johnson Space Center opened a facility, the NASA Space Radiation Laboratory, at Brookhaven National Laboratory, that employs particle accelerators to simulate space radiation. The facility studies its effects on living organisms along with shielding techniques. Initially, there was some evidence that this kind of low level, chronic radiation is not quite as dangerous as once thought; and that radiation hormesis occurs. However, results from a 2006 study indicated that protons from cosmic radiation may cause twice as much serious damage to DNA as previously expected, exposing astronauts to greater risk of cancer and other diseases. As a result of the higher radiation in the Martian environment, the summary report of the Review of U.S. Human Space Flight Plans Committee released in 2009 reported that “Mars is not an easy place to visit with existing technology and without a substantial investment of resources.” NASA is exploring a variety of alternative techniques and technologies such as deflector shields of plasma to protect astronauts and spacecraft from radiation.

# Are there potential risks?

Mars requires less energy per unit mass (delta V) to reach from Earth than any planet except Venus. Using a Hohmann transfer orbit, a trip to Mars requires approximately nine months in space. Modified transfer trajectories that cut the travel time down to seven or six months in space are possible with incrementally higher amounts of energy and fuel compared to a Hohmann transfer orbit, and are in standard use for robotic Mars missions. Shortening the travel time below about six months requires higher delta-v and an exponentially increasing amount of fuel, and is not feasible with chemical rockets, but might be feasible with advanced spacecraft propulsion technologies, some of which have already been tested, such as Variable Specific Impulse Magnetoplasma Rocket, and nuclear rockets. In the former case, a trip time of forty days could be attainable, and in the latter, a trip time down to about two weeks. In 2016, NASA scientists said they could further reduce travel time to Mars down to “as little as 72 hours” with the use of a “photonic propulsion” system instead of the fuel-based rocket propulsion system. During the journey the astronauts are subject to radiation, which requires a means to protect them. Cosmic radiation and solar wind cause DNA damage, which increases the risk of cancer significantly. The effect of long term travel in interplanetary space is unknown, but scientists estimate an added risk of between 1% and 19%, for people to die of cancer because of the radiation during the journey to Mars and back to Earth.

# How were going to land on Mars?

Mars has a gravity 0.38 times that of Earth and the density of its atmosphere is about 0.6% of that on Earth. The relatively strong gravity and the presence of aerodynamic effects makes it difficult to land heavy, crewed spacecraft with thrusters only, as was done with the Apollo Moon landings, yet the atmosphere is too thin for aerodynamic effects to be of much help in aerobraking and landing a large vehicle. Landing piloted missions on Mars will require braking and landing systems different from anything used to land crewed spacecraft on the Moon or robotic missions on Mars. If one assumes carbon nanotube construction material will be available with a strength of 130 GPa then a space elevator could be built to land people and material on Mars. A space elevator on Phobos has also been proposed.

# What is needed to make this happen?

Colonization of Mars will require a wide variety of equipment—both equipment to directly provide services to humans and production equipment used to produce food, propellant, water, energy and breathable oxygen—in order to support human colonization efforts. Required equipment will include Habitats Storage facilities, Shop workspaces, Resource extraction equipment—initially for water and oxygen, later for a wider cross section of minerals, building materials, etc., Energy production and storage equipment, some solar and perhaps other forms as well, Food production spaces and equipment. Propellant production equipment, generally thought to be hydrogen and methane through the Sabatier reaction for fuel—with oxygen oxidizer—for chemical rocket engines, Fuels or other energy source for use with surface transportation. Carbon monoxide/oxygen (CO/O2) engines have been suggested for early surface transportation use as both carbon monoxide and oxygen can be straightforwardly produced by zirconium dioxide electrolysis from the Martian atmosphere without requiring use of any of the Martian water resources to obtain hydrogen.

# How will we communicate with Mars?

Communications with Earth are relatively straightforward during the half-sol when Earth is above the Martian horizon. NASA and ESA included communications relay equipment in several of the Mars orbiters, so Mars already has communications satellites. While these will eventually wear out, additional orbiters with communication relay capability are likely to be launched before any colonization expeditions are mounted. The one-way communication delay due to the speed of light ranges from about 3 minutes at closest approach (approximated by perihelion of Mars minus aphelion of Earth) to 22 minutes at the largest possible superior conjunction (approximated by aphelion of Mars plus aphelion of Earth). Real-time communication, such as telephone conversations or Internet Relay Chat, between Earth and Mars would be highly impractical due to the long time lags involved. NASA has found that direct communication can be blocked for about two weeks every synodic period, around the time of superior conjunction when the Sun is directly between Mars and Earth, although the actual duration of the communications blackout varies from mission to mission depending on various factors—such as the amount of link margin designed into the communications system, and the minimum data rate that is acceptable from a mission standpoint. In reality most missions at Mars have had communications blackout periods of the order of a month. A satellite at the L4 or L5 Earth–Sun Lagrangian point could serve as a relay during this period to solve the problem; even a constellation of communications satellites would be a minor expense in the context of a full colonization program. However, the size and power of the equipment needed for these distances make the L4 and L5 locations unrealistic for relay stations, and the inherent stability of these regions, although beneficial in terms of station-keeping, also attracts dust and asteroids, which could pose a risk. Despite that concern, the STEREO probes passed through the L4 and L5 regions without damage in late 2009. Recent work by the University of Strathclyde’s Advanced Space Concepts Laboratory, in collaboration with the European Space Agency, has suggested an alternative relay architecture based on highly non-Keplerian orbits. These are a special kind of orbit produced when continuous low-thrust propulsion, such as that produced from an ion engine or solar sail, modifies the natural trajectory of a spacecraft. Such an orbit would enable continuous communications during solar conjunction by allowing a relay spacecraft to “hover” above Mars, out of the orbital plane of the two planets. Such a relay avoids the problems of satellites stationed at either L4 or L5 by being significantly closer to the surface of Mars while still maintaining continuous communication between the two planets.

# Transportation for trade

The path to a human colony could be prepared by robotic systems such as the Mars Exploration Rovers Spirit, Opportunity and Curiosity. These systems could help locate resources, such as ground water or ice that would help a colony grow and thrive. The lifetimes of these systems would be measured in years and even decades, and as recent developments in commercial spaceflight have shown, it may be that these systems will involve private as well as government ownership. These robotic systems also have a reduced cost compared with early crewed operations, and have less political risk. Wired systems might lay the groundwork for early crewed landings and bases, by producing various consumables including fuel, oxidizers, water, and construction materials. Establishing power, communications, shelter, heating, and manufacturing basics can begin with robotic systems, if only as a prelude to crewed operations. Mars Surveyor 2001 Lander MIP (Mars ISPP Precursor) was to demonstrate manufacture of oxygen from the atmosphere of Mars, and test solar cell technologies and methods of mitigating the effect of Martian dust on the power systems. Before any people are transported to Mars on the notional 2030s Mars Colonial Transporter envisioned by SpaceX, a number of robotic cargo missions would be undertaken first in order to transport the requisite equipment, habitats and supplies. Equipment that would be necessary would include machines to produce fertilizer, methane and oxygen from Mars’ atmospheric nitrogen and carbon dioxide and the planet’s subsurface water ice as well as construction materials to build transparent domes for initial agricultural areas.

# Beginning attempts for Mars

In 1948, Wernher von Braun described in his book The Mars Project that a fleet of 10 spaceships could be built using 1000 three-stage rockets. These could bring a population of 70 people to Mars. All of the early human missions to Mars as conceived by national governmental space programs—such as those being tentatively planned by NASA, FKA and ESA—would not be direct precursors to colonization. They are intended solely as exploration missions, as the Apollo missions to the Moon were not planned to be sites of a permanent base. Colonization requires the establishment of permanent bases that have potential for self-expansion. A famous proposal for building such bases is the Mars Direct and the Semi-Direct plans, advocated by Robert Zubrin. Other proposals that envision the creation of a settlement have come from Jim McLane and Bas Lansdorp (the man behind Mars One, which envisions no planned return flight for the humans embarking on the journey), as well as from Elon Musk whose SpaceX company, as of 2015, is funding development work on a space transportation system called the Mars Colonial Transporter. The Mars Society has established the Mars Analogue Research Station Program at sites Devon Island in Canada and in Utah, United States, to experiment with different plans for human operations on Mars, based on Mars Direct. Modern Martian architecture concepts often include facilities to produce oxygen and propellant on the surface of the planet.

# Thinking ahead

As with early colonies in the New World, economics would be a crucial aspect to a colony’s success. The reduced gravity well of Mars and its position in the Solar System may facilitate Mars–Earth trade and may provide an economic rationale for continued settlement of the planet. Given its size and resources, this might eventually be a place to grow food and produce equipment to mine the asteroid belt. A major economic problem is the enormous up-front investment required to establish the colony and perhaps also terraform the planet. Some early Mars colonies might specialize in developing local resources for Martian consumption, such as water and/or ice. Local resources can also be used in infrastructure construction. One source of Martian ore currently known to be available is metallic iron in the form of nickel–iron meteorites. Iron in this form is more easily extracted than from the iron oxides that cover the planet. Another main inter-Martian trade good during early colonization could be manure. Assuming that life doesn’t exist on Mars, the soil is going to be very poor for growing plants, so manure and other fertilizers will be valued highly in any Martian civilization until the planet changes enough chemically to support growing vegetation on its own. Solar power is a candidate for power for a Martian colony. Solar insolation (the amount of solar radiation that reaches Mars) is about 42% of that on Earth, since Mars is about 52% farther from the Sun and insolation falls off as the square of distance. But the thin atmosphere would allow almost all of that energy to reach the surface as compared to Earth, where the atmosphere absorbs roughly a quarter of the solar radiation. Sunlight on the surface of Mars would be much like a moderately cloudy day on Earth. Nuclear power is also a good candidate, since the fuel is very energy-dense for cheap transportation from Earth. Nuclear power also produces heat, which would be extremely valuable to a Mars colony. Mars’s reduced gravity together with its rotation rate makes possible the construction of a space elevator with today’s materials, although the low orbit of Phobos could present engineering challenges. If constructed, the elevator could transport minerals and other natural resources extracted from the planet. Space colonization on Mars can roughly be said to be possible when the necessary methods of space colonization become cheap enough (such as space access by cheaper launch systems) to meet the cumulative funds that have been gathered for the purpose. Although there are no immediate prospects for the large amounts of money required for any space colonization to be available given traditional launch costs, there is some prospect of a radical reduction to launch costs in the 2010s, which would consequently lessen the cost of any efforts in that direction. With a published price of US$56.5 million per launch of up to 13,150 kg (28,990 lb) payload to low Earth orbit, SpaceX Falcon 9 rockets are already the cheapest in the industry. Advancements currently being developed as part of the SpaceX reusable launch system development program to enable reusable Falcon 9s could drop the price by an order of magnitude, sparking more space-based enterprise, which in turn would drop the cost of access to space still further through economies of scale. SpaceX’ reusable plans include Falcon Heavy and future methane-based launch vehicles including the Mars Colonial Transporter. If SpaceX is successful in developing the reusable technology, it would be expected to have a major impact on the cost of access to space, and change the increasingly competitive market in space launch services. Alternative funding approaches might include the creation of inducement prizes. For example, the 2004 President’s Commission on Implementation of United States Space Exploration Policy suggested that an inducement prize contest should be established, perhaps by government, for the achievement of space colonization. One example provided was offering a prize to the first organization to place humans on the Moon and sustain them for a fixed period before they return to Earth.



# The poles of Mars

Mars’s north and south poles once attracted great interest as settlement sites because seasonally-varying polar ice caps have long been observed by telescopes from Earth. Mars Odyssey found the largest concentration of water near the North Pole, but also showed that water likely exists in lower latitudes as well, making the poles less compelling as a settlement locale. Like Earth, Mars sees a midnight sun at the poles during local summer and polar night during winter. Mars Odyssey found what appear to be natural caves near the volcano Arsia Mons. It has been speculated that settlers could benefit from the shelter that these or similar structures could provide from radiation and micrometeoroids. Geothermal energy is also suspected in the equatorial regions. The exploration of Mars’s surface is still underway. Landers and rovers such as Phoenix, the Mars Exploration Rovers Spirit and Opportunity, and the Mars Science Laboratory Curiosity have encountered very different soil and rock characteristics. This suggests that the Martian landscape is quite varied and the ideal location for a settlement would be better determined when more data becomes available. As on Earth, seasonal variations in climate become greater with distance from the equator. Valles Marineris, the Grand Canyon of Mars, is over 3,000 km long and averages 8 km deep. Atmospheric pressure at the bottom would be some 25% higher than the surface average, 0.9 kPa vs 0.7 kPa. River channels lead to the canyon, indicating it was once flooded. Several lava tube skylights on Mars have been located on the flanks of Arsia Mons. Earth based examples indicate that some should have lengthy passages offering complete protection from radiation and be relatively easy to seal using on-site materials, especially in small subsections.

Robotic spacecraft to Mars are required to be sterilized, to have at most 300,000 spores on the exterior of the craft—and more thoroughly sterilized if they contact “special regions” containing water, otherwise there is a risk of contaminating not only the life-detection experiments but possibly the planet itself. It is impossible to sterilize human missions to this level, as humans are host to typically a hundred trillion microorganisms of thousands of species of the human microbiome, and these cannot be removed while preserving the life of the human. Containment seems the only option, but it is a major challenge in the event of a hard landing. There have been several planetary workshops on this issue, but with no final guidelines for a way forward yet. Human explorers would also be vulnerable to back contamination to Earth if they become carriers of microorganisms.

# Conclusion

Mars colonization is advocated by several non-governmental groups for a range of reasons and with varied proposals. One of the oldest groups is the Mars Society who promote a NASA program to accomplish human exploration of Mars and have set up Mars analog research stations in Canada and the United States. Mars to Stay advocates recycling emergency return vehicles into permanent settlements as soon as initial explorers determine permanent habitation is possible. Mars One, which went public in June 2012, aims to establish a fully operational permanent human colony on Mars by 2023 with funding coming from a reality TV show and other commercial exploitation, although this approach has been widely criticized as unrealistic and infeasible. Elon Musk founded SpaceX with the long-term goal of developing the technologies that will enable a self-sustaining human colony on Mars. In 2015 he stated “I think we’ve got a decent shot of sending a person to Mars in 11 or 12 years”. Richard Branson, in his lifetime, is “determined to be a part of starting a population on Mars. I think it is absolutely realistic. It will happen… I think over the next 20 years, we will take literally hundreds of thousands of people to space and that will give us the financial resources to do even bigger things”. In June 2013, Buzz Aldrin, American engineer and former astronaut, and the second person to walk on the Moon, wrote an opinion, published in The New York Times, supporting a manned mission to Mars and viewing the Moon “not as a destination but more a point of departure, one that places humankind on a trajectory to homestead Mars and become a two-planet species.” In August 2015, Aldrin, in association with the Florida Institute of Technology, presented a “master plan”, for NASA consideration, for astronauts, with a “tour of duty of ten years”, to colonize Mars before the year 2040.



Elon Musk Founder of Tesla Motors & SpaceX