

Colonization of Mars

The hypothetical **colonization of Mars** has received interest from public space agencies and private corporations, and has received extensive treatment in science fiction writing, film, and art.

Organizations have proposed plans for a human mission to Mars, the first step towards any colonization effort, but no person has set foot on the planet. However, landers and rovers have successfully explored the planetary surface and delivered information about conditions on the ground. Virtual visits to Mars, using haptic technologies, have been proposed, and may precede humans visiting the planet.^[2]

Reasons for colonizing Mars include curiosity, the potential for humans to provide more in-depth observational research than unmanned rovers, economic interest in its resources, and the possibility that the settlement of other planets could decrease the likelihood of human extinction. Difficulties and hazards include radiation exposure during a trip to Mars and on its surface, toxic soil, low gravity, the isolation that accompanies Mars' distance from Earth, a lack of water, and cold temperatures.

The most recent commitments to researching permanent settlement include those by public space agencies—NASA, ESA, Roscosmos, ISRO and the CNSA—and private organizations—SpaceX, Lockheed Martin, and Boeing.

Contents

Mission concepts and timelines

Relative similarity to Earth

Differences between Earth and Mars

Gravity and magnetosphere

The atmosphere

Water and climate

Soil

Survivability

Conditions for human habitation

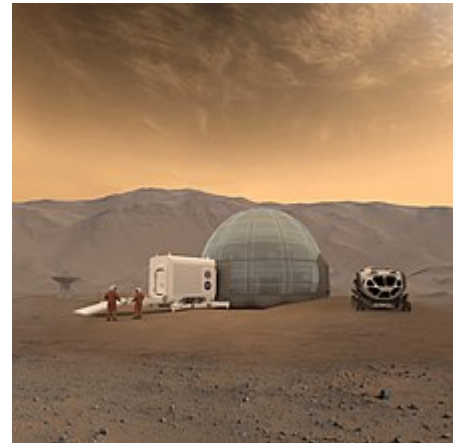
Effects on human health

Physical effects

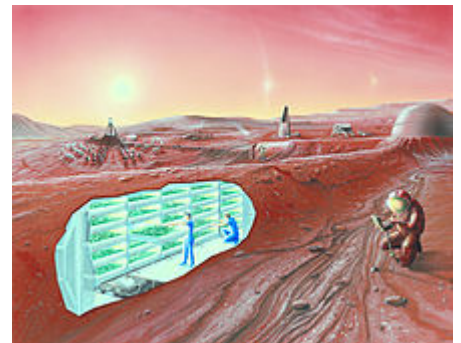
Radiation

Psychological effects

Terraforming



An artist's conception of a human Mars habitat, with a 3D-printed dome made of water ice, an air lock, and a pressurized Mars rover^[1]



An artist's conception of a human Mars base, with a cutaway revealing an interior horticultural area

Transportation[Interplanetary spaceflight](#)[Landing on Mars](#)**Equipment needed for colonization**[Basic utilities](#)[Communication with Earth](#)**Robotic precursors****Economics**[Economic drivers](#)**Possible locations for settlements**[Equatorial regions](#)[Lava tubes](#)[Hellas Planitia](#)**Planetary protection****Ethical, political and legal challenges**[Colonialism](#)[Dangers to pregnancy](#)**Advocacy****In fiction****Interactive Mars map****See also****References****Further reading****External links**

Mission concepts and timelines

Since the 20th century, there have been several proposed [human missions to Mars](#) both by government agencies and private companies.

All of the human mission concepts as currently conceived by national governmental space programs would not be direct precursors to colonization. Programs such as those being tentatively planned by NASA, [Roscosmos](#), and [ESA](#) are intended solely as exploration missions, with the establishment of a permanent base possible but not yet the main goal.

Colonization requires the establishment of permanent habitats that have the potential for self-expansion and self-sustenance. Two early proposals for building habitats on Mars are the [Mars Direct](#) and the [Semi-Direct](#) concepts, advocated by [Robert Zubrin](#), an advocate of the colonization of Mars.^[3]



Artist's rendition of various components of a human Mars surface mission

5/7/2021

Colonization of Mars - Wikipedia

SpaceX has proposed the development of Mars transportation infrastructure in order to facilitate the eventual colonization of Mars. The mission architecture includes fully reusable launch vehicles, human-rated spacecraft, on-orbit propellant tankers, rapid-turnaround launch/landing mounts, and local production of rocket fuel on Mars via in situ resource utilization (ISRU). SpaceX's aspirational goal is to land their cargo starships on Mars by 2024 and the first 2 crewed starships by 2026.^{[4][5]}

Relative similarity to Earth

Earth is similar to Venus in bulk composition, size and surface gravity, but Mars' 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.^[6]
- Mars has a surface area that is 28.4% of Earth's, which is 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 on average they last nearly twice as long because the Martian year is about 1.88 Earth years.
- Observations by NASA's Mars Reconnaissance Orbiter, ESA's Mars Express and NASA's Phoenix Lander confirm the presence of water ice on Mars.

Differences between Earth and Mars

Gravity and magnetosphere

The surface gravity of Mars is just 38% that of Earth. Although microgravity is known to cause health problems such as muscle loss and bone demineralization,^{[8][9]} it is not known if Martian gravity would have a similar effect. The Mars Gravity Biosatellite was a proposed project designed to learn more about what effect Mars' lower surface gravity would have on humans, but it was cancelled due to a lack of funding.^[10]

Atmospheric pressure comparison

Location	Pressure
Olympus Mons summit	0.03 kPa (0.0044 psi)
Mars average	0.6 kPa (0.087 psi)
Hellas Planitia bottom	1.16 kPa (0.168 psi)
Armstrong limit	6.25 kPa (0.906 psi)
Mount Everest summit ^[7]	33.7 kPa (4.89 psi)
Earth sea level	101.3 kPa (14.69 psi)

Due to the lack of a magnetosphere, solar particle events and cosmic rays can easily reach the Martian surface.^{[11][12][13]}

The atmosphere

Atmospheric pressure on Mars is far below the Armstrong limit at which people can survive without pressure suits. Since terraforming cannot be expected as a near-term solution, 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 atmosphere is also toxic as most of it consists of carbon dioxide (95% carbon dioxide, 3% nitrogen, 1.6% argon, and traces totaling less than 0.4% of other gases including oxygen).

This thin atmosphere does not filter out ultraviolet sunlight, which causes instability in the molecular bonds between atoms. For example, ammonia (NH₃) is not stable in the Martian atmosphere and breaks down after a few hours.^[14] Also due to the thinness of the atmosphere, the temperature difference between day and night is much larger than on Earth, typically around 70 °C (125 °F).^[15] However, the day/night temperature variation is much lower during dust storms when very little light gets through to the surface even during the day, and instead warms the middle atmosphere.^[16]

Water and climate

Water on Mars is scarce, with rovers *Spirit* and *Opportunity* finding less than there is in Earth's driest desert.^{[17][18][19]}

The climate is much colder than Earth, with mean surface temperatures between 186 and 268 K (−87 and −5 °C; −125 and 23 °F) (depending on the season and latitude).^{[20][21]} The lowest temperature ever recorded on Earth was 184 K (−89.2 °C, −128.6 °F) in Antarctica.

Because Mars is about 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.^[22] However, due to the much thinner atmosphere, a higher fraction of the solar energy reaches the surface.^{[23][24]} The maximum solar irradiance on Mars is about 590 W/m² compared to about 1000 W/m² at the Earth's surface; optimal conditions on the Martian equator can be compared to those on Devon Island in the Canadian Arctic in June.^[25]

Global dust storms are common throughout the year and can cover the entire planet for weeks, blocking sunlight from reaching the surface.^{[26][27]} This has been observed to cause temperature drops of 4 °C (7 °F) for several months after the storm.^[28] In contrast, the only comparable events on Earth are infrequent large volcanic eruptions such as Krakatoa which threw large amounts of ash into the atmosphere in 1883, causing a global temperature drop of around 1 °C (2 °F). Perhaps more importantly, these storms affect electricity production from solar panels for long periods, as well interfering with communications with Earth.^[16]

Mars has no rain and virtually no clouds, so although cold, it is permanently sunny (apart from during dust storms). This means solar panels can always operate at maximum efficiency on dust-free days. And Mars' orbit is more eccentric than Earth's, increasing temperature and solar constant variations over the course of the Martian year.

Soil

The Martian soil is toxic due to relatively high concentrations of chlorine and associated compounds which are hazardous to all known forms of life.^{[29][30]}

Survivability

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.^[31]

Conditions for human habitation

Conditions on the surface of Mars are closer to the conditions on Earth in terms of temperature and sunlight than on any other planet or moon, except for the cloud tops of Venus.^[32] However, the surface is not hospitable to humans or most known life forms due to the radiation, greatly reduced air pressure, and an atmosphere with only 0.16% oxygen.

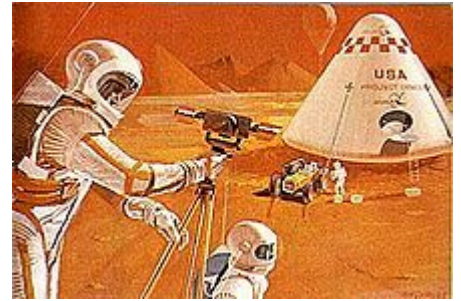
In 2012, it was reported that some lichen and cyanobacteria survived and showed remarkable adaptation capacity for photosynthesis after 34 days in simulated Martian conditions in the Mars Simulation Laboratory (MSL) maintained by the German Aerospace Center (DLR).^{[33][34][35]} Some scientists think that cyanobacteria could play a role in the development of self-sustainable crewed outposts on Mars.^[36] 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.^[36]

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.^[37] The atmospheric pressure at the highest altitudes reached by piloted balloon ascents (35 km (114,000 feet) in 1961,^[38] 38 km in 2012) is similar to that on the surface of Mars. However, the pilots were not exposed to the extremely low pressure, as it would have killed them, but seated in a pressurized capsule.^[39]

Human survival on Mars would require living in artificial Mars habitats with complex life-support systems. One key aspect of this would be water processing systems. Being made mainly of water, a human being would die in a matter of days without it. Even a 5–8% decrease in total body water causes fatigue and dizziness and a 10% decrease physical and mental impairment (See Dehydration). A person in the UK uses 70–140 litres of water per day on average.^[40] Through experience and training, astronauts on the ISS have shown it is possible to use far less, and that around 70% of what is used can be recycled using the ISS water recovery systems. Half of all water is used during showers.^[41] Similar systems would be needed on Mars, but would need to be much more efficient, since regular robotic deliveries of water to Mars would be prohibitively expensive (the ISS is supplied with water four times per year). Potential access to in-situ water (frozen or otherwise) via drilling has been investigated by NASA.^[42]

Effects on human health

Mars presents a hostile environment for human habitation. Different technologies have been developed to assist long-term space exploration and may be adapted for habitation on Mars. The existing record for the longest consecutive space flight is 438 days by cosmonaut Valeri Polyakov,^[43] and the most accrued time in space is 878 days by Gennady Padalka.^[44] The longest time spent outside the protection of the Earth's Van Allen radiation belt is about 12 days for the Apollo 17 moon landing. This is minor in comparison to the 1100-day journey^[45] planned by NASA as soon as the year 2028. Scientists have also hypothesized that many different biological functions can be negatively affected by the environment of



An expedition-style crewed mission would operate on the surface, but for limited amounts of time



Dust is one concern for Mars missions

Mars colonies. Due to higher levels of radiation, there are a multitude of physical side-effects that must be mitigated.^[46] In addition, Martian soil contains high levels of toxins which are hazardous to human health.

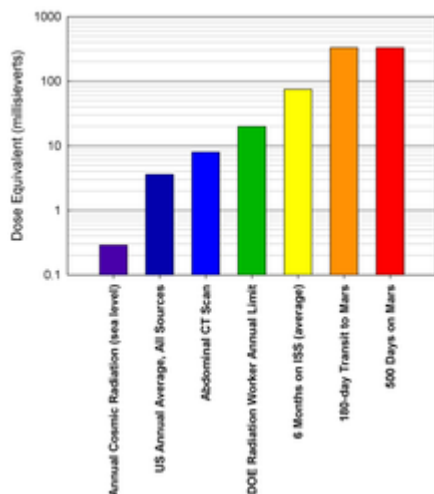
Physical effects

The difference in gravity would negatively affect human health by weakening bones and muscles. There is also risk of osteoporosis and cardiovascular problems. Current rotations on the International Space Station put astronauts in zero gravity for six months, a comparable length of time to a one-way trip to Mars. This gives researchers the ability to better understand the physical state that astronauts going to Mars would arrive in. Once on Mars, surface gravity is only 38% of that on Earth. Microgravity affects the cardiovascular, musculoskeletal and neurovestibular (central nervous) systems. The cardiovascular effects are complex. On earth, blood within the body stays 70% below the heart, and in microgravity this is not case due to nothing pulling the blood down. This can have several negative effects. Once entering into microgravity, the blood pressure in the lower body and legs is significantly reduced.^[47] This causes legs to become weak through loss of muscle and bone mass. Astronauts show signs of a puffy face and chicken legs syndrome. After the first day of reentry back to earth, blood samples showed a 17% loss of blood plasma, which contributed to a decline of erythropoietin secretion.^{[48][49]} On the skeletal system which is important to support our body's posture, long space flight and exposure to microgravity cause demineralization and atrophy of muscles. During re-acclimation, astronauts were observed to have a myriad of symptoms including cold sweats, nausea, vomiting and motion sickness.^[50] Returning astronauts also felt disorientated. Journeys to and from Mars being six months is the average time spent at the ISS. Once on Mars with its lesser surface gravity (38% percent of Earth's), these health effects would be a serious concern.^[51] Upon return to Earth, recovery from bone loss and atrophy is a long process and the effects of microgravity may never fully reverse.

Radiation

Mars has a weaker global magnetosphere than Earth does as it has lost its inner dynamo, which significantly weakened the magnetosphere—the cause of so much radiation reaching the surface, despite its far distance from the Sun compared to Earth. Combined with a thin atmosphere, this permits a significant amount of ionizing radiation to reach the Martian surface. There are two main types of radiation risks to traveling outside the protection of Earth's atmosphere and magnetosphere: galactic cosmic rays (GCR) and solar energetic particles (SEP). Earth's magnetosphere protects from charged particles from the Sun, and the atmosphere protects against uncharged and highly energetic GCRs. There are ways to mitigate against solar radiation, but without much of an atmosphere, the only solution to the GCR flux is heavy shielding amounting to roughly 15 centimeters of steel, 1 meter of rock, or 3 meters of water, limiting human colonists to living underground most of the time.^[52]

The Mars Odyssey spacecraft carries an instrument, the Mars Radiation Environment Experiment (MARIE), to measure the radiation. MARIE found that radiation levels in orbit above Mars are 2.5 times higher than at the International Space Station. The average daily dose was about 220 µGy (22 mrad)—equivalent to 0.08 Gy per year.^[53] A three-year exposure to such levels would exceed the safety limits currently adopted by NASA,^[54] and the risk of developing cancer due to radiation exposure after a Mars mission could be two times greater than what scientists previously thought.^{[55][56]} Occasional solar proton events (SPEs) produce much higher doses, as observed in September 2017, when NASA reported radiation levels on the surface of Mars were temporarily doubled, and were associated with an aurora 25-times brighter than any observed earlier, due to a massive, and unexpected, solar storm.^[57] Building living quarters underground (possibly in Martian lava tubes) would significantly lower the colonists' exposure to radiation.



Comparison of radiation doses—includes the amount detected on the trip from Earth to Mars by the RAD on the MSL (2011–2013).^{[58][59][60]}

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, as well as experimenting with shielding techniques.^[61] 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.^[62] However, results from a 2006 study indicated that protons from cosmic radiation may cause twice as much serious damage to DNA as previously estimated, exposing astronauts to greater risk of cancer and other diseases.^[63] 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."^[63] NASA is exploring a variety of alternative techniques and technologies such as deflector shields of plasma to protect astronauts and spacecraft from radiation.^[63]

Psychological effects

Due to the communication delays, new protocols need to be developed in order to assess crew members' psychological health. Researchers have developed a Martian simulation called HI-SEAS (Hawaii Space Exploration Analog and Simulation) that places scientists in a simulated Martian laboratory to study the psychological effects of isolation, repetitive tasks, and living in close-quarters with other scientists for up to a year at a time. Computer programs are being developed to assist crews with personal and interpersonal issues in absence of direct communication with professionals on Earth.^[64] Current suggestions for Mars exploration and colonization are to select individuals who have passed psychological screenings. Psychosocial sessions for the return home are also suggested in order to reorient people to society.

Terraforming

Various works of fiction put forward the idea of terraforming Mars to allow a wide variety of life forms, including humans, to survive unaided on Mars' surface. Some ideas of possible technologies that may be able to contribute to the terraforming of Mars have been conjectured, but none would be able to bring the entire planet into the Earth-like habitat pictured in science fiction.^[65]

Transportation

Interplanetary spaceflight

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.^[66] Modified transfer trajectories that cut the travel time down to four to seven 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 increasing amount of fuel, and is difficult with chemical rockets. It could be feasible with advanced spacecraft propulsion technologies, some of which have already been tested to varying levels, such as Variable Specific Impulse Magnetoplasma Rocket,^[67] and nuclear rockets. In the former case, a trip time of forty days could be attainable,^[68] and in the latter, a trip time down to about two weeks.^[3] In 2016, a University of California, Santa Barbara scientist said they could further reduce travel time for a small robotic probe to Mars down to "as little as 72 hours" with the use of a laser propelled sail (directed photonic propulsion) system instead of the fuel-based rocket propulsion system.^{[69][70]}

During the journey the astronauts would be subject to radiation, which would require 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% (one estimate is 3.4%) for males to die of cancer because of the radiation during the journey to Mars and back to Earth. For females the probability is higher due to generally larger glandular tissues.^[71]



Mars (*Viking 1*, 1980)

Mars has a surface gravity 0.38 times that of Earth, and the density of its atmosphere is about 0.6% of that on Earth.^[72] The relatively strong gravity and the presence of aerodynamic effects make 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 would require braking and landing systems different from anything used to land crewed spacecraft on the Moon or robotic missions on Mars.^[73]

If one assumes carbon nanotube construction material will be available with a strength of 130 GPa (19,000,000 psi) then a space elevator could be built to land people and material on Mars.^[74] A space elevator on Phobos (a Martian moon) has also been proposed.^[75]

Equipment needed for colonization



Artist's conception of the process of terraforming Mars as discussed in some works of science fiction



Rendezvous, an interplanetary stage and lander stage come together over Mars



Painting of a landing on Mars (1986)

Colonization of Mars would 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:^[3]

- Basic utilities (oxygen, power, local communications, waste disposal, sanitation and water recycling)
- Habitats
- Storage facilities
- Shop workspaces
- Airlock, for pressurization and dust management
- Resource extraction equipment—initially for water and oxygen, later for a wider cross section of minerals, building materials, etc.
- Equipment for energy production and energy storage, some solar and perhaps nuclear as well
- Food production spaces and equipment.
- Propellant production equipment, generally thought to be hydrogen and methane through the Sabatier reaction^[76] 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.^[77]
- Off-planet communication equipment
- Equipment for moving over the surface—Mars suit, crewed rovers and possibly even Mars aircraft.



Mars greenhouses feature in many colonization designs, especially for food production and other purposes

Basic utilities

In order to function at all the colony would need the basic utilities to support human civilization. These would need to be designed to handle the harsh Martian environment and would either have to be serviceable whilst wearing an EVA suit or housed inside a human habitable environment. For example, if electricity generation systems rely on solar power, large energy storage facilities will also be needed to cover the periods when dust storms block out the sun, and automatic dust removal systems may be needed to avoid human exposure to conditions on the surface.^[28] If the colony is to scale beyond a few people, systems will also need to maximise use of local resources to reduce the need for resupply from Earth, for example by recycling water and oxygen and being adapted to be able to use any water found on Mars, whatever form it is in.



Various technologies and devices for Mars are shown in the illustration of a Mars base

Communication with Earth

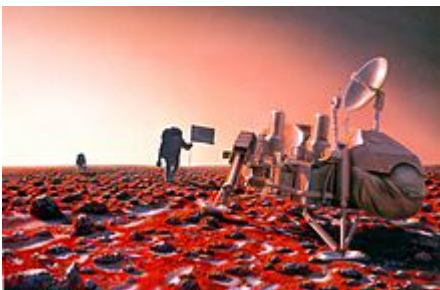
Communications with Earth are relatively straightforward during the half-sol when Earth is above the Martian horizon. NASA and ESA included communications relay equipment in several of the Mars orbiters, so Mars already has communications satellites. While these will eventually wear out, additional orbiters 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,^[78] 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.^[79]

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.^[80] 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.^[81] 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.

Robotic precursors



Astronauts approach Viking 2 lander probe

The path to a human colony could be prepared by robotic systems such as the Mars Exploration Rovers *Spirit*, *Opportunity*, *Curiosity* and *Perseverance*. 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 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,^[82] and test solar cell technologies and methods of mitigating the effect of Martian dust on the power systems.^[83]

Before any people are transported to Mars on the notional 2020s Mars transportation infrastructure envisioned by SpaceX, a number of robotic cargo missions would be undertaken first in order to transport the requisite equipment, habitats and supplies.^[84] 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.^[85]

Economics

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.

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.^[86] 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.^[87] 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.^[88]

Economic drivers

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,^[89] there is some prospect of a radical reduction to launch costs in the 2020s, which would consequently lessen the cost of any efforts in that direction. With a published price of US\$62 million per launch of up to 22,800 kg (50,300 lb) payload to



Iron–nickel meteorite found on Mars' surface (Heat Shield Rock)

low Earth orbit or 4,020 kg (8,860 lb) to Mars,^[90] SpaceX Falcon 9 rockets are already the "cheapest in the industry".^[91] SpaceX's reusable plans include Falcon Heavy and future methane-based launch vehicles including the Starship. 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.^[92]

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.^[93]

Possible locations for settlements

Equatorial regions

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.^[94]

Lava tubes

Several possible Martian lava tube skylights 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.^[95]



Cropped version of a HiRISE image of a lava tube skylight entrance on the Martian volcano Pavonis Mons.

Hellas Planitia

Hellas Planitia is the lowest lying plain below the Martian geodetic datum. The air pressure is relatively higher in this place when compared to the rest of Mars.

Planetary protection

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,^{[96][97]} 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 (i.e. crash).^[98] There have been several planetary workshops on this issue, but with no final guidelines for a way forward yet.^[99] Human explorers would also be vulnerable to back contamination to Earth if they become carriers of microorganisms should Mars have life.^[100]

Ethical, political and legal challenges

It is unforeseen how the first human landing on Mars will change the current policies regarding the exploration of space and occupancy of celestial bodies. In the 1967 United Nations Outer Space Treaty, it was determined that no country may take claim to space or its inhabitants. Since the planet Mars offers a challenging environment and dangerous obstacles for humans to overcome, the laws and culture on the planet will most likely be very different from those on Earth.^[101] With Elon Musk announcing his plans for travel to Mars, it is uncertain how the dynamic of a private company possibly being the first to put a human on Mars will play out on a national and global scale.^{[102][103]} NASA had to deal with several cuts in funding. During the presidency of Barack Obama, the objective for NASA to reach Mars was pushed to the background.^[104] In 2017, president Donald Trump promised to return humans to the Moon and eventually Mars,^[105] effectively taking action by increasing NASA budget with \$1.1 billion,^[106] and mostly focus on the development of the new Space Launch System.^{[107][108]}

Colonialism

Space colonization in general has been discussed as continuation of imperialism and colonialism,^[109] especially regarding Mars colonial decision making and reasons for colonial labor^[110] and land exploitation have been questioned with postcolonial critique. Seeing the need for inclusive^[111] and democratic participation and implementation of any space and Mars exploration, infrastructure, or colonialization, many have called for dramatic sociological reforms and guarantees to prevent racism, sexism, and other forms of prejudice and bigotry.^[112]

The narrative of space exploration as a "New Frontier" has been criticized as unreflected continuation of settler colonialism and manifest destiny, continuing the narrative of colonial exploration as fundamental to the assumed human nature.^{[113][114][115]}

The predominant perspective of territorial colonization in space has been called *surfacism*, especially comparing advocacy for colonization of Mars opposed to Venus.^[116]

Dangers to pregnancy

One possible ethical challenge that space travelers might face is that of pregnancy during the trip. According to NASA's policies, it is forbidden for members of the crew to engage in sex in space. NASA wants its crewmembers to treat each other like coworkers would in a professional environment. A pregnant member on a spacecraft is dangerous to all those aboard. The pregnant woman and child would need additional nutrition from the rations aboard, as well as special treatment and care. The pregnancy would impede on the pregnant crew member's duties and abilities. It is still not fully known how the environment in a spacecraft would affect the development of a child aboard. It is known however that an unborn child in space would be more susceptible to solar radiation, which would likely have a negative effect on its cells and genetics.^[118] During a long trip to Mars, it is likely that members of craft may engage in sex due to their stressful and isolated environment.^[119]

Advocacy



The logo and name of the Lunar Gateway references the St. Louis Gateway Arch, associating Mars with the American frontier.^[117]

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.



Buzz Aldrin, the Apollo 11 astronaut and second person to set foot on the Moon, has recommended human Mars missions

Elon Musk founded SpaceX with the long-term goal of developing the technologies that will enable a self-sustaining human colony on Mars.^{[102][120]} In 2015, he stated "I think we've got a decent shot of sending a person to Mars in 11 or 12 years"(as in 2026–7).^[121]

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," [from 2012] "we will take literally hundreds of thousands of people to space and that will give us the financial resources to do even bigger things".^[122]

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 human 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".^[123] 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.^[124]

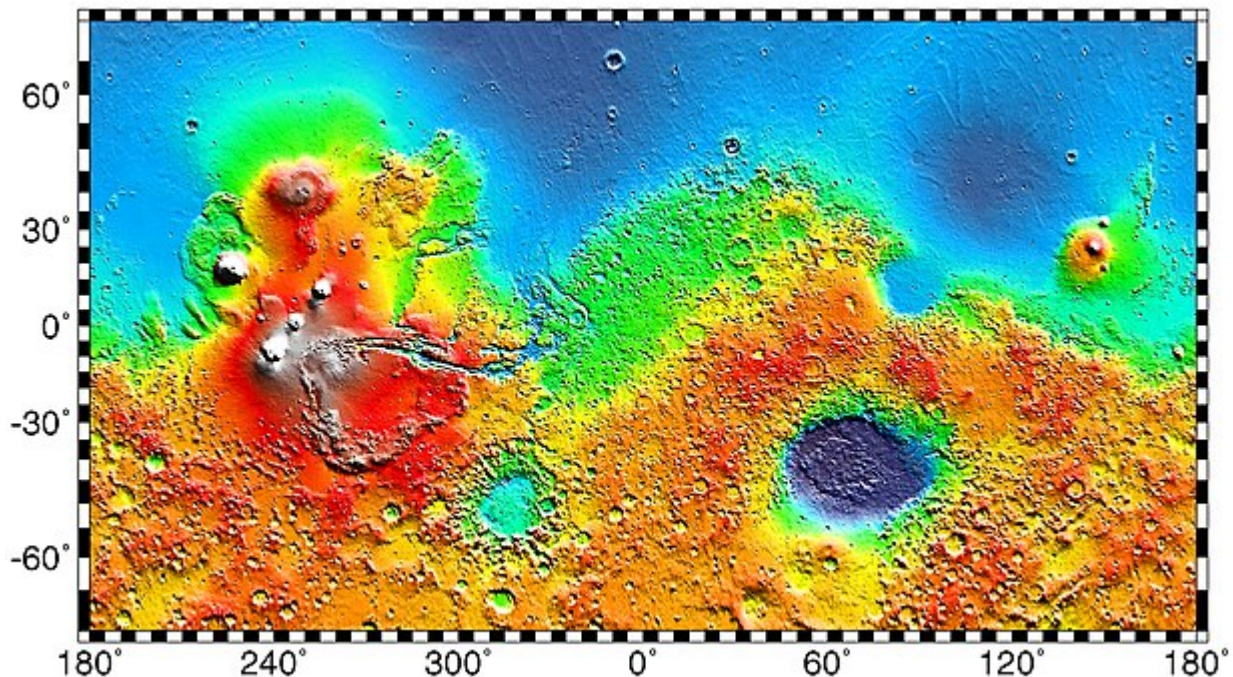
In fiction

A few instances in fiction provide detailed descriptions of Mars colonization. They include:

- "Away" (2020), published by Netflix
- Surviving Mars (2018), developed by Haemimont Games, published by Paradox Interactive
- The Expanse (2016-2021) airing originally on Syfy, then Amazon Prime
- TerraGenesis (2016) developed by Edgeworks Entertainment, published by Tilting Point
- The Space Between Us (2016 film), by Peter Chelsom
- Mars (2016) by National Geographic
- John Carter (2012), by Mark Andrews
- The Martian (2011), by Andy Weir (and the 2015 film, directed by Ridley Scott)
- Mr. Nobody (2009), by Jaco Van Dormael
- Tom and Jerry: Blast Off to Mars (2005) animated science fiction comedy film by Warner Bros. Animation and Turner Entertainment

- *Aria* (2002–2008), by [Kozue Amano](#)
- *First Landing* (2002), by [Robert Zubrin](#)
- *Red Faction* (2001), developed by [Volition](#), published by [THQ](#)
- *Mars Diaries* (2000), by [Sigmund Brouwer](#)
- *Martian Gothic: Unification* (2000), developed by Creative Reality for Microsoft Windows and Coyote Developments for PlayStation, published by [TalonSoft](#) for Microsoft Windows and [Take-Two Interactive](#) for PlayStation
- *Mars Underground* (1997), by [William K. Hartmann](#)
- *Climbing Olympus* (1994), by [Kevin J. Anderson](#)
- *The Martian* (1992) and *Return to Mars* (1999), by [Ben Bova](#)
- *Total Recall* (1990), by [Paul Verhoeven](#)
- *Icehenge* (1985), the Mars trilogy (*Red Mars*, *Green Mars*, *Blue Mars*, 1992–1996), and *The Martians* (1999), by [Kim Stanley Robinson](#)
- *Man Plus* (1976), by [Frederik Pohl](#)
- *The Destruction of Faena* (1974), by [Alexander Kazantsev](#)
- *We Can Remember It for You Wholesale* (1966), by [Philip K. Dick](#)
- *The Sands of Mars* (1951), by [Arthur C. Clarke](#)
- *The Martian Chronicles* (1950), by [Ray Bradbury](#)

Interactive Mars map



 [Interactive image map of the global topography of Mars](#). Hover your mouse over the image to see the names of over 60 prominent geographic features, and click to link to them. Coloring of the base map indicates relative [elevations](#), based on data from the [Mars Orbiter Laser Altimeter](#) on NASA's *Mars Global Surveyor*. Whites and browns indicate the highest elevations (+12 to +8 km); followed by pinks and reds (+8 to +3 km); yellow is 0 km; greens and blues are lower elevations (down to -8 km). [Axes](#) are [latitude](#) and [longitude](#); [Polar regions](#) are noted.

(See also: [Mars Rovers map](#) and [Mars Memorial map](#)) ([view](#) • [discuss](#))

See also

- Astrobotany – The study of plants grown in spacecraft
- Climate of Mars – Climate patterns of the terrestrial planet
- Colonization of the Moon – Proposed establishment of a permanent human community or robotic industries on the Moon
- Colonization of Venus – Proposed colonization of the planet Venus
- Effect of spaceflight on the human body – Medical consequences of spaceflight
- Exploration of Mars – Overview of the exploration of Mars
- Health threat from cosmic rays
- Human mission to Mars – Various proposed crewed mission concepts to Mars
- Human outpost – Artificially-created, controlled human habitats located in environments inhospitable for humans, such as in space
- In situ resource utilization – Astronautical use of materials harvested in outer space
- Inspiration Mars
- Space architecture – Architecture
- SpaceX Mars transportation infrastructure
- Life on Mars – Scientific assessments on the microbial habitability of Mars
- List of crewed Mars mission plans
- Mars analog habitat – Research simulating the environment on Mars
- Mars Desert Research Station
- Mars habitat – A facility where humans could live on Mars
- Mars race – Attempts by various countries to land a human on Mars
- Martian – Extraterrestrial ethnic group
- Martian soil
- Vision for Space Exploration – 2004 US human space exploration plan
- NewSpace
- Terraforming of Mars – Hypothetical modification of Mars into a habitable planet
- *The Case for Mars* – Book by Robert Zubrin on the potential colonization of Mars
- Water on Mars – Study of past and present water on Mars

References

1. 3D Printing With Ice on Mars. (<http://www.marsicehouse.com/3d-printing-with-ice/>) Mars Ice House. 2015. Accessed: 25 August 2018.
2. Von Drehle, David (December 15, 2020). "Humans don't have to set foot on Mars to visit it" (https://www.washingtonpost.com/opinions/humans-dont-have-to-set-foot-on-mars-to-visit-it/2020/12/15/b1df2afe-3f05-11eb-9453-fc36ba051781_story.html). *The Washington Post*. Retrieved December 16, 2020.
3. Zubrin, Robert (1996). *The Case for Mars: The Plan to Settle the Red Planet and Why We Must* (<http://archive.org/details/caseformarsplant00zubr>). Touchstone. ISBN 978-0-684-83550-1.
4. Amos, Jonathan (September 29, 2017). "Elon Musk: Rockets will fly people from city to city in minutes" (<https://www.bbc.com/news/science-environment-41441877>). *BBC*. Archived (<https://web.archive.org/web/20180908174216/https://www.bbc.com/news/science-environment-41441877>) from the original on September 8, 2018. Retrieved July 21, 2018.

5. Etherington, Darrell (September 28, 2017). "Elon Musk shares images of "Moon Base Alpha" and "Mars City" ahead of IAC talk" (<https://techcrunch.com/2017/09/28/elon-musk-tweets-image-of-moon-base-alpha-concept-ahead-of-mars-talk/>). *TechCrunch*. Archived (<https://web.archive.org/web/20170930035539/https://techcrunch.com/2017/09/28/elon-musk-tweets-image-of-moon-base-alpha-concept-ahead-of-mars-talk/>) from the original on September 30, 2017. Retrieved September 29, 2017.
6. Badescu, Viorel (2009). *Mars: Prospective Energy and Material Resources* (<https://books.google.com/books?id=BnPE37Ms5awC>) (illustrated ed.). Springer Science & Business Media. p. 600. ISBN 978-3-642-03629-3. Extract of page 600 (<https://books.google.com/books?id=BnPE37Ms5awC&pg=PA600>)
7. West, John B. (March 1, 1999). "Barometric pressures on Mt. Everest: new data and physiological significance" (<http://jap.physiology.org/content/86/3/10.full>). *Journal of Applied Physiology (Bethesda, Md. : 1985)*. Jap.physiology.org. **86** (3): 1062–6. doi:10.1152/jappl.1999.86.3.1062 (<https://doi.org/10.1152%2Fjappl.1999.86.3.1062>). PMID 10066724 (<https://pubmed.ncbi.nlm.nih.gov/10066724/>). Retrieved May 15, 2012.
8. Fong, MD, Kevin (February 12, 2014). "The Strange, Deadly Effects Mars Would Have on Your Body" (<https://www.wired.com/opinion/2014/02/happens-body-mars/>). *Wired*. Retrieved February 12, 2014.
9. "Gravity Hurts (so Good)" (https://science.nasa.gov/science-news/science-at-nasa/2001/ast02aug_1/). NASA. 2001.
10. "Mars Mice" (https://science.nasa.gov/science-news/science-at-nasa/2004/20jan_marsmice/). *science.nasa.gov*. 2004.
11. Phillips, Tony (January 31, 2001). "The Solar Wind at Mars" (https://science.nasa.gov/science-news/science-at-nasa/2001/ast31jan_1/). NASA.
12. "What makes Mars so hostile to life?" (<http://www.bbc.co.uk/science/0/20915340>). *BBC News*. January 7, 2013.
13. Keating, A.; Goncalves, P. (November 2012). "The impact of Mars geological evolution in high energy ionizing radiation environment through time". *Planetary and Space Science – Elsevier*. **72** (1): 70–77. Bibcode:2012P&SS...72...70K (<https://ui.adsabs.harvard.edu/abs/2012P&SS...72...70K>). doi:10.1016/j.pss.2012.04.009 (<https://doi.org/10.1016%2Fj.pss.2012.04.009>).
14. Whitehouse, David (July 15, 2004). "Dr. David Whitehouse – Ammonia on Mars could mean life" (<http://news.bbc.co.uk/2/hi/3896335.stm>). *BBC News*. Retrieved August 14, 2012.
15. "Mars Weather" (<https://archive.today/20151025050810/http://cab.inta-csic.es/remis/index.htm>). Centro de Astrobiología. 2015. Archived from the original (<http://cab.inta-csic.es/remis/index.htm>) on October 25, 2015. Retrieved May 31, 2015.
16. "Opportunity Hunkers Down During Dust Storm" (<https://www.nasa.gov/feature/jpl/opportunity-hunkers-down-during-dust-storm>). NASA. June 8, 2018. Retrieved November 26, 2018.
17. "Why is Mars So Dry?" (<https://www.universetoday.com/9303/why-is-mars-so-dry/>). *Universe Today*. February 16, 2004. Retrieved November 26, 2018.
18. Hecht, M. H. (2002). "Metastability of Liquid Water on Mars". *Icarus*. **156** (2): 373–386. Bibcode:2002Icar..156..373H (<https://ui.adsabs.harvard.edu/abs/2002Icar..156..373H>). doi:10.1006/icar.2001.6794 (<https://doi.org/10.1006%2Ficar.2001.6794>).
19. Webster, Guy; Brown, Dwayne (December 10, 2013). "NASA Mars Spacecraft Reveals a More Dynamic Red Planet" (<http://www.jpl.nasa.gov/news/news.php?release=2013-361&1#1>). NASA. Retrieved March 2, 2014.
20. Hamilton, Calvin. "Mars Introduction" (<http://www.solarviews.com/eng/mars.htm>).
21. Elert, Glenn. "Temperature on the Surface of Mars" (<http://hypertextbook.com/facts/2001/AlbertEydelman.shtml>).
22. Kluger, J. (1992). "Mars, in Earth's Image" (<http://discovermagazine.com/1992/sep/marsinearthsimag105>). *Discover Magazine*. **13** (9): 70. Bibcode:1992Disc...13...70K (<https://ui.adsabs.harvard.edu/abs/1992Disc...13...70K>). Retrieved June 12, 2015.

23. Haberle, R. M.; McKay, C. P.; Pollack, J. B.; Gwynne, O. E.; Atkinson, D. H.; Appelbaum, J.; Landis, G. A.; Zurek, R. W.; Flood, D. J. (1993). *Atmospheric Effects on the Utility of Solar Power on Mars* (<https://web.archive.org/web/20160305054458/http://www.uapress.arizona.edu/onlinebks/ResourcesNearEarthSpace/resources30.pdf>) (PDF). Bibcode:1993rnes.book..845H (<https://ui.adsabs.harvard.edu/abs/1993rnes.book..845H>). Archived from the original (<http://www.uapress.arizona.edu/onlinebks/ResourcesNearEarthSpace/resources30.pdf>) (PDF) on March 5, 2016.
24. Sharonov, V. V. (1957). "1957SvA.....1..547S Page 547". *Harvard.edu*. 1: 547. Bibcode:1957SvA.....1..547S (<https://ui.adsabs.harvard.edu/abs/1957SvA.....1..547S>).
25. "Sunlight on Mars – Is There Enough Light on Mars to Grow Tomatoes?" (<https://www.firsttheseedfoundation.org/resource/tomatosphere/background/sunlight-mars-enough-light-mars-grow-tomatoes/>). *first the seed foundation*. Retrieved November 26, 2018.
26. Viorel Badescu (2009). *Mars: Prospective Energy and Material Resources* (<https://books.google.com/books?id=BnPE37Ms5awC&pg=PA83>). Springer Science & Business Media. p. 83. ISBN 978-3-642-03629-3.
27. Tomatosphere. "Teachers guide – Sunlight on mars – Tomatosphere" (<https://web.archive.org/web/20150623152330/http://tomatosphere.org/teachers/guide/grades-8-10/mars-agriculture>). *tomatosphere.org*. Archived from the original (<http://tomatosphere.org/teachers/guide/grades-8-10/mars-agriculture>) on June 23, 2015. Retrieved June 12, 2015.
28. Fenton, Lori K.; Geissler, Paul E.; Haberle, Robert M. (2007). "Global warming and climate forcing by recent albedo changes on Mars" (<https://web.archive.org/web/20070708011126/http://humbabe.arc.nasa.gov/~fenton/pdf/fenton/nature05718.pdf>) (PDF). *Nature*. **446** (7136): 646–649. Bibcode:2007Natur.446..646F (<https://ui.adsabs.harvard.edu/abs/2007Natur.446..646F>). doi:10.1038/nature05718 (<https://doi.org/10.1038%2Fnature05718>). PMID 17410170 (<https://pubmed.ncbi.nlm.nih.gov/17410170>). S2CID 4411643 (<https://api.semanticscholar.org/CorpusID:4411643>). Archived from the original (<http://humbabe.arc.nasa.gov/~fenton/pdf/fenton/nature05718.pdf>) (PDF) on July 8, 2007.
29. "Mars covered in toxic chemicals that can wipe out living organisms, tests reveal" (<https://www.theguardian.com/science/2017/jul/06/mars-covered-in-toxic-chemicals-that-can-wipe-out-living-organisms-tests-reveal>). *The Guardian*. Retrieved November 26, 2018.
30. "Toxic Mars: Astronauts Must Deal with Perchlorate on the Red Planet" (<https://www.space.com/21554-mars-toxic-perchlorate-chemicals.html>). *space.com*. Retrieved November 26, 2018.
31. "Can Life exist on Mars?" (<https://web.archive.org/web/20010222154617/http://library.thinkquest.org/12145/lifeon.htm>). *Mars Academy*. ORACLE-ThinkQuest. Archived from the original (<http://library.thinkquest.org/12145/lifeon.htm>) on February 22, 2001.
32. Landis, Geoffrey A.; Colozza, Anthony; LaMarre, Christopher M. (June 2002). "Atmospheric Flight on Venus" (<https://web.archive.org/web/20111016143148/http://gltrs.grc.nasa.gov/reports/2002/TM-2002-2-211467.pdf>) (PDF). Glenn Research Center, National Aeronautics and Space Administration. Archived from the original (<http://gltrs.grc.nasa.gov/reports/2002/TM-2002-2-211467.pdf>) (PDF) on October 16, 2011.
33. Baldwin, Emily (April 26, 2012). "Lichen survives harsh Mars environment" (<https://web.archive.org/web/20120528145425/http://www.skymania.com/wp/2012/04/lichen-survives-harsh-martian-setting.html>). Skymania News. Archived from the original (<http://www.skymania.com/wp/2012/04/lichen-survives-harsh-martian-setting.html>) on May 28, 2012. Retrieved April 27, 2012.
34. de Vera, J.-P.; Kohler, Ulrich (April 26, 2012). "The adaptation potential of extremophiles to Martian surface conditions and its implication for the habitability of Mars" (https://web.archive.org/web/20120504224706/http://media.egu2012.eu/media/filer_public/2012/04/05/10_solarsystem_devera.pdf) (PDF). *Egu General Assembly Conference Abstracts*. European Geosciences Union. **14**: 2113. Bibcode:2012EGUGA..14.2113D (<https://ui.adsabs.harvard.edu/abs/2012EGUGA..14.2113D>). Archived from the original (http://media.egu2012.eu/media/filer_public/2012/04/05/10_solarsystem_devera.pdf) (PDF) on May 4, 2012. Retrieved April 27, 2012.

35. "Surviving the conditions on Mars" (https://web.archive.org/web/20180323053655/http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-3409/#/gallery/5671). DLR. Archived from the original (http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-3409/) on May 23, 2018.
36. Verseux, Cyprien; Baqué, Mickael; Lehto, Kirsi; de Vera, Jean-Pierre P.; et al. (August 3, 2015). "Sustainable life support on Mars – the potential roles of cyanobacteria" (<https://doi.org/10.1017%2FS147355041500021X>). *International Journal of Astrobiology*. **15** (1): 65–92. Bibcode:2016IJAsB..15...65V (<https://ui.adsabs.harvard.edu/abs/2016IJAsB..15...65V>). doi:10.1017/S147355041500021X (<https://doi.org/10.1017%2FS147355041500021X>).
37. "Extreme Planet Takes Its Toll" (<https://web.archive.org/web/20131102112312/http://marsrover.nasa.gov/spotlight/20070612.html>). *Mars Exploration Rovers*. Jet Propulsion Laboratory, California Institute of Technology. June 12, 2007. Archived from the original (<http://marsrover.nasa.gov/spotlight/20070612.html>) on November 2, 2013. Retrieved March 12, 2014.
38. "Higher, Farther, and Longer — Record Balloon Flights in the Second Part of the Twentieth Century" (https://web.archive.org/web/20030430070850/http://www.centennialofflight.gov/essay/Lighter_than_air/20th_cent_records-2/LTA12.htm). U.S. Centennial Of Flight Commission. Archived from the original (http://www.centennialofflight.gov/essay/Lighter_than_air/20th_cent_records-2/LTA12.htm) on April 30, 2003. Retrieved September 22, 2014.
39. "Barometric Pressure vs. Altitude Table" (<https://web.archive.org/web/20071025050551/http://www.sablesys.com/baro-altitude.html>). Sable Systems International. 2014. Archived from the original (<http://www.sablesys.com/baro-altitude.html>) on October 25, 2007.
40. "How much water does an average person use?" (<https://www.southwestwater.co.uk/frequently-asked-questions/saving-water/how-much-water-does-an-average-person-use/>). *South West Water*. Retrieved November 26, 2018.
41. Mui, K. W., Wong, L. T., & Law, L. Y. (2007). Domestic water consumption benchmark development for Hong Kong. *Building Services Engineering Research & Technology*, 28(4), 329.
42. Gillard, Eric (December 9, 2016). "Students Work to Find Ways to Drill for Water on Mars" (<https://www.nasa.gov/feature/langley/students-work-to-find-ways-to-drill-for-water-on-mars>). NASA. Retrieved January 21, 2018.
43. Schwirtz, Michael (March 30, 2009). "Staying Put on Earth, Taking a Step to Mars" (<https://www.nytimes.com/2009/03/31/science/space/31mars.html>). *The New York Times*. Retrieved May 15, 2010.
44. Cheng, Kenneth (March 27, 2015). "Breaking Space Records" (<https://web.archive.org/web/20150405145407/http://www.nytimes.com/live/international-space-station-launch/breaking-space-records/>). *The New York Times*. Archived from the original (<https://www.nytimes.com/live/international-space-station-launch/breaking-space-records/>) on April 5, 2015. Retrieved June 28, 2015.
45. "NASA's Journey to Mars – Pioneering Next Steps in Space Exploration" (https://www.nasa.gov/sites/default/files/atoms/files/journey-to-mars-next-steps-20151008_508.pdf) (PDF). NASA. October 2015. Retrieved March 19, 2017.
46. "Speech Monitoring of Cognitive Deficits and Stress – NSBRI" (<http://nsbri.org/researches/speech-monitoring-of-cognitive-deficits-and-stress/>). NSBRI. Retrieved March 18, 2017.
47. Nguyen Nguyen, Gyutae Kim, & Kyu-Sung Kim. (2020). Effects of Microgravity on Human Physiology. *Korean Journal of Aerospace & Environmental Medicine*, 30(1), 25–29. <https://doi.org/10.46246/KJAsEM.30.1.25>
48. Aubert AE, Beckers F, Verheyden B. Cardiovascular function and basics of physiology in microgravity. *Acta Cardiologica* 2005;60(2):129-151.
49. Williams D, Kuipers A, Mukai C, Thirsk R. Acclimation during space flight: effects on human physiology. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne* 2009;180(13):1317-1323.
50. Heer M, Paloski WH. Space motion sickness: Incidence, etiology, and countermeasures. *Autonomic Neuroscience* 2006;129(1):77-79.

51. "How Will Living On Mars Affects Our Human Body?" (<http://www.spacesafetymagazine.com/space-exploration/mars-mission/earthlings-martians-living-red-planet-affect-human-bodies/>). *Space Safety Magazine*. February 11, 2014. Retrieved March 19, 2017.
52. <https://ntrs.nasa.gov/search.jsp?R=19910008686>
53. "References & Documents" (https://web.archive.org/web/20100530060723/http://hacd.jsc.nasa.gov/projects/space_radiation_marie_references.cfm). Human Adaptation and Countermeasures Division, Johnson Space Center, NASA. Archived from the original (http://hacd.jsc.nasa.gov/projects/space_radiation_marie_references.cfm) on May 30, 2010.
54. Real Martians: How to Protect Astronauts from Space Radiation on Mars. (<https://www.nasa.gov/feature/goddard/real-martians-how-to-protect-astronauts-from-space-radiation-on-mars>) *Moon To Mars*. NASA. 30 September 2015. Quote: "[...] a trip to interplanetary space carries more radiation risk than working in low-Earth orbit, said Jonathan Pellish, a space radiation engineer at Goddard."
55. Study: Collateral Damage from Cosmic Rays Increases Cancer Risk for Mars Astronauts (<https://www.unlv.edu/news/release/study-significant-collateral-damage-cosmic-rays-increases-cancer-risks-mars-astronauts>). University of Nevada, Las Vegas (UNLV). May 2017.
56. "Non-Targeted Effects Models Predict Significantly Higher Mars Mission Cancer Risk than Targeted Effects Models." Francis A. Cucinotta, and Eliedonna Cacao. *Nature*, Scientific Reports, volume 7, Article number: 1832. 12 May 2017. doi:10.1016/j.issr.2015.04.002 (<https://doi.org/10.1016%2Fj.issr.2015.04.002>)
57. Scott, Jim (September 30, 2017). "Large solar storm sparks global aurora and doubles radiation levels on the martian surface" (<https://phys.org/news/2017-09-large-solar-storm-global-aurora.html>). *Phys.org*. Retrieved September 30, 2017.
58. Kerr, Richard (May 31, 2013). "Radiation Will Make Astronauts' Trip to Mars Even Riskier". *Science*. **340** (6136): 1031. Bibcode:2013Sci...340.1031K (<https://ui.adsabs.harvard.edu/abs/2013Sci...340.1031K>). doi:10.1126/science.340.6136.1031 (<https://doi.org/10.1126%2Fscience.340.6136.1031>). PMID 23723213 (<https://pubmed.ncbi.nlm.nih.gov/23723213>).
59. Zeitlin, C.; Hassler, D. M.; Cucinotta, F. A.; Ehresmann, B.; Wimmer-Schweingruber, R. F.; Brinza, D. E.; Kang, S.; Weigle, G.; et al. (May 31, 2013). "Measurements of Energetic Particle Radiation in Transit to Mars on the Mars Science Laboratory". *Science*. **340** (6136): 1080–1084. Bibcode:2013Sci...340.1080Z (<https://ui.adsabs.harvard.edu/abs/2013Sci...340.1080Z>). doi:10.1126/science.1235989 (<https://doi.org/10.1126%2Fscience.1235989>). PMID 23723233 (<https://pubmed.ncbi.nlm.nih.gov/23723233>). S2CID 604569 (<https://api.semanticscholar.org/CorpusID:604569>).
60. Chang, Kenneth (May 30, 2013). "Data Point to Radiation Risk for Travelers to Mars" (<https://www.nytimes.com/2013/05/31/science/space/data-show-higher-cancer-risk-for-mars-astronauts.html>). *The New York Times*. Retrieved May 31, 2013.
61. "Space Radiobiology" (<http://www.bnl.gov/medical/NASA/LTSF.asp>). *NASA/BNL Space Radiation Program*. NASA Space Radiation Laboratory. November 1, 2011.
62. Zubrin, Robert (1996). *The Case for Mars: The Plan to Settle the Red Planet and Why We Must* (<https://archive.org/details/caseformarsplant00zubr/page/114>). Touchstone. pp. 114–116 (<https://archive.org/details/caseformarsplant00zubr/page/114>). ISBN 978-0-684-83550-1.
63. Gutierrez-Folch, Anita (September 17, 2009). "Space Radiation Hinders NASA's Mars Ambitions" (<http://www.findingdulcinea.com/news/science/2009/september/Space-Radiation-Hinders-NASA-s-Mars-Ambitions-.html>). Finding Dulcinea.
64. "Mental preparation for Mars" (<http://www.apa.org/monitor/julaug04/mental.aspx>). American Psychological Association. Retrieved March 19, 2017.
65. Zubrin, Robert M.; McKay, Christopher P. "Technological Requirements for Terraforming Mars" (<http://www.users.globalnet.co.uk/~mfogg/zubrin.htm>).

66. Stern, David P. (December 12, 2004). "#21b, Flight to Mars: How Long? Along what Path?" (<http://www.phy6.org/stargaze/Smars1.htm>). *From Stargazers to Starships*. Phy6.org. Retrieved August 1, 2013.
67. "Variable-Specific-Impulse Magnetoplasma Rocket" (<http://www.techbriefs.com/content/view/1768/32/>). *Tech Briefs*. NASA.
68. "Ion engine could one day power 39-day trips to Mars" (<https://www.newscientist.com/article/dn17476-ion-engine-could-one-day-power-39day-trips-to-mars.html?full=true>). *New Scientist*.
69. "NASA Scientist: I can get humans to Mars in a month" (<https://www.usatoday.com/story/tech/2016/02/26/nasa-scientist-can-get-humans-mars-month/80980218/>). *USA TODAY*. Retrieved March 1, 2016.
70. Starlight: Directed Energy for Relativistic Interstellar Missions. (<https://www.deepspace.ucsb.edu/projects/starlight>) UCSB Experimental Cosmology Group. Accessed on 9 November 2019.
71. "Space radiation between Earth and Mars poses a hazard to astronauts" (https://science.nasa.gov/science-news/science-at-nasa/2004/17feb_radiation). NASA.
72. Williams, Dr. David R. (September 1, 2004). "Mars Fact Sheet" (<http://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html>). NASA Goddard Space Flight Center. Retrieved September 18, 2007.
73. Atkinson, Nancy (July 17, 2007). "The Mars Landing Approach: Getting Large Payloads to the Surface of the Red Planet" (<http://www.universetoday.com/2007/07/17/the-mars-landing-approach-getting-large-payloads-to-the-surface-of-the-red-planet>). Retrieved September 18, 2007.
74. "The Space Elevator – Chapters 2 & 7" (https://web.archive.org/web/20050603001216/http://www.isr.us/Downloads/niac_pdf/chapter2.html). Archived from the original (http://www.isr.us/Downloads/niac_pdf/chapter2.html) on June 3, 2005.
75. Weinstein, Leonard M. (2003). "Space Colonization Using Space-Elevators from Phobos" (https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20030065879_2003074809.pdf) (PDF). *Space Technology and Applications International Forum - Staif 2003*. **654**: 1227–1235. Bibcode:2003AIPC..654.1227W (<https://ui.adsabs.harvard.edu/abs/2003AIPC..654.1227W>). doi:10.1063/1.1541423 (<https://doi.org/10.1063%2F1.1541423>).
76. Belluscio, Alejandro G. (March 7, 2014). "SpaceX advances drive for Mars rocket via Raptor power" (<http://www.nasaspaceflight.com/2014/03/spacex-advances-drive-mars-rocket-raptor-power/>). *NASASpaceflight.com*. Retrieved March 14, 2014.
77. Landis (2001). "Mars Rocket Vehicle Using In Situ Propellants". *Journal of Spacecraft and Rockets*. **38** (5): 730–735. Bibcode:2001JSpRo..38..730L (<https://ui.adsabs.harvard.edu/abs/2001JSpRo..38..730L>). doi:10.2514/2.3739 (<https://doi.org/10.2514%2F2.3739>).
78. "During Solar Conjunction, Mars Spacecraft Will Be on Autopilot" (<http://marsrovers.jpl.nasa.gov/spotlight/20061020.html>). *Spotlight*. JPL, NASA. October 20, 2006.
79. Gangale, T. (2005). "MarsSat: Assured Communication with Mars". *Annals of the New York Academy of Sciences*. **1065**: 296–310. Bibcode:2005NYASA1065..296G (<https://ui.adsabs.harvard.edu/abs/2005NYASA1065..296G>). doi:10.1196/annals.1370.007 (<https://doi.org/10.1196%2Fannals.1370.007>). PMID 16510416 (<https://pubmed.ncbi.nlm.nih.gov/16510416>). S2CID 22087209 (<https://api.semanticscholar.org/CorpusID:22087209>).
80. "Sun-Mars Libration Points and Mars Mission Simulations" (https://web.archive.org/web/20130927055355/http://www.stk.com/downloads/resources/user-resources/downloads/whitepapers/0201_sun_mars_lib_pts.pdf) (PDF). Stk.com. Archived from the original (http://www.stk.com/downloads/resources/user-resources/downloads/whitepapers/0201_sun_mars_lib_pts.pdf) (PDF) on September 27, 2013. Retrieved October 6, 2013.
81. "A Novel Interplanetary Communications Relay" (http://strathprints.strath.ac.uk/25836/2/Macdonald_M_-_strathprints_-_A_novel_interplanetary_communications_relay_Aug_2010.pdf) (PDF). August 2010. Retrieved February 14, 2011.

82. Kaplan, D.; et al. (1999). "The Mars In-Situ-Propellant-Production Precursor (MIP) Flight Demonstration" (<http://www.lpi.usra.edu/meetings/marsmiss99/pdf/2503.pdf>) (PDF). *Workshop on Mars 2001: Integrated Science in Preparation for Sample Return and Human Exploration* (991): 54. Bibcode:1999misp.conf...54K (<https://ui.adsabs.harvard.edu/abs/1999misp.conf...54K>). Paper presented at *Mars 2001: Integrated Science in Preparation for Sample Return and Human Exploration*, Lunar and Planetary Institute, Oct. 2–4 1999, Houston, TX.
83. Landis, G. A.; Jenkins, P.; Scheiman, D.; Baraona, C. "MATE and DART: An Instrument Package for Characterizing Solar Energy and Atmospheric Dust on Mars" (<http://www.lpi.usra.edu/meetings/robomars/pdf/6136.pdf>) (PDF). Presented at *Concepts and Approaches for Mars Exploration*, July 18–20, 2000 Houston, Texas.
84. Gwynne Shotwell (March 21, 2014). *Broadcast 2212: Special Edition, interview with Gwynne Shotwell* (<https://web.archive.org/web/20140322013556/http://archived.thespaceshow.com/shows/2212-BWB-2014-03-21.mp3>) (audio file). The Space Show. Event occurs at 29:45–30:40. 2212. Archived from the original (<http://archived.thespaceshow.com/shows/2212-BWB-2014-03-21.mp3>) (mp3) on March 22, 2014. Retrieved March 22, 2014. "would have to throw a bunch of stuff before you start putting people there. ... It is a transportation system between Earth and Mars."
85. "Huge Mars Colony Eyed by SpaceX Founder" (<http://news.discovery.com/space/alien-life-exoplanets/mars-colony-spacex-121126.htm>). Discovery News. December 13, 2012. Retrieved March 14, 2014.
86. Landis, Geoffrey A. (2009). "Meteoritic steel as a construction resource on Mars". *Acta Astronautica*. **64** (2–3): 183. Bibcode:2009AcAau..64..183L (<https://ui.adsabs.harvard.edu/abs/2009AcAau..64..183L>). doi:10.1016/j.actaastro.2008.07.011 (<https://doi.org/10.1016/j.actaastro.2008.07.011>).
87. Lovelock, James and Allaby, Michael, *"The Greening of Mars"* 1984
88. "Effect of Clouds and Pollution on Insolation" (<http://www.ftexploring.com/solar-energy/clouds-and-pollution.htm>). Retrieved October 4, 2012.
89. Globus, Al (February 2, 2012). "Space Settlement Basics" (<http://settlement.arc.nasa.gov/Basics/www.html>). NASA Ames Research Center.
90. "SpaceX Capabilities and Services" (<https://web.archive.org/web/20131007205105/http://www.spacex.com/about/capabilities>). SpaceX. 2017. Archived from the original (<http://www.spacex.com/about/capabilities>) on October 7, 2013. Retrieved March 12, 2017.
91. Belfiore, Michael (December 9, 2013). "The Rocketeer" (https://foreignpolicy.com/articles/2013/12/02/the_rocketeer_elon_musk). *Foreign Policy*. Retrieved December 11, 2013.
92. Amos, Jonathan (September 30, 2013). "Recycled rockets: SpaceX calls time on expendable launch vehicles" (<https://www.bbc.co.uk/news/science-environment-24331860>). *BBC News*. Retrieved October 2, 2013.
93. "A Journey to Inspire, Innovate, and Discover" (http://www.nasa.gov/pdf/60736main_M2M_report_small.pdf) (PDF). *Report of the President's Commission on Implementation of United States Space Exploration Policy*. June 2004.
94. Fogg, Martyn J. (1997). "The utility of geothermal energy on Mars" (<http://www.users.globalnet.co.uk/~mfogg/fogg1996.pdf>) (PDF). *Journal of the British Interplanetary Society*. **49**: 403–22. Bibcode:1997JBIS...50..187F (<https://ui.adsabs.harvard.edu/abs/1997JBIS...50..187F>).
95. Cushing, G. E.; Titus, T. N.; Wynne1, J. J.; Christensen, P. R. "THEMIS Observes Possible Cave Skylights on Mars" (<http://www.lpi.usra.edu/meetings/lpsc2007/pdf/1371.pdf>) (PDF). Retrieved June 18, 2010.
96. Queens University Belfast scientist helps NASA Mars project (<https://www.bbc.co.uk/news/uk-northern-ireland-27526981>) "No-one has yet proved that there is deep groundwater on Mars, but it is plausible as there is certainly surface ice and atmospheric water vapour, so we wouldn't want to contaminate it and make it unusable by the introduction of micro-organisms."

97. COSPAR PLANETARY PROTECTION POLICY (https://science.nasa.gov/media/medialibrary/2012/05/04/COSPAR_Planetary_Protection_Policy_v3-24-11.pdf) Archived (https://web.archive.org/web/20130306111646/https://science.nasa.gov/media/medialibrary/2012/05/04/COSPAR_Planetary_Protection_Policy_v3-24-11.pdf) 2013-03-06 at the [Wayback Machine](#) (20 October 2002; As Amended to 24 March 2011)
98. When Biospheres Collide – a history of NASA's Planetary Protection Programs (http://www.nasa.gov/connect/ebooks/when_biospheres_collide_detail.html#.U_uVh_mwJcQ), Michael Meltzer, May 31, 2012, see Chapter 7, Return to Mars – final section: "Should we do away with human missions to sensitive targets"
99. Johnson, James E. "Planetary Protection Knowledge Gaps for Human Extraterrestrial Missions: Goals and Scope." (2015) (<http://www.hou.usra.edu/meetings/ppw2015/pdf/1010.pdf>)
00. Safe on Mars page 37 (http://www.nap.edu/openbook.php?record_id=10360&page=37) "Martian biological contamination may occur if astronauts breathe contaminated dust or if they contact material that is introduced into their habitat. If an astronaut becomes contaminated or infected, it is conceivable that he or she could transmit Martian biological entities or even disease to fellow astronauts, or introduce such entities into the biosphere upon returning to Earth. A contaminated vehicle or item of equipment returned to Earth could also be a source of contamination."
01. Szocik, Konrad, Kateryna Lysenko-Ryba, Sylwia Banaś, and Sylwia Mazur. "Political and Legal Challenges in a Mars Colony." *Space Policy* (2016): n. pag. Web. 24 Oct. 2016.
02. Chang, Kenneth (September 27, 2016). "Elon Musk's Plan: Get Humans to Mars, and Beyond" (<https://www.nytimes.com/2016/09/28/science/elon-musk-spacex-mars-exploration.html>). *The New York Times*. Retrieved September 27, 2016.
03. *Commercial Space Exploration: Ethics, Policy and Governance*, 2015. Print.
04. <https://www.space.com/35394-president-obama-spaceflight-exploration-legacy.html>
05. <https://www.nasa.gov/press-release/new-space-policy-directive-calls-for-human-expansion-across-solar-system>
06. <http://www.sciencemag.org/news/2018/03/updated-us-spending-deal-contains-largest-research-spending-increase-decade>
07. Chiles, James R. "Bigger Than Saturn, Bound for Deep Space" (<http://www.airspacemag.com/space/bigger-saturn-bound-deep-space-180952802/>). *Airspacemag.com*. Retrieved January 2, 2018.
08. "Finally, some details about how NASA actually plans to get to Mars" (<https://arstechnica.com/science/2017/03/for-the-first-time-nasa-has-begun-detailing-its-deep-space-exploration-plans/>). *Arstechnica.com*. Retrieved January 2, 2018.
09. Gabrielle Cornish (July 22, 2019). "How imperialism shaped the race to the moon" (<https://www.washingtonpost.com/outlook/2019/07/22/how-imperialism-shaped-race-moon/>). *The Washington Post*. Retrieved September 19, 2019.
10. Keith A. Spencer (October 8, 2017). "Against Mars-a-Lago: Why SpaceX's Mars colonization plan should terrify you" (<https://www.salon.com/2017/10/08/against-mars-a-lago-why-spacexs-mars-colonization-plan-should-terrify-you/>). *Salon.com*. Retrieved September 20, 2019.
11. Zuleyka Zevallos (March 26, 2015). "Rethinking the Narrative of Mars Colonisation" (<https://othersociologist.com/2015/03/26/rethinking-the-narrative-of-mars-colonisation/>). *Other Sociologist*. Retrieved September 20, 2019.
12. Keith A. Spencer (May 2, 2017). "Keep the Red Planet Red" (<https://www.jacobinmag.com/2017/02/mars-elon-musk-space-exploration-nasa-colonization>). *Jacobin (magazine)*. Retrieved September 20, 2019.
13. Caroline Haskins (August 14, 2018). "The racist language of space exploration" (<https://theoutline.com/post/5809/the-racist-language-of-space-exploration>). *The Outline*. Retrieved September 20, 2019.
14. DNLee (March 26, 2015). "When discussing Humanity's next move to space, the language we use matters" (<https://blogs.scientificamerican.com/urban-scientist/when-discussing-humanity-8217-s-next-move-to-space-the-language-we-use-matters/>). *Scientific American*. Retrieved September 20, 2019.

15. Drake, Nadia (November 9, 2018). "We need to change the way we talk about space exploration" (<https://www.nationalgeographic.com/science/2018/11/we-need-to-change-way-we-talk-about-space-exploration-mars/>). *National Geographic*. Retrieved October 19, 2019.
16. David Warmflash (March 14, 2017). "Colonization of the Venusian Clouds: Is 'Surfacism' Clouding Our Judgement?" (<https://www.visionlearning.com/blog/2017/03/14/colonization-venusian-clouds-surfacism-clouding-judgement/>). *Vision Learning*. Retrieved September 20, 2019.
17. Robert Z. Pearlman (September 18, 2019). "NASA Reveals New Gateway Logo for Artemis Lunar Orbit Way Station" (<https://www.space.com/nasa-lunar-gateway-moon-station-logo.html>). *Space.com*. Retrieved June 28, 2020.
18. Minkel, JR. "Sex and Pregnancy on Mars: A Risky Proposition." *Space.com*. Space.com, 11 Feb. 2011. Web. 09 Dec. 2016.
19. Schuster, Haley, and Steven L. Peck. "Mars Ain't the Kind of Place to Raise Your Kid: Ethical Implications of Pregnancy on Missions to Colonize Other Planets." *Life Sciences, Society and Policy* 12.1 (2016): 1–8. Web. 9 Dec. 2016.
20. Alex Knapp (November 27, 2012). "SpaceX Billionaire Elon Musk Wants A Martian Colony Of 80,000 People" (<https://www.forbes.com/sites/alexknapp/2012/11/27/spacex-billionaire-elon-musk-wants-a-martian-colony-of-80000-people/>). *Forbes*. Retrieved June 12, 2015.
21. "Musk thinks we'll be on Mars soon – Business Insider" (<http://www.businessinsider.com/musk-thinks-well-be-on-mars-soon-2015-4>). *Business Insider*. April 24, 2015. Retrieved June 12, 2015.
22. "Richard Branson on space travel: 'I'm determined to start a population on Mars'" (<https://www.cbsnews.com/news/richard-branson-on-space-travel-im-determined-to-start-a-population-on-mars/>). *cbsnews.com*. September 18, 2012. Retrieved June 15, 2019.
23. Aldrin, Buzz (June 13, 2013). "The Call of Mars" (<https://www.nytimes.com/2013/06/14/opinion/global/buzz-aldrin-the-call-of-mars.html>). *The New York Times*. Retrieved June 17, 2013.
24. Dunn, Marcia (August 27, 2015). "Buzz Aldrin joins university, forming 'master plan' for Mars" (<https://web.archive.org/web/20150904072417/http://apnews.excite.com/article/20150827/us-sci-buzz-aldrin-c7bc5ba293.html>). *AP News*. Archived from the original (<http://apnews.excite.com/article/20150827/us-sci-buzz-aldrin-c7bc5ba293.html>) on September 4, 2015. Retrieved August 30, 2015.

Further reading

- Buzz Aldrin and Leonard David (2013). *Mission to Mars: My Vision for Space Exploration*. National Geographic Books. ISBN 978-1-4262-1017-4. (at BuzzAldrin.com (<https://buzzaldrin.com/mission-to-mars-my-vision-for-space-exploration/>))
- Robert Zubrin, *The Case for Mars: The Plan to Settle the Red Planet and Why We Must*, Simon & Schuster/Touchstone, 1996, ISBN 0-684-83550-9
- Frank Crossman and Robert Zubrin, editors, *On to Mars: Colonizing a New World*. Apogee Books Space Series, 2002, ISBN 1-896522-90-4.
- Frank Crossman and Robert Zubrin, editors, *On to Mars 2: Exploring and Settling a New World*. Apogee Books Space Series, 2005, ISBN 978-1-894959-30-8.
- Resource Utilization Concepts for MoonMars (https://docs.google.com/viewer?a=v&q=cache:BoCLn aCIdwIj:www.spacegeneration.org/files/images/MMWFILES/ISRU_presentation.pdf+human+outpost&hl=en&gl=ca&sig=AHIEtbR531BikZhNPCsx08s2KFYV1WbArg); By Iris Fleischer, Olivia Haider, Morten W. Hansen, Robert Peckyno, Daniel Rosenberg and Robert E. Guinness; 30 September 2003; IAC Bremen, 2003 (29 Sept–03 Oct 2003) and MoonMars Workshop (26–28 Sept 2003, Bremen). Accessed on 18 January 2010
- *MARTIAN OUTPOST: The Challenges of Establishing a Human Settlement on Mars* (<http://www.praxis-publishing.co.uk/9780387981901.htm>); by Erik Seedhouse; Praxis Publishing; 2009; ISBN 978-0-387-98190-1. Also see [1] (<https://www.springer.com/astronomy/space+exploration/book/978-0-387->

98190-1), [2] (<https://www.amazon.com/Martian-Outpost-Challenges-Establishing-Exploration/dp/038798190X>)

- Ice, mineral-rich soil could support human outpost on Mars (<https://web.archive.org/web/20170208034458/http://news.idg.no/cw/art.cfm?id=CB21C80A-17A4-0F78-3174039834A1E181>); by Sharon Gaudin; 27 June 2008; [IDG News Service](#)

External links

- Mars Society (<http://www.marssociety.org/>)
- The Planetary Society: Mars Millennium Project (<http://mmp.planetary.org/index.html>)
- 4Frontiers Corporation (<https://web.archive.org/web/20180917143417/http://www.4frontierscorp.com/>)
- The Mars Foundation (<http://www.marshome.org/>)
- Making Mars the New Earth – National Geographic (<http://ngm.nationalgeographic.com/big-idea/07/mars>)
- [Should we colonize Mars?](#) – Wikidebate in Wikiversity

Retrieved from "https://en.wikipedia.org/w/index.php?title=Colonization_of_Mars&oldid=1021392689"

This page was last edited on 4 May 2021, at 13:32 (UTC).

Text is available under the Creative Commons Attribution-ShareAlike License; additional terms may apply. By using this site, you agree to the Terms of Use and Privacy Policy. Wikipedia® is a registered trademark of the Wikimedia Foundation, Inc., a non-profit organization.