Can we, and should we, go to Mars?

A note for decision-makers

Cyprien Verseux, Lucie Poulet, Muriel Gargaud,
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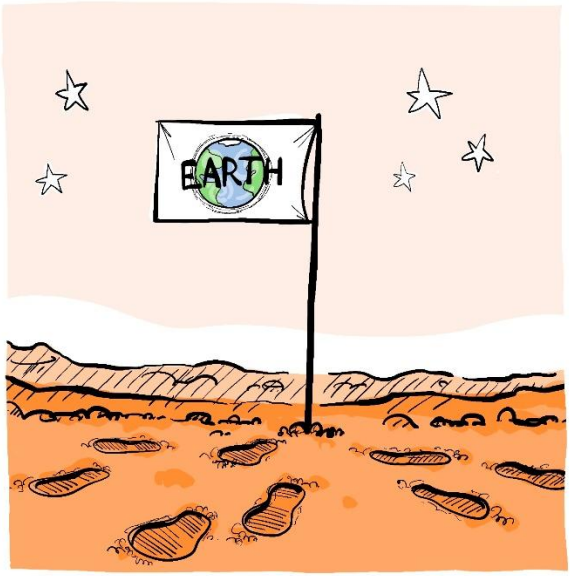
on behalf of the authors of the book
Mars and the Earthlings: A Realistic View on Mars Exploration and Settlement.

Illustrations: Joséphine Jobard



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Executive summary

Human missions to Mars are appearing feasible and choices must be made on whether to support them. However, debates on this matter are increasingly polarized.

To support constructive discussions and sound decision-making, an interdisciplinary European group of over sixty world-renowned scientists, astronauts and science fiction writers conducted a thorough analysis of the most popular scenarios dealing with a human presence on Mars.

The outcome evidences a wide variation in the feasibility of these scenarios. It also underscores the immense value which could be produced by sensible human missions to Mars, as well as the tremendous risks they would pose if performed without adequate consideration. For instance, small-scale exploration missions could be implemented in the coming decades, while terraforming is largely beyond any technology that we can envision. Science-driven missions are worthy but picturing Mars as a fallback plan, should the Earth be devastated, is misleading and unethical.

Catastrophic breaches of ethics must be avoided without forfeiting the exploration of Mars. This requires gaining an ability to discuss the matter with nuances, relying on established scientific knowledge, considering scenarios one by one rather than as a whole, and refusing to let the exploration of Mars become a partisan issue.

A vivid debate

During his Inaugural Address on January 20, 2025, US President Donald Trump pledged that astronauts would plant a flag on Mars, once again stimulating vivid debates on the feasibility and relevance of crewed missions to the red planet. Such missions have, in fact, long been considered by spacefaring nations. In the 2018 ISECG Global Exploration Roadmap[1], landing humans on Mars is even listed as a shared driving goal.

While that goal may indeed be reached by space agencies, in partnership with private companies, there is a tendency to overpromise: distant aspirations are increasingly being presented as short-term plans. Aesthetic depictions of large settlements, or even of a terraformed Mars with oceans, fields and forests, have stimulated the collective imagination, such that one may get the impression that humanity will become – in the next few decades – a multiplanetary civilisation. Many, sensing that such visions are overly optimistic, are led to disbelief in any crewed mission to Mars. It would indeed be a mistake to take even the simplest of such missions for granted: their implementation will require vast amounts of funding and innovation. Grandiose depictions of Mars exploration are, however, not devoid of truth: humans may indeed land there, and they may do so in the next few decades.

It is crucial to question not only what can be done, but also what should be done. One may opt for an unnuanced stand:

[1] ISECG (International Space Exploration Coordination Group) is a consortium of the world's main space agencies.

that of rejecting any plan to place even one boot on Mars. Unconditional support for a human presence there could, it is true, lead to dramatic breaches of ethics, as well as the spreading of dangerous delusions – such as the belief that humanity could be transferred to Mars should the Earth be devastated by unrestrained exploitation. However, choosing never to go would mean sacrificing an opportunity for transformative scientific discoveries, internationally unifying goals, and a most meaningful endeavour.

Seeking to determine whether or not humans could, or should, go to Mars, would be addressing a question simpler than that which must be faced. All mission goals are not equivalent. Exploring, settling, colonising and terraforming greatly differ in their feasibility, their costs and their consequences. This point may be illustrated by an analogy with Antarctica. Claiming that large cities should be established on this continent would be seen as preposterous; warming it up to replace ice with crop fields would appear criminal; but few would despise Robert F. Scott for the expeditions he led there in the early twentieth century, or request the dismantlement of Antarctic stations which have a low impact on the local environment. In the case of Mars, projects equally remote from each other as these Antarctic examples tend to be conflated.

While debates around crewed Mars exploration have long been largely theoretical, recent technological advances and political commitments from competing superpowers mean that pragmatic decisions must be made. We believe that it is highly challenging for the general public to form educated opinions, and for policy makers to make informed decisions.

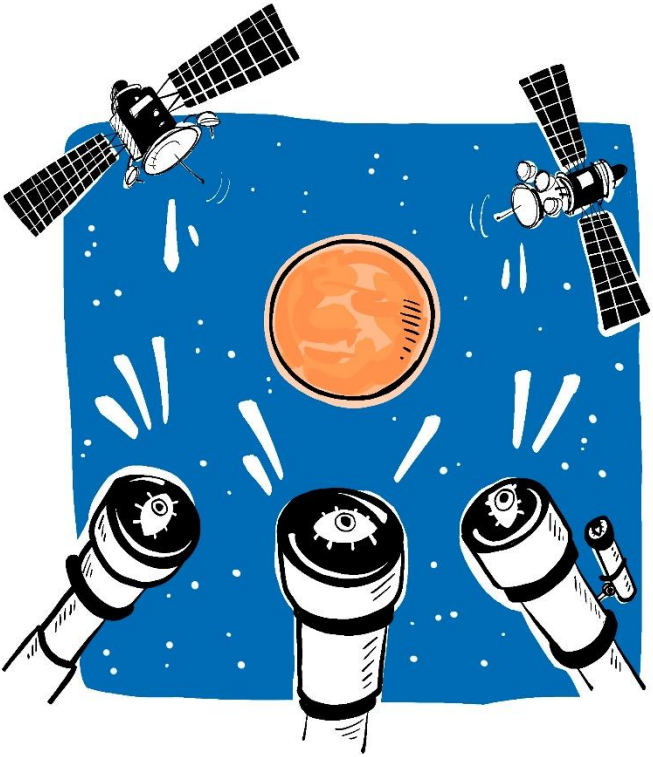
For choices to be sound, constructive discussions must be held. The latter, in turn, require unbiased overviews; but debates have become heated and unnuanced, fostering the rapid spreading of half-truths and misconceptions.

Objective assessments are direly needed and, to remediate their absence, over sixty European experts from a variety of fields including astronomy, planetology, geology, biology, medicine, philosophy, law and economics, as well as astronauts and science fiction writers, were gathered to discuss Mars missions ranging from near-term robotic expeditions to settlements and terraforming. This led to the publication of the book *Mars and the Earthlings: A Realistic View on Mars Exploration and Settlement*,[2] whose main messages are presented below.

[2] Verseux, C., Gargaud, M., Lehto, K., Viso, M. (eds). 2025. Space and Society series. Springer, Cham. doi.org/10.1007/978-3-031-66881-4

1. The Martian desert

The Martian surface is harsh but could support crewed missions, provided adequate technology is available on site.[3]



Mars formed around 4.6 billion years ago. Early in its history, this planet had a thick atmosphere, a magnetic field, and

[3] This section is based on Chapter 2: Siljeström, S. *et al.* (2024). Mars in Short: Past and Present Geology and Climate.

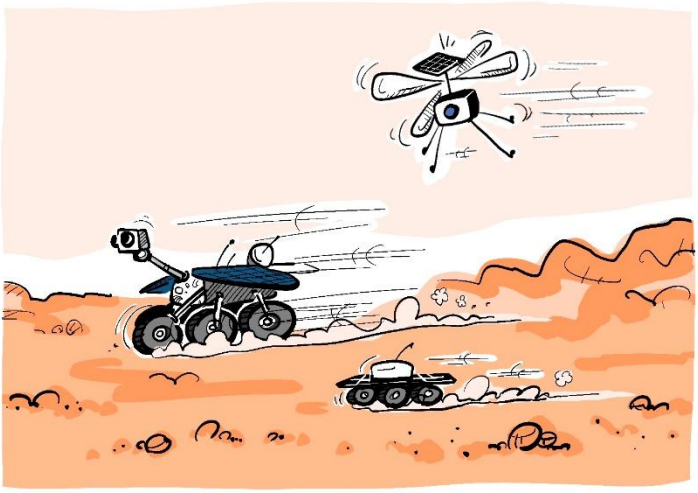
surface liquid water – conditions that may have allowed the emergence of microbial life. The surface may have been habitable until a bit over 3 billion years ago. A dramatic climate shift then transformed Mars over time into a cold, dry and barren world with a thin atmosphere and high levels of radiation.

Today's environmental conditions, while much less hospitable than those of the Earth, are still rather benign when compared to those on other planets of the Solar System. If life did exist on Mars in the past, traces may have been preserved; and it cannot be ruled out that life evolved and persisted to the present day, perhaps in the deep subsurface. This in itself warrants further exploration.

Elements from the Martian ground and atmosphere could also, provided suitable technologies are available, be turned into consumables which support human survival: breathable air, crop fertilizer, fuel and drinkable water, to name a few. A human presence over the long term could therefore be more self-reliant there than on, for instance, the Moon.

2. Robotic explorers

Robotic exploration has generated remarkable knowledge, but pressing questions remain, some of which cannot be answered without humans on site.[4]



Most of what is known about Mars has been discovered through robotic exploration. The space race led to flyby missions, orbiters and controlled landings as early as the1960s and 1970s. As of today, over 50 Mars missions, led by a range of nations (Soviet Union, United States, Japan, Europe, Russia, India, United Arab Emirates and China), have been launched. Roughly half of them have been

[4] This section is based on Chapter 3: Briones, C. *et al*. (2024). Robotic Missions to Mars.

successful and the ever-increasing performance of the carried instruments has sustained a high rate of discoveries.

These missions have been largely driven by scientific curiosity: by a desire to understand Mars's geological history and current activity, to investigate the presence and loss of a dense atmosphere and of surface liquid water, to identify and map organic compounds, and to search for traces of extinct or extant life. They have been enabled by intense, international collaboration and rapid technological progress.

Robotic missions have led to groundbreaking discoveries, some of which are summarized in the section above. Despite this, major questions remain, and definitive answers cannot be provided without humans on site: robots cannot match their versatility, mobility, dexterity, or adaptability.

3. Preserving both planets

Ethical questions pertaining to humans on Mars must be thoroughly addressed, for the protection of both planets.[5]

The introduction of humans to the Martian environments would affect the latter, and care must be taken to protect the planet from undesirable – and irreversible – consequences. The biological footprint of human activities could for instance affect indigenous ecosystems, if some exist, and extensive industries may affect a landscape which future generations would not see in its pristine state. Similarly, if Martian life exists and is brought to Earth, it may harm terrestrial life through competition, pathogenicity, or toxicity.

[5] This section is based on Chapter 4: Puumala, M. *et al.* (2024). Mars Historical and Ethical Context: Past, Present, and Imagination.

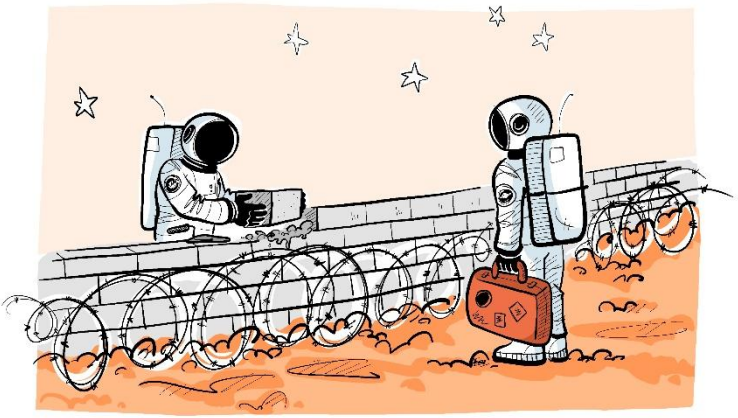
While the likelihood of such an occurrence is extremely low, its severity could be so high that it must not be neglected.

Mars is sometimes seen as a ground where a new society, free from mistakes of the past, could be seeded. While new values and norms might indeed emerge, the establishment of a human presence there would not provide an entirely fresh start: settlers would bring some of our culture and our politics. Settlements would remain connected to history, and the fate of the people on both planets will remain intertwined.

The ethical issues raised by Mars exploration may appear as distant problems, both spatially and temporally, but what humanity does in the following decades will affect generations upon generations. These issues cannot be left unaddressed.

4. Treaties and regulations

A basis exists for a legal and institutional framework regulating Mars missions, but challenges lie at both political and strategic levels.[6]



Establishing a legal and institutional framework for small-scale activities on Mars (e.g., within short stays or small research stations) does not require ground-breaking innovation. A solid foundation exists: since 1967, space activities have been governed by an international treaty ratified by almost all countries. This Treaty on the Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space (better known as the Outer Space Treaty) enshrines the freedom of peaceful space exploration and the responsibility of participants in the event

[6] This section is based on Chapter 5: Clerc, P., *et al*. (2024). Legal and International Context: Law and Disorder.

of damage to third parties. It grants protection of the terrestrial, orbital and planetary environments, and the duty of assistance between players. It forbids the appropriation and national jurisdiction over any territories in outer space, including on Mars, such that no Martian land can be claimed by any nation. Soft law also exists which is relevant to Mars missions; a notable example is the Artemis Accords, a set of agreements between the United States and other governments – 53 states have signed it so far – which regulate the exploration and use of astronomical objects.

If missions extend beyond early exploratory missions and to non-scientific activities, difficulties will arise at both the political and strategic levels, and in the need for governments and their representatives to build consensus. The main challenges will be to conceive a form of governance involving the various stakeholders, both public and private, and to supplement the Outer Space Treaty within a new international economic law. A fair balance must be found between cooperation and assistance, healthy competition between private players, environmental protection, investment, and the interests of all present stakeholders and future generations.

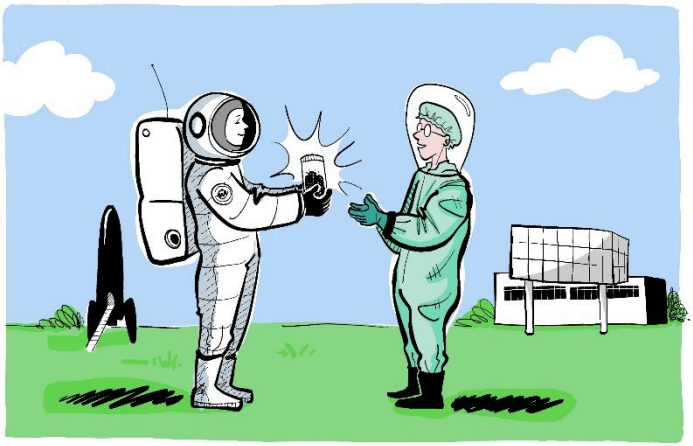
Settling Mars on a larger scale would require the establishment of local law and governance to deal with all the administrative, civil, economic and everyday life issues that can no longer be controlled from Earth.

Finally, in the scenario where a territory becomes independent of all Earth sovereignty, an interplanetary agreement between the two planets will have to be devised. Its purpose will be to manage the relations between the two

entities peacefully and in their mutual interest, as well as to promote common principles on human rights and on the rights of future generations to their shared environments.

5. Short-term missions

Short, science-oriented human missions to Mars are challenging but could be implemented in the near future.[7]



The fast progress of spacefaring technologies may soon enable human missions to Mars. The main driver may be political will, stimulated by a fierce competition between nations or groups of nations. As whoever lands first will set the tone for future activities, there is a strong political interest in reaching the red planet first (this is clearly expressed within US policy documents and is displayed as the third step of the American-led Artemis programme, but Chinese policies, though less publicized, follow a similar track) and there will

[7] This section is based on Chapter 6: Chatzitheodoridis, E. *et al.* (2024) Perspectives for Crewed Missions to Mars: Exploration from Orbit and/or Short Stay;

be a strong incentive for latecomers not to leave the winner of the race alone on Mars.

Regardless of political motivations, it is likely that the goals of early crewed missions will lie primarily in science: to advance our understanding of planetary evolution and perform unprecedented investigations on a putative Martian life. The first crewed mission will also be an important proof-of-concept, and testbed, for the preparation of later missions.

The main challenges arise from the physiological and psychological dangers and stresses caused by the environment in deep space (radiation, microgravity, vacuum) and on the Martian surface (radiation, low pressure, low gravity, unbreathable air), and by extended confinement in small habitats. While extensive knowledge has been gained in low Earth orbit, the limits of human endurance away from Earth remain unknown. Providing a suitable environment and adequate supplies of consumables requires hauling considerable payloads: it has been estimated that the first crewed mission requires at least two preceding cargo missions, each landing 25 metric tons (though the number largely depends on the exact mission architecture), while the largest rover landed on Mars weighs about one metric ton.

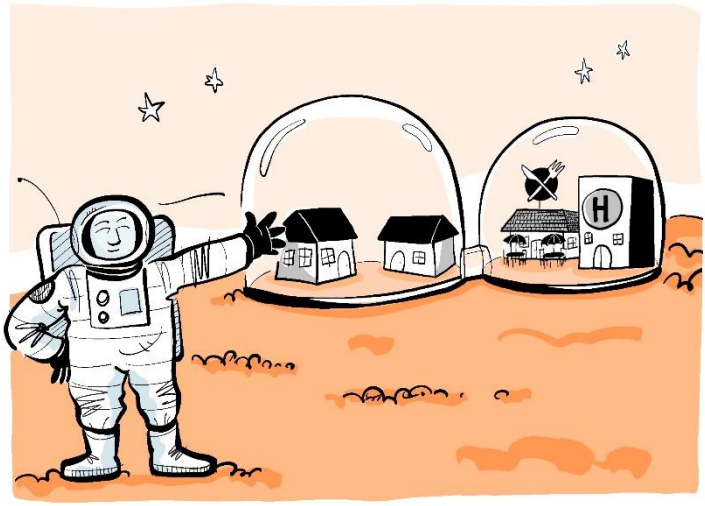
A large part of the mission costs will stem from the development, building and testing of the infrastructure; from expenses related to the technical, design and administrative personnel; and from the construction of launch facilities. Rough estimates can be obtained from previous crewed space programmes, e.g., the Apollo programme, as well as from current estimates of the Artemis programme: a hundred to a few hundred billion US dollars. This cost may seem high,

depending on one's perspective, but it is comparable to the annual revenue of the global film industry – and the monetary price of a war, or reconstruction thereafter, can be an order of magnitude higher. In addition, the costs of space technologies are rapidly decreasing due to the emergence of a profitable space economy, as well as to collaborations between public and private actors.

Ethical considerations are essential as crewed missions will involve a rather high level of danger. This level may be acceptable when involving well-informed astronauts.

6. Permanent outposts

Early missions may lead to small permanent stations whose goals extend beyond science.[8]



The first missions to Mars may be followed by longer stays and by larger crews. This will create new needs and a durable, safe and comfortable base camp will be required. Key features of such a base camp must include a radiation-sheltered habitat, reliable power sources, automated systems for the provision and recycling of life support supplies, sophisticated medical facilities, and the largely autonomous monitoring of all the essential infrastructure and their

[8] This section is based on Chapter 7: Chatzitheodoridis, E. *et al.* (2024). Mars as a Science Base: Towards a Small Permanent Outpost.

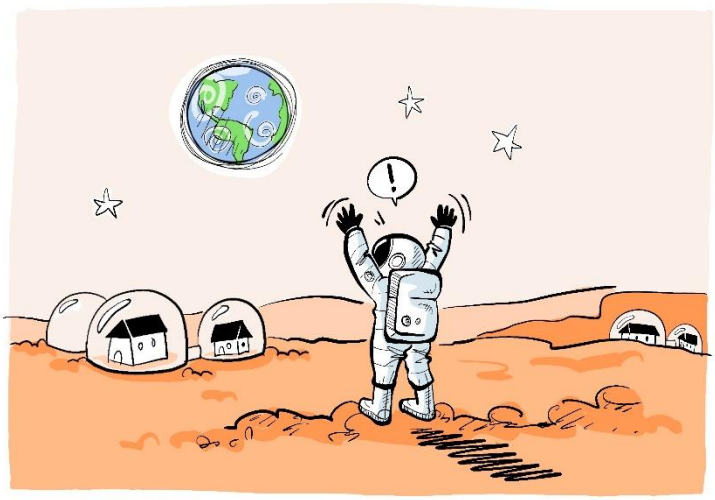
environment. The surface infrastructure may gradually develop into long-lasting stations that enable a permanent presence.

The feasibility of extended missions will be challenged by their cost. Visions for making them more economical lie in utilizing local resources as much as possible: consumables necessary for survival, notably water, oxygen and food, initially brought entirely from Earth, may be produced to an increasing proportion from local resources. This, however, requires high initial investments. The funding most likely would come from public national resources. The price tag cannot be estimated before missions are defined in more detail, but it can be expected to considerably exceed the US$ 150-billion tag of the International Space Station.

It is conceivable that small bases and settlements be established by stakeholders beyond space agencies, such as commercial actors or political alliances. While part of the mission goals will likely, at first, remain driven by science and exploration, bases may be created for different purposes. Plausible motivations include mining, construction, and the creation of military outposts. This would significantly affect the ethical, political and social issues associated with humans on Mars, and may cause complications – including conflicts – between operators. The legislation covering current space missions would not suffice as the legal framework.

7. Settlements

Permanent settlements may in principle be created on Mars, but not in the near future: extensive progress is required and numerous questions – medical, ethical, political, and societal – must be answered before such settlements are established.[9]



If early crewed outposts enable the development of adequate habitats and *in situ* resource utilisation capabilities, they may eventually evolve into small permanent settlements. Potential motivations for relocating there are diverse: serving as a member of the scientific, engineering or maintenance staff, establishing an ideological or artistic community, or

[9] This section is based on Chapter 8: Chatzitheodoridis, E. *et al.* (2024). Towards Permanent Settlements on Mars (from 1000 to 100,000 People).

becoming engaged in profitable industries – perhaps based on hydrogen fuel production or the mining of deuterium, or using the Martian surface as a home base for the exploitation of the Martian moons Phobos and Deimos, or even the asteroid belt.

While conceivable over the long term, the establishment of a permanent human settlement requires a wealth of novel technologies and extensive experience with Moon and Mars missions of a smaller scale. As an obvious example, the interplanetary journey and landing on Mars would need to become cheaper and safer, and the bulk of essential resources (e.g., oxygen, water, structural materials and produced food) should be produced on site and from local resources so little needs to be hauled from Earth.

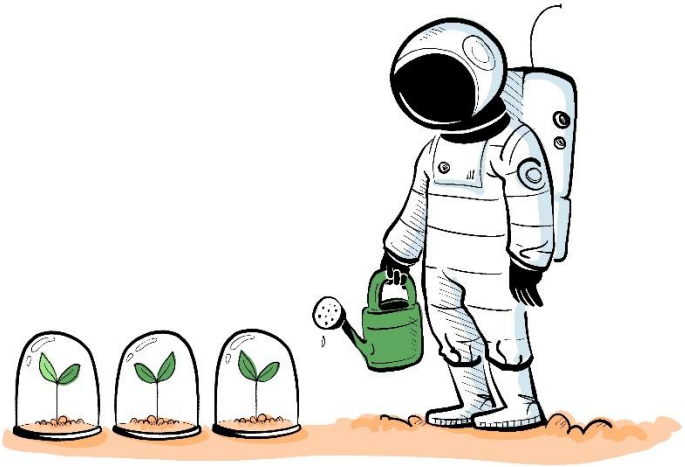
Ensuring the physical and psychological health of settlers will be a challenge greater than for the first missions: exposure times will be larger; the selection process undergone by the settlers will be less stringent than for early astronauts; and the age range will be wider. A further concern is reproductive physiology. Whether pregnancies, embryo and foetus development, and childbirth would proceed normally in the lower gravity and harsh Martian environment is currently unknown, as is the answer to the questions of whether children would develop adequately and whether they will be able to ever visit the Earth. Further questions pertain to the general well-being of the community. Education, societal, social and cultural services must be provided, which will further increase the size of the settlement. These needs, and the ethical concerns being raised should they not be met, will be exacerbated if it is found that humans are not

physiologically capable of returning to Earth after a long stay on Mars or after being born there.

Settlements will also require a legal code and governance that are adjusted to local circumstances, which promote the safety and security of the settlements and investors, and which respect the rights of all humanity – including future generations. More broadly, the identity of the settlements and their relationship with terrestrial operators, founders, and legal systems may be complex and must be considered well ahead of time.

8. Terraforming

Terraforming is not feasible with technologies foreseeable today; if it were, it should be questioned on ethical, moral and philosophical grounds.[10]



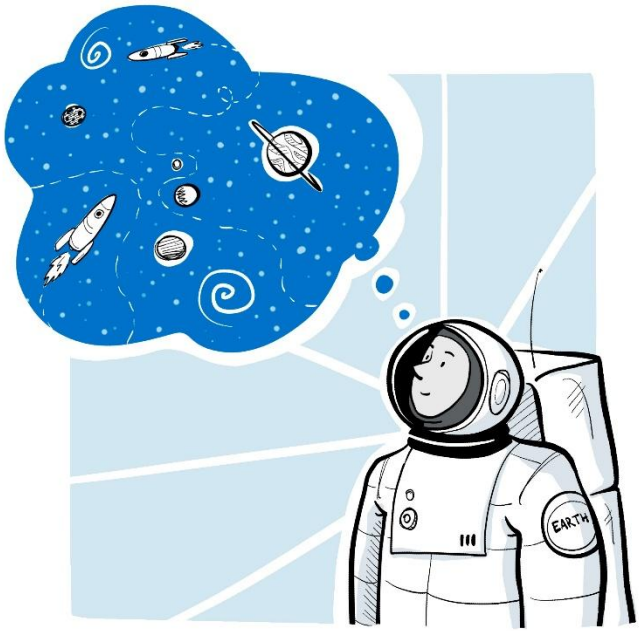
The concept of terraforming Mars – of making its surface habitable – has been popularised through fiction, essays, and publicized statements. Leading planetary scientists in the 1990s suggested a process to do so in an estimated 100,000 years or more. While plausible at the time, it appears infeasible in light of the knowledge gained over the following three decades. Other methods have been proposed; none withstands rigorous scrutiny. Terraforming cannot be achieved with any technology we can conceive of at present.

Should it become possible in a remote future, terraforming will raise vivid ethical concerns. It would, for instance, violate several principles of environmental ethics – especially if indigenous life is found. If done for the purpose of habitation, it would also bring about numerous legal and societal issues, pertaining notably to the relationships between communities on Mars and the populations, structures and rules on Earth. If performed to reduce the risk of humanity's extinction, which has been proposed multiple times within prominent public forums, it must be questioned on ethical, moral and philosophical grounds. These relate, for instance, to the selection of the individuals to be transferred there, as well as to the resources which would be drawn from the society and ecosystems of the Earth.

[10] This section is based on Chapter 9: Forget, F. *et al.* (2024). Mars as a Planet B?

9. Science fiction

Science fiction has largely contributed to the public's perception and understanding of Mars missions and will likely continue to do so.[11]

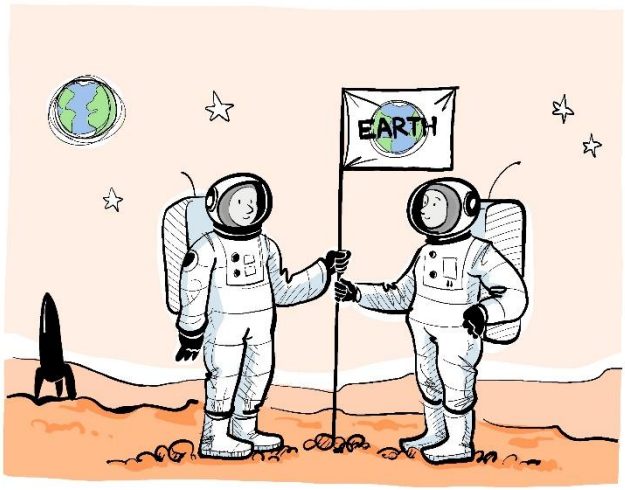


Fantasist claims made by the otherwise highly rational scientific community, and the heated debates on Mars exploration and settlement, can hardly be understood without considering the influence of science fiction on our

[11] This section is based on Chapter 10: Nováková, J.N. *et al.* (2024). Mars in Science Fiction and Our Perceptions of the Red Planet.

perspectives. One should not underestimate the role it plays in shaping the public's opinions, be they well-founded or misled. Moreover, its popularity gives it a large potential for outreach and education. Science fiction may therefore be instrumental in improving society's understanding of any crewed missions undertaken on the red planet.

A closing statement



Human missions to Mars are close to being technologically possible and practical choices must be made. At the same time, our society's abilities to hold constructive discussions on the matter are being challenged by the lack of nuances in the opinions most prominently expressed. This is aggravated by the involvement of polarizing political figures, to the extent that the prospect of such missions may come to be seen as tied to a specific political group.

In order to set the ground for constructive discussions, the authors of the book *Mars and the Earthlings: A Realistic View on Mars Exploration and Settlement*, from which the present document is drawn, conducted a thorough analysis of the most popular scenarios pertaining to the exploration,

exploitation or settlement of the red planet. The book evidences large differences in feasibility among these various scenarios. It also underscores the immense value which could be produced by well-planned and well-executed human missions to Mars, as well as the tremendous risks they would pose if led without intense scrutiny.

One important conclusion is that short, science-oriented missions could be implemented in the coming decades. The exact timescale depends on the political will of leading spacefaring nations and on their economic investment. There are a number of processes which are required and have not yet been proven, for instance landing large masses on Mars; maintaining a breathable atmosphere over the long term, and producing large amounts of fuel from Mars's atmosphere or surface elements, if there is no resupply; and ensuring adequate radiation protection. None of these seems to pose a firm barrier. Important ethical, legal and political questions must be raised, pertaining for instance to the protection of the Martian environment; but provided these are correctly addressed, missions of this scale can be justified by their inspirational, unifying and scientific value.

The need for technological development, as well as the range of the medical, ethical, political, and societal issues raised, increase greatly with mission scale. It may be that small-scale outposts akin to polar research stations withstand scrutiny and be found to be realistic and desirable. Beyond this, feasibility seems doubtful in the foreseeable future and the benefits are less obvious. Arguments have been drawn from economics but remain rather vague. Extensive efforts are also required to determine how – if at all – very large-scale missions could be performed in a way which is ethical. A definitive answer

can only be reached for a given mission type, or even a given mission scenario.

At the larger end of the spectrum of considered scenarios, answers are more definitive. It is clear that terraforming is at odds with our current knowledge of life and of Mars. When used to minimize the need to care for our planet, for instance in the face of climate change, pretending that Mars offers a fallback solution (sometimes referred to as “Planet B”) is either extremely naive or direly unethical. For decades and perhaps centuries to come, the biosphere to which humans belong will have only one home: the Earth.

This does not mean that the red planet should not be explored. If one can avoid delusions and abide by ethics, it certainly is a valuable endeavour. It may happen in a way comparable to that of Antarctica: with heroic expeditions and, perhaps, permanent research stations. One should however not take this for granted: the challenges are large and facing them will require vast amounts of resources, and not least human ingenuity. It also requires gaining an ability to discuss the matter with nuances, considering scenarios one by one rather than as a whole, and refusing to let the exploration of Mars become a partisan issue.

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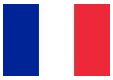

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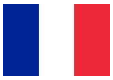

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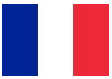

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Can we, and should we, go to Mars?

A note for decision-makers

Cyprien Verseux, Lucie Poulet, Muriel Gargaud, Nigel Mason, Kirsi Lehto, Michel Viso,
on behalf of the authors of the book *Mars and the Earthlings: A Realistic View on Mars Exploration and Settlement*[i]

Illustrations: Joséphine Jobard

During his Inaugural Address on January 20, 2025, US President Donald Trump pledged that astronauts would plant a flag on Mars, stimulating vivid debates on the feasibility and relevance of crewed missions to the red planet.

While such missions have long been on the agenda of spacefaring nations – albeit without a clear goal or determined schedule – they are now becoming technologically feasible. Pragmatic decisions must therefore be made on which mission scenarios to support, and which to push against. Unfortunately, sound decision-making is being impaired by the polarization of debates on this matter.

Over sixty renowned European scientists were gathered to discuss Mars mission scenarios ranging from near-term robotic missions, all the way to large-scale settlements and terraforming. Each was examined through a wide range of disciplines – such as engineering, biology, law or ethics – to determine what is feasible and help assess what is desirable.

Their main conclusions were gathered in the present booklet, which is intended to support the shaping of informed opinions.

Direct link to the booklet on Zenodo: https://zenodo.org/records/15607010

[i] Verseux, C., Gargaud, M., Lehto, K., Viso, M. (eds). 2025. Space and Society series. Springer, Cham. doi.org/10.1007/978-3-031-66881-4