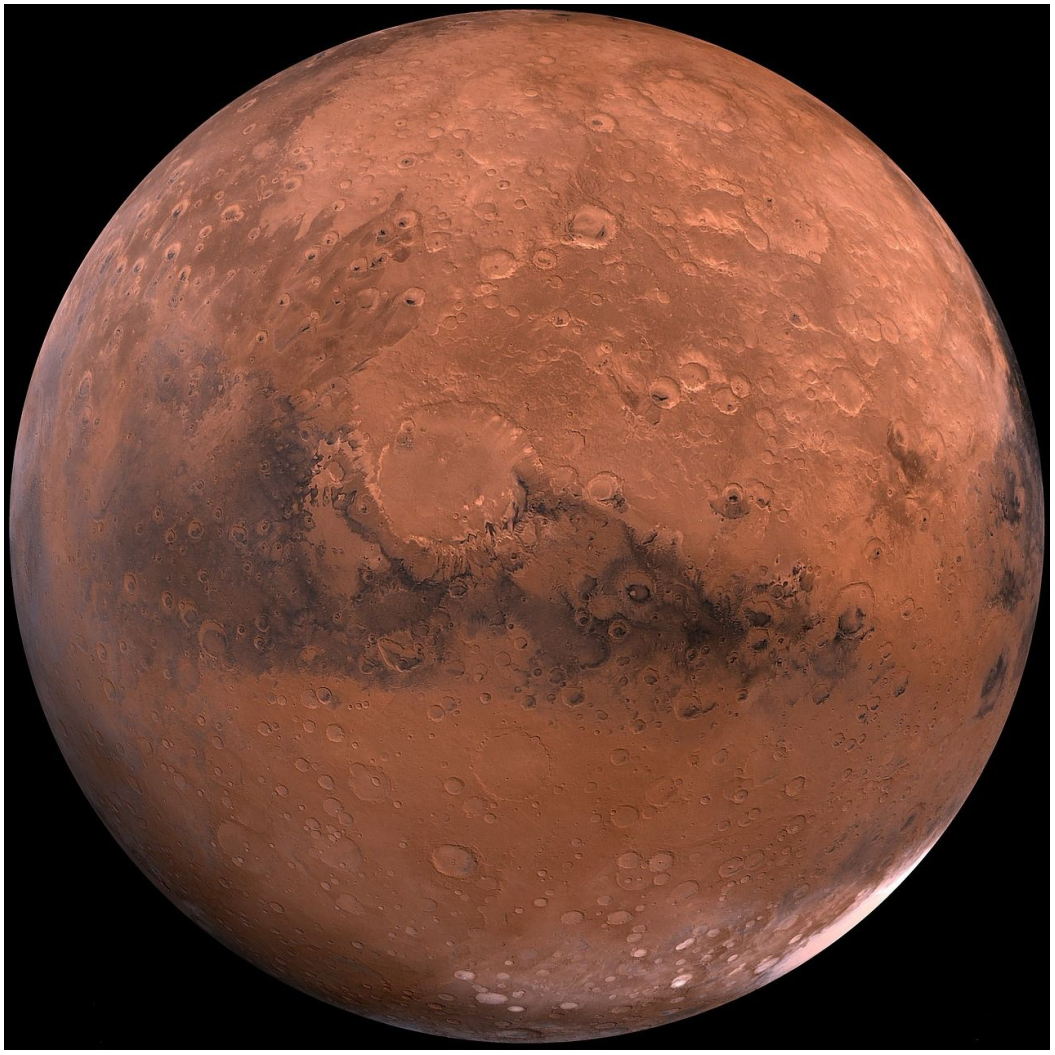
Colonizing Mars

Report by Frida Kampp, Matthew Romang, Melissa Emilie McGrail

On behalf of iGem teams PharMARSy, Project Perchlorate, Hyphae Hackers



iGem 2018

October 25-28th 2018

Table of contents

Abstract

This report examines the reasons for colonising Mars and the potential risk of contamination colonization may cause. It analysis the reasons for colonization from a historical and a rhetorical perspective, and discusses the potential risk of contamination from a bioethical perspective. In the historical analysis it is concluded that the major historical reasons for exploration of space and colonization of land on earth has been demonstration of power and eagerness to explore new land, however support from the public seems to play an important role in motivating such decisions. The main conclusion in the rhetorical analysis of argumentation in the public debate is that there are major arguments against colonizing Mars right now, that the average world citizen is likely to take into consideration. In the discussion of potential risk of contamination, it is concluded that that the risk is rather small due to extensive sterilization procedures and that it is considered unlikely that any bacteria coming from humans would be able to survive in a martian environment and thereby contaminate Mars.

Introduction

This report is a collaboration between the three iGem teams PharMARSy, Hyphae Hackers, and Project Perchlorate representing respectively the University of Copenhagen, the Technical University of Denmark, and University of Exeter.

In this report, we examine the reasons for humanity to colonize Mars and the potential risks it may cause. We are approaching the question historically, rhetorically and ethically in order to look at the subject from different angles and gain insight into the motivation for wanting to colonize Mars. We will do this in three subparts.

Part 1

First, we will investigate the historical reasons behind both exploring space by manned missions and colonization of land on Earth. We find the historical angle relevant in order to get a nuanced view of how the events leading up to a potential Mars mission may plan out. And perhaps more importantly - what the motivation for comparable events has been throughout history. From this, we will draw the conclusion that public support and opinion played an especially important role leading up to the moon landing compared to the further study of imperialism and its' causes for taking over and expanding land although the remaining arguments were similar. Here it is found that economy and countries' position of strength in a global context are crucial although it started off with more humble wishes for

local trade and missionary and that big decisions on behalf of their country ultimately have been made by the respective potentate.

Part 2

Following part 1, we analyse motivations in the public debate by analyzing 4 chosen arguments that are often found in the debate around colonization of Mars. We do this in order to shed light upon the arguments that the world citizen will meet in the media and investigate the quality of the arguments in terms of persuasion. Following this analysis we conclude that there is some major problems on earth that most citizens likely will prioritize over expanding the planetary territory. However, the major arguments against colonization is not actual arguments against colonization, but rather arguments against prioritizing colonization over current problems. Therefore we find it unlikely that colonizing Mars will gain significant public support right now, but we asses that Mars colonization will likely awake stronger opinions from the public as the technology improves thus making humanity move closer to colonization being a reality. This could either become a primary motivator or the exact opposite.

Part 3

Following our historical and rhetorical analysis, we will examine another aspect of the colonization on Mars; the bioethical concerns. If we choose to colonize Mars or any other planet, contamination will be an undeniable risk. We will examine the existing regulations in relation to the biosecurity measures needed in order to colonize Mars responsibly. Contamination could damage any potential life on Mars or the traces of life which could answer questions regarding the evolution of life on Earth. We will furthermore discuss the extent of contamination risks of colonizing Mars and whether it is ethically justifiable to do so despite the potential risk.

Part 1

What has the incentive of launching space missions been, historically?

In this chapter, we will try to answer the questions “what needs to happen for us to land a mission on Mars” as well as the imperialistic question of “how would a new space-based society work”. Although we can never truly answer these questions before the events have taken place, we will look back at how history has dealt with similar problematics in order to predict future events.

Moon landing

Firstly, we'll look at the critical events related to the first moon landing back in the 60s. Particularly how the political tension between the east and west affected the technological development. Then we will take that knowledge and try to apply it to the present day to make a prediction of how we, as a society, would find the incentive to send a space mission to Mars.

In the time after World War II, the tension grew between the east and west - particularly between the two powerful states USSR and USA. Because of this, many of the newly decolonized states chose not to ally themselves with either of the states. Where the US chose not to support the countries that weren't allied with them, the USSR supported these states as an attempt to win their affection during the cold war (Syskind, 2003). It was a time that was characterized by bipolarization and demonstration of power. One of the ways this was manifested was technologically. In 1955, both countries declared that they would send satellites into orbit. The Soviets were the first to achieve this in 1957 followed by the USA four months later. The Soviet demonstration of power only grew as they succeeded in sending a man into space in 1961. Again, the US were behind by three weeks in achieving the same. Embarrassed by the turn of events, Kennedy made a claim that at the end of the decade the USA would land a man on the moon (Space News, 2012). While several other technological leaps were made in the time leading up 1969, the space race culminated when the Apollo 11 mission landed on the moon. This has later be viewed as the end of the space race as the people's interest in space missions decreased. In 1975, however, a joint space mission indicated improved relations between the two powers (Thuren, 1984).

NASA was heavily involved in the space race. The conditions were different than usual within the association due to the political pressure of the time. As Kennedy promised to land a manned mission on the moon before 1970 on behalf of the country, he proved willing to spend the money it took to develop the technology within the given time frame increasing the funds given to NASA from 0.1% given in 1958 to 2.31% in 1969 of the total US spending hitting an all-time high in 1966 at 4.41% (Nasa budget, 2016). Because of the order given by the president of the United States as well as the pressure from the public, NASA was able to fulfil the ambition (Syskind, 2003).

From this, we can conclude that a key factor over the course of the space race was the political climate at the time. This was largely caused by division between two power nations following World War II. A driving factor in achieving the actual space mission might also have been the ambitious deadlines which led to large sums of money being spent on the respective space projects. Also worth noticing is the fact the public engagement was high.

It seems that an important element of landing a potential space mission on Mars could be a heavy motivation. It may not have to be an actual war, but demonstration of power and greatness could be a driving element. According to professor and chief consultant at DTU Space, Michael Linden-Vørnle, a Mars mission has always been "30 years away" - even today. He states that the extreme political conditions seen in the 60s, as well as the large sums of money that followed, were what made the moon landing happen. If a space agency got the command today to send a mission to Mars within the next 10 years for whichever reason, Linden-Vørnle believes that we already have the technology to make that happen. The final push may be down to motivation be that in the form of power, money, and support from the public.

Although we may make a qualified guess of how a manned Mars mission could be set into place, it is naturally impossible to predict the course of time - even when following the tendencies in society up until that point. A recent example of this could be the election of Donald Trump as President of the United States after the opposing candidate Hillary Clinton had been estimated to win throughout most of the period leading up to the election both by polls and news media's estimates (Zurcher 2016).

Imperialism

This chapter is related to the societal challenges related to sending an amount of people to habitats in space for longer time periods. Society is an ever-changing and fluent concept and can't be evaluated quite as easily as the concrete historical events of the space race. Therefore, this chapter will be largely based on historians', philosophers', and psychologists' opinions of why society is prone to expanding and even colonizing.

First of all, imperialism is essentially extending national territory by impounding other countries' territory and can be compared to extending territory to other planets like Mars, as is being discussed in this report.

There has been presented several theories of the reasoning behind imperialism. It can be useful to divide the years around the height of imperialism into phases. To shed some light on the extent of imperialism, European possessions covered 55% of the Earth in 1800, 67% in 1878 and 84,4% in 1914 (Nielsen, 1979). There are many possible phase divisions so we're going to continue with the phases suggested by English historian D. K. Fieldhouse. The following sequence is cited from Nielsen, 1979.

The period leading up to 1882 was characterized mostly by local conquests of land. Generally, the interest in expansion wasn't part of a larger plan but happened because of immediate needs such as security, local trade and missionary affiliation. The government

didn't directly take responsibility for this but could secured the responsible explorers, tradespeople etc. through treaties. This type of imperialism is referred to as informal.

In the period of 1883-1890 the way imperialism worked changed remarkably. European governments claimed almost all of Africa, Southeast Asia, and Oceania. This happened largely as a consequence of Prussian chancellor Bismarck's agenda of conquering both for domestic and foreign political purposes. Domestically, he wished for political support from nationalist liberals, foreignly he wanted to have lands to trade with other diplomats. This led to diplomats following his methods and dividing lands between them.

In the period of 1890-1914, mostly consisted of keeping the lands that was won in the previous year. Eagerness to conquer the remaining lands also defined these years.

In conclusion, imperialism was fuelled by many different intentions. In the earlier years they were more immediate and less planned out, but later they would be part of a strategic expansion of lands both for purposes such as power and trade. Lastly, diplomats became more desperate to conquer lands thus leading to great disputes between powers.

Connecting this to actual possession of Martian land is hard seeing as there are so many possible intentions for wanting to expand. The intentions defined by the earlier years of imperialism such as exploration and trade are possible contenders. In the later years, the reasons for colonizing and expanding were largely due to political manifestation of power. There are several different modern views on imperialism, one of them were defined by psychologist Alfred Adlers. He explained imperialism as "der Wille zur Macht" meaning that the main driving force of human actions is the will for power. This view was first suggested by well-renowned philosopher Friedrich Nietzsche and has later been supported by philosophers and political scientists among others (Miyasaki, 2004). While there are many potential reasons for landing space missions on Mars, it may simply be that it is an inevitable consequence of an essential human need to expand its power and to explore its abilities as suggested by Adlers' theory.

Part 2

What are the main arguments for and against colonization?

In this chapter we will explore colonization of Mars in a democratic perspective. As concluded in the previous chapter, the opinion of and the support from the democratic citizen is a crucial motivator and a determining factor for whether or not humanity decides to colonize Mars.

Therefore we will in this chapter zoom into the typically used arguments for and against colonization and take the perspective of the global citizen as a decisionmaker in the democratic society. We do that because we consider colonising Mars or not is a political decision that should be made by citizens, at least if it is funded by their tax-money, but also in terms of the making of international space laws regarding colonization, bioethics and biosafety.

In order to explore the arguments for and against colonization, we will use the well known British philosopher Stephen Toulmin's argumentation model to analyse some of the most common publicly used arguments for and against colonization of Mars. We will therefore start by explaining Toulmin's basic model of argumentation and after that we will introduce selected arguments and analyse them.

Toulmin's argumentation model

Stephen Toulmin is an academic figure overlapping classical philosophical and rhetorical disciplines. His argumentation model is focusing on practical argumentation, which makes it a hybrid between rhetorical argumentation, focused on convincing an audience and formal logic, concerned with logical validity (not to confuse with truth).

Toulmin argues that Aristotle's model of argumentation is insufficient and that the elements within the model needs to be structured, renamed and more factors need to be taken into consideration (Toulmin, 1958, s. 96). He proposes a model with three basic elements that can be considered the skeleton or basic structure of any argument. The three element will always be present in an argument (while not always being explicitly presented) (Toulmin, 1958, s. 98-102) and three constituents that can be present and helps backing up the basic elements[1] (Toulmin, 1958, 104-111).

In this analysis we will be using the basic elements of practical argumentation in order to understand some of the most used arguments in the debate on Mars colonization.

The Basic elements of argumentation

- Claim - The conclusion, e.g. "We should colonize Mars"
- Ground - The evidence for the conclusion, e.g. "Mars is a good place to live"
- Warrant - The movement from ground to claim, in this case "Colonization should be done in places that are good to live at"

[1] We do not use the constituent elements in this analysis as we have chosen to focus upon the bigger picture instead of close reading written or spoken arguments.

Practical argumentation in reality is messy - putting human interaction on form is a difficult task. We have chosen to do an analysis of the argumentation within this topic, despite the messiness, and we are therefore fully aware that there might be implicit arguments that we have missed. However if we miss them, there is a good chance that they will not be present in the minds of the average citizen.

The main arguments in the debate

The choosing of arguments in a world of rowdy deliberation is not easy either. We have done our best to find reliable popular scientific sources covering the topic and then cherry-picked what we perceived as the best arguments especially in terms of having most relevance for the general public.

Claim	Ground	Warrant
1: We should colonize Mars	One day the earth won't be livable	When planet earth is not livable, we need another planet
2: We should colonize Mars	It is the next step for humanity	We want to take humanity to the next step
3: We should not colonize Mars	It is too expensive	Economy should be a concern when making decisions
4: We should not colonize Mars	We have problems that needs to be fixed on our current planet	Finding solutions to current problems should be prioritized over expanding our territory.

1. The first argument is answering the claim "We should colonize Mars" with the ground "One day the planet earth won't be livable", and therefore has the warrant "when planet earth is not livable, we need another planet". The argument is concerned with homo sapiens long term survival as a species, which might become an increasingly relevant discussion as climate change threatens future generations. It is often explicited by Mars colonization front runners such as Elon Musk and Stephen Hawking. According to Olivia Solon, Elon Musk argues that "Humans must prioritise the colonisation of Mars so the species can be conserved in the event of a third world war" (Solon, 2018), He furthermore states that the Moon is not far enough from Earth to make sure that it will survive if something should make the earth inhabitable (Solon, 2018). Hawking is equally worried about the future of our species as he

states that humanity has to become a multiplanetary species within the next hundred years, in order to prevent extinction (Fecht, 2017). Though it might seem obvious that the survival of our species is a weighty topic, it might not be very central in the daily life of most people. As we have seen with the last forty years of activists and scientist trying to convince people to make actual changes in their lives in order to prevent damaging our planet, most people are not very oriented towards changing their behavior for long term purposes. Therefore this is an argument that might be convincing in terms of intellectual decicion-making, but also might not convince normal people to invest in the project. The argument says implicitly that the human species should be concerned with long term survival and even though that might seem obvious to many people, it could also be questioned. It is quite normal for a lot of species to extinct at some point, we (humanity) have been the course of many species extinction historically - so maybe it is ok that we will not be here forever. While the argument might be intellectually convincing to people who already is accepting the premise that the (very long term) survival of the human species are important and that Mars can function as a new planetary home, it might not make them donate significant amounts of money or vote for a more Mars positive politician.

2. The second argument is answering the claim "We should colonize Mars" with the ground "It is the next step for humanity", thereby the warrant is "We want to take humanity to the next step". This argument is concerned with scientific development and development as a species. It is often more or less implicit and also sometimes links to an argument that implies that going to Mars will enable technological innovation.The argument is e.g. found on the popular spaceblog *Astronotes,* according to *them* "Mars is the next big colonisation step. We've been to the Moon, and there are plans for the Moon in the future, however Mars is the place we have our sights set on as our next habitat. I know what you're thinking. Why? Why would anyone leave the wonderful comfort of our own planet, with internet, good food, family and friends? For the adventure of course!"

If we look at Maslows hierachy of needs (Khanacademy, 2013), this is in argument that only speaks to the people that is in the absolute top of the pyramid. However not all members of our species are this priviliged, so it cannot be the next step for our species, it can only be the next step for the elite. It might seem slightly paradoxical to see the human species as a whole using a "we" that implicitly includes everyone, while at the same time not seeing (or at least taking into consideration) that a very big part of this "we" actually hasn't come anywhere near this development step. However this might be one of the arguments that is very effective, not for convincing people who are not already interested in the topic, but for justification between people who are already in the top of the hierarchy of needs.

3. The third argument is answering the claim "We should not colonize Mars" with the ground "It cannot be justified economically", and therefore the warrant "We want to be able to economically justify what we do". The argument can e.g. be found in the article "All the reasons humans shouldn't colonize Mars, according to experts" by Brad Jones on the site

Futurism. Jones states "One of the biggest obstacles standing in the path of a human colony on Mars is the price tag. Getting to Mars will be prohibitively expensive, and figuring out a method of paying for the project isn't so easy." This argument is focused on economy and takes a rather practical approach. It However it doesn't take into consideration who's paying and what their motivation might be, and that is an unknown factor. In case the majority of human beings simultaneously decided to donate decent amounts of money voluntarily, it might help a lot, but that will only happen if there is another great motivation. Therefore this argument is mostly an acknowledgement of the fact that there has to be another major motivation for going to Mars than money and that we might be more motivated to spend our money on other things at this point.

4. The fourth argument is answering the claim "We should not colonize Mars" with the ground "we have problems on earth that needs to be solved" making the warrant "We should not expand our territory when we have problems on earth". This argument is focused on prioritizing. It isn't really an argument against colonization as much as it is an argument against colonization right now. As Zahan Bharmal writes in the article "The case against Mars colonization" in the British media The Guardian "The most polarising issue in the Mars debate is arguably the tension between those dreaming of a second home and those prioritising the one we have now." (Bharmal, 2018) He furthermore points out that " ...if we have not figured out how to deal with problems of our own making here on Earth, there is no guarantee that the same fate would not befall Mars colonists." (Bharmal 2018). A similar perspective can be found in the article "Before we colonise Mars, let's look to our problems on Earth"(Glikson, 2017) on the website Phys-org. In the article Glikson states that "Given the problems we face here on Earth it's important to ask whether we should be better tasked with looking after the only planet we know (so far) that can harbour life." (Glikson, 2017) he furthermore argues that the idea of colonising other planets are misleading because "It yields an impression in many people's mind that an alternative exists to Earth, a unique (so far) haven of life in the Solar system, currently suffering from global warming, rising oceans, extreme weather events, mass extinction of species and growing risk of nuclear wars." (Glikson, 2017). This argument is not really an argument that is universally against colonization of Mars, but is rather an argument against colonization of Mars as a priority right now. We asses this to be a strong argument in terms of persuasion of the public, as the international medias are focussing a lot on poverty, climate challenges and other undeniably comprehensive problems for humanity.

We find that economy and priority proves to be very relevant and weighty arguments arguing against colonization of Mars in the near future, and we therefore asses that these will be taken into serious consideration by the average citizen. However they are not really arguments against colonization as a concept as much as they are arguments against colonization as a priority right now. Therefore we find it unlikely that the wish to colonize Mars will gain significant public support right now. However in the future, as technology improves and the realisation of colonizing Mars moves closer, and the current mayor problems for humanity

hopefully takes an end the topic might gain more public interest and awake stronger opinions and more engagement from the public. The result of this could either become a primary motivator for colonization of Mars or the exact opposite.

Especially argument nr 2, can be related to some of the major motivations for colonizing land historically. When looking at the massive expansion and possession of land throughout the era of imperialism, it has later been speculated if the need to possess, explore, and expand is a fundamental human need. As has the argument "it's the next step for humanity" also found its way into the debate on whether or not we should colonize Mars. However it is worth thinking about that it is not all of humanity who has come to this step, just as the explorers of "unexplored" land often seemed to ignore that there were people living there already. We might be forgetting that there are lots of people on our planet who are on the lower steps in the hierarchy of needs as theorised by Maslow and who does not have the privilege of thinking about the next step for humanity. While that is not an argument against colonization of Mars, it is one for consciously prioritizing our resources and choose the right time to colonize and the argument of demonstrating political power isn't favorable for the good of humanity as a whole.

Part 3

What are the ethical implications for colonization and transport of biomaterial?

Contamination risk and space travel

Another important aspect of potentially colonising Mars, is the consequences it might have for our ability to investigate life on Mars if we contaminate the planet with life forms from earth. In this chapter we will therefore shed light on safety procedures regarding sterilization techniques and discuss whether they are sufficient for avoiding contamination and if the potential risk of contamination is worth taking.

The use of genetically modified organisms (GMO) is a controversial topic terrestrially, with concerns over their interactions with wild organisms and unknown long term impacts upon health. It is therefore logical that there would be even graver concerns with using GMOs in space, an environment where terrestrial life is largely untested and the bacterial reaction to microgravity is poorly understood. There is recent evidence that bacterial response to microgravity could even be considered dangerous due to its persister like reaction making it highly antibiotic resistant.

However, the use of GMOs is now considered a possible solution to many of the issues currently impeding further space travel. For instance, NASA are currently exploring the use of genetically modified algae in integrated life support systems and the use of GMOs to synthesise useful materials for constructing and maintaining habitats is widely documented.

In order to facilitate the expansion of synthetic biology into the extra-terrestrial arena there would need to be a paradigm shift in the legal framework surrounding GMO use and reconsideration of the function of planetary protection laws. Comprehensive risk-benefit analysis would need to be undertaken in order to rework any legislation, compensating the risks of cross contamination with highly efficient life support systems and habitat creation. In this chapter we will examine the current regulations governing space exploration in order to understand the current scope for the use of GMOs extra-terrestrially and subsequently identify whether any changes would need to be made.

Regulations governing GMOs in Space with specific reference to Mars

Mars poses a unique risk when considering contamination. Life has yet to be found on Mars and as such we have no idea how it would interact with terrestrial organisms or even if it uses DNA as genetic material. As such it could pose a unique danger to human life as is often popularised in the media. However terrestrial life could also pose a unique threat to it, our highly sophisticated immune defence systems and the array of microorganisms we bring with us could feasibly completely outcompete any life that there is on Mars. This could deprive us of the opportunity to study a completely new tree of life and answer questions on how life originally formed on our own planet.

The laws governing exploration of outer space were set out in the United Nations Outer Space Treaty of 1967 and set out the framework from which more recent regulations have expanded upon (UNOOSA, 2018). Key to our report are the principles stating that

- ‘States shall be responsible for national space activities whether carried out by governmental or non-governmental entities’
- ‘States shall be liable for damage caused by their space objects’
- ’States shall avoid harmful contamination of space and celestial bodies.

These three principles determine that any GMOs employed in space are the responsibility of the State which deploys them, regardless of whether it is a commercial or a governmental expedition. Any damage caused by GMOs are the responsibility of the State, COSPAR (The committee on space research council) has expanded this to include potential damage to native life on foreign bodies (COSPAR, 2008). Which especially relates to the third principle regarding contamination, the biggest argument against utilising GMOs in space exploration. To avoid infringement of these three principles of The Outer Space Treaty, international

space agencies such as NASA and ESA operate under the Planetary Protection Protocols, overseen by COSPAR.

Planetary Protection Protocols

NASA has made protocols for planetary protection (PPP) which categorises each Mission depending on both the type of planetary body and the mission type. The design of the PPP for Mars are based on a two way system, firstly that no terrestrial organic material will come into contact with the Martian Biosphere and secondly that no Martian organic material will come into contact with the Earth's biosphere. These categorisations are determined by the Space Studies Board and international policy guidelines. Missions are categorised I-V and the cleanliness of the spacecraft will depend upon the category the mission is given. For example a category V mission will undergo more sterilisation procedures than a category I mission.

Whilst all of Mars is considered significant in terms of planetary protection, as referenced in category IVc missions (NASA, 2018), there is a system of regions of special interest on Mars called 'Martian Special Regions'. COSPAR defines a special region as 'areas on Mars where terrestrial life may have the potential to proliferate if introduced' (National Academies of Sciences, Engineering and Medicine, 2015). In 2013 the special regions science analysis group (SR-SAG2) was established to update the areas of Mars defined as 'special regions' based upon the latest discoveries of both the martian surface and extremophile organisms (Rummel et al, 2014). The report was reviewed by both NASA and the ESA before being published in 2014. The main finding of the report was to add methane sources to the physical parameters indicating a special region due to the potential association between methane seepage and ancient or extant microbial metabolism (Oehler et Etiope, 2017).

Current sterilisation techniques employed by space agencies

Sterilization techniques are employed by space agencies such as NASA in order to minimise the contamination of a spacecraft. The extent of the sterilization depends on the mission category. Category V missions must detail their plans for safeguarding Earth's biosphere from extra-terrestrial contamination, the two way containment system. The current sterilisation techniques employed revolve around a series of clean rooms, sterile rooms in which all particles entering the room are strictly controlled to create microbial barriers. (Frick et al, 2014) Followed by chemical cleaning and sterilisation to prevent recontamination and mission planning to prevent heavy impacts and contamination of solar system bodies (NASA, 2018). Bioburden assay methods are also employed to ensure effective sterilisation has occurred and no sporulating bacteria have survived (Lundin, 2000) (Venkateswaran et al, 2003)

Mission categorisation also determines what sections of spacecraft need to be cleaned, for example for landers or rovers where only certain parts of the machine are exposed to the surface, only these parts must meet the required contamination protocols (NASA, 2013) . This assumes that the internal sections were sterilised and assembled in a clean room of category ISO class 8 or above (Connect2cleanrooms, 2018).

Whilst these methods are used within a sterile environment, spacecraft are launched from open air launchpads thereby challenging planetary protection through recontamination (Bernardnill et al, 2014). In order to prevent recontamination spacecraft are specially packaged to prevent contact with microbes in the open air environment (Frick et al, 2014). This process can include, deployable biobarriers, filtration systems reducing particulate transport, overpressure approaches and assembly techniques (Hogan et al, 2006). Recontamination is the most difficult part of ensuring sterilisation for spacecraft whilst they are launched from Earth and different techniques are required for different stages of launch and different parts of the craft.

These prevention methods are designed to minimise contamination of not only Mars but other icy satellites including Ganymede, Enceladus and Europa. Contamination is believed to be a high risk upon impact with planetary surfaces and in order to minimise this, trajectory corrections and biases are used to lower the probability of contamination (NASA, 1997). These trajectories primarily ensure that there is no chance of impacting upon or contaminating liquid bodies of water.

Risk of GMOs on Mars

The extensive sterilisation protocols put into place by space agencies such as NASA means that unwanted contamination is minimised, thus the chances of interactions between GMOs and terrestrial bacteria are minimised.

The main risk of contamination of Mars would come from humans themselves. Humans contain a rich microbiome containing many species of bacteria, the majority of which live in the gut but also inhabiting the mouth and the surface of the skin. These bacteria would be much harder to contain and prevent contamination of special regions on Mars. However these bacteria are also highly evolved to live in the habitat that humans provide; warm and with high volumes of liquid. Therefore these are not the extremophile bacteria that would be able to survive on the martian surface or sporulate and lie dormant on the surface until suitable conditions presented themselves.
So whilst contamination of the martian surface could be a possibility from manned missions to mars, colonisation of the surface by such bacteria is unlikely due to the conditions presented by the Martian surface itself.

Lastly the Martian surface is believed to be inhospitable for many bacteria to survive and as such any native microorganisms are believed to be deep sub-surface colonies, as has been theorised by Professor Charles Cockell (Cockell et al, 2018). This means that whilst we should aim not to contaminate the surface of Mars with terrestrial organisms, even if it should happen, it is unlikely that they would interact with the Martian Biosphere and thus any martian organisms which we found would be left intact.

The low probability of bacterial degradation of native Martian organisms does not negate the concept of planetary protection, which is irrefutably crucial, since the opportunity to reduce contamination risks wherever possible is necessary to preserve the untouched martian biosphere. Considering this, a trade off must be made as to whether the risk of GMO contamination is worth taking in order to advance knowledge of Mars and further explore the possibility of colonization.

Benefits of GMOs on Mars

Genetic modification is a viable method for optimising organisms for human benefit. On Earth we use genetic modification for a wide range of reasons, ranging from insulin production in diabetics to pesticide resistance in crops. It is accepted that it would be difficult for humans to survive on Mars, even for a small, well equipped research group. Genetically modifying organisms could help to alleviate many of these problems.
NASA is already researching how algae could be used to develop closed system life support for the astronauts on Mars and expanding upon the principle of insulin production, we could feasibly create many other chemicals which would help humans stay on Mars for longer periods of time (NASA, 2015). These processes would need to happen in tightly regulated, enclosed environments to ensure contamination risks are minimal. Furthermore Mars has many natural resources which could make these processes highly sustainable, for example perchlorate salts or natural minerals such as Magnesium or Potassium found in the Martian regolith which could be used by bacteria to produce products useful for humans (Space.com, 2017).

In a way the methods of surviving on Mars are similar to the methods of cultivation practices by stone age humans. We use the technology available to us to help us survive in new environments and stay for longer periods of time. Whereas we once used selective breeding to select for desirable traits we now use molecular Biology to insert desirable genes into target organisms so that we may survive in a more hostile environment.

Conclusion

The overall question in this report has been “why colonize Mars?”. In three parts, we have tried to cover the question from different angles in order to give an informed answer.

In part 1, it was made clear that similar events have happened historically and that a general motivating factor for both the space race and imperialism has been to demonstrate political power. Another important conclusion to be drawn from is that attention and support from the public has a big effect in what decisions get made on behalf of a country. As seen previously during the space race, once the attention of the public drops, so does the government’s funding and consequently the development within that field.

In part 2 we conclude, that there are some major problems on earth at this point that many people will likely find more urgent than colonizing another planet. However as technology moves closer and hopefully some of the important problems on earth will be solved, it is likely that the question of colonising Mars will gain more interest and more people will get involved in the discussion.

In part 3 we discuss whether colonizing Mars requires taking a significant risk in terms of contaminating the planet. We find that the risk is rather small due to extensive sterilization procedures and that it is considered unlikely that any bacteria coming from humans would be able to survive in a martian environment and thereby contaminate Mars. However there is a risk and that risk is important to take into consideration when deciding whether or not to colonize Mars.

Perspective

During this report we've approached the overall question of space colonization - specifically in relation to Mars. Will we colonize, why will we colonize, and how will we colonize? This was done as an attempt of exploring the relevance of our universities' contributions to the annual iGem competition which are all space-related and should be used in the context of space travel. The project by the Technical University of Denmark deals with mycotecture in space by making a building material of mycelium which has been modified to suit extreme environments. Although the material could be used terrestrially, the aim is for it to be applied on planets like Mars and it is therefore relevant to explore the prospects of Mars travel becoming a reality. The project by the University of Copenhagen is aiming towards making a portable system for protein production that can provide future Mars habitants with protein drugs when they need them. The system allows for producing and purification in one step, and therefore requires way less resources than conventional protein production. The system for protein production and purification can be used terrestrially as well, but the aim for it is that it should be applied for long term space travel and colonization of e.g. Mars due to it's portability. The project by the university of Exeter focuses on eliminating perchlorate from the martian surface by using genetically engineered bacteria with perchlorate and chlorite reducing enzymes that breaks down the compounds into oxide and chloride.

These projects are targeted at making Mars colonization a reality by offering sustainable solutions for living. None of our projects rely on fossil resources as these are generally not encouraged in today's society and assumably not in a Mars colony either. As seen from a practical angle, it would not be favorable to have long lines of transportation from Earth to Mars, so coming up with a self-sustainable solution has been prioritized in all three projects.

References

BenardiniII. James N. Myron T. La Duc, David Ballou, and Robert Koukol. 'Methane Seepage on Mars: Where to look and Why.' Astrobiology.Jan 2014.ahead of print, http://doi.org/10.1089/ast.2013.1011

Bharmal, Zahan 2018: "The case against Mars colonization" (last visited 1/10/2018) https://www.theguardian.com/science/blog/2018/aug/28/the-case-against-mars-colonisation

Cockell CS, Holt J, Campbell J, Groseman H, Josset JL, Bontognali TRR et al. 'Subsurface scientific exploration of extraterrestrial environments (MINAR 5): analogue science, technology and education in the Boulby Mine, UK.' International Journal of Astrobiology. 2018 Jul 2;1-26. Available from, DOI: 10.1017/S1473550418000186

COSPAR, 'COSPAR planetary protection policy' (2008) http://w.astro.berkeley.edu/~kalas/ethics/documents/environment/COSPAR%20Planetary%20Protection%20Policy.pdf

Desai, Shreena 2013: Maslow's Hierarchy of needs (last visited 8/10/2018) https://www.khanacademy.org/test-prep/mcat/behavior/physiological-and-sociocultural-concepts-of-motivation-and-attitudes/v/maslows-hierarchy-of-needs

Fecht, Sarah 2017: "Stephen Hawking says we have 100 years to colonize a new planet - or die. Could we do it?" (last visited 1/10/2018) https://www.popsci.com/stephen-hawking-human-extinction-colonize-mars

Frick, A. F. et al. Overview of Current Capabilities and Research and Technology Developments for Planetary Protection. Adv. Space Res. 54, 221-240 (2014).

Foto, M et al. 'Modification of the Limulus amebocyte lysate assay for the analysis of glucan in indoor environments.' Anal. Bioanal. Chem. 379, 156-162 (2004)

Glikson, Andrew: 2017 "Before we colonise Mars, Let's look to our problems on earth" (last visited 1/10/2018) https://phys.org/news/2017-12-colonise-mars-problems-earth.html

Jones, Brad 2017: “All the reasons why humans shouldn’t colonize mars” (last visited 1/10/2018) https://futurism.com/humans-shouldnt-colonize-mars-experts/

Hogan, J.A., Race, M.S., Fisher, J.W., Joshi, J.A., Rummel, J.D. (Eds.), ‘Life Support and Habitation and Planetary Protection Workshop: Final Report.’ National Aeronautics and Space Administration, NASA/TM-2006-213485, 2006.

Lundin, A. Use of firefly luciferase in ATP-related assays of biomass, enzymes, and metabolites. Methods Enzymol. 305, 346-370 (2000).

Morris, H. C., Monaco, L. A., Steele, A. & Wainwright, N. ‘Setting a standard: the limulus amebocyte lysate assay and the assessment of microbial contamination on spacecraft surfaces.’ Astrobiology 10, 845-852 (2010).

NASA (2018) ‘Biological Contamination Control for Outbound and Inbound Planetary Spacecraft (Last visited 12/10/18) https://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PD_8020_007G_&page_name=main&search_term=contamination

NASA (2015) ‘Characterizing Biological Closed-Loop Life Support Systems for Thermal Control and Revitalization of Spacecraft Cabin Environments’ (Last visited 12/10/2018) https://www.nasa.gov/feature/characterizing-biological-closed-loop-life-support-systems-for-thermal-control-and

NASA (1997) ‘’Mars Pathfinder Navigation’ (Last visited 12/10/18) https://mars.nasa.gov/MPF/mpf/mpfnavpr.html

NASA (2018) ‘Mission categories’ (Last visited 12/10/18) https://planetaryprotection.nasa.gov/categories

NASA (2018) ‘Mission requirements’ (Last visited 12/10/2018) https://planetaryprotection.nasa.gov/requirements

“Nasa budget: US spending on space travel since 1958 UPDATED”. (2016). (last visited 10/10/2018) https://www.theguardian.com/news/datablog/2010/feb/01/nasa-budgets-us-spending-space-travel#data

National Academies of Sciences, Engineering, and Medicine. 2015. Review of the MEPAG Report on Mars Special Regions. Washington, DC: The National Academies Press. https://doi.org/10.17226/21816.

No author stated (will be referred to as 'Connect 2 Cleanrooms') (2018) ISO 14644-1 Class 8 Cleanroom Classification Guidelines' (Last visited 12/10/18) https://www.connect2cleanrooms.com/knowledge-base/iso-14644-1-class-8-cleanroom-classification-guidelines

Oehler, Dorothy Z. et al. Astrobiology. Dec 2017. Ahead of print, http://doi.org/10.1089/ast.2017.1657

Rummel, John D. et al. Astrobiology. Nov. 2014. Ahead of print. http://doi.org/10.1089/ast.2014.1227

Skovgaard Nielsen, Henrik (1979): Imperialismen 1870-1914, column 34-45, 113-118, 127-131. Gjellerup

Solon, Olivia 2018: "Elon Musk: We must colonise Mars to preserve our species in a third world war" (last visited 1/10/2018) https://www.theguardian.com/technology/2018/mar/11/elon-musk-colonise-mars-third-world-war

Space.com (2017) 'What is Mars Made Of? | Composition of Planet Mars' (Last visited 12/10/18) https://www.space.com/16895-what-is-mars-made-of.html

Space News et al. (2012): "Timeline: 50 Years of Spaceflight" (last visited 10/10/2018) https://www.space.com/4422-timeline-50-years-spaceflight.html

Syskind, Casper et al. (2003): Det 20. århundredes verdenshistorie: Fra den industrielle revolution til i dag, chapter 12, page 125-137. Systime

Tateshi Miyasaki, Donovan (2004): " Freud *or* Nietzsche" (last visited 10/10/2018) http://www.academia.edu/531928/Freud_or_Nietzsche_The_Drives_Pleasure_and_Social_Happiness

Taylor, Heather 2017: "Colonising Mars, the next big step for humanity" (last visited 1/10/2018) http://www.armaghplanet.com/blog/colonising-mar-the-next-big-step.html

Thurén, Torsten (1984): Kold krig og fredelig sameksistens: Stormagtspolitikken 1945-1984, chapter 3, 4, page 51-69. Munksgaard

Toulmin, Stephen (1958) : The Layout of arguments, I: The uses of argument, chapter 3, page 94-145. Cambridge University Press, Cambridge

United Nations office for outer space affairs (2018) 'Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies' (last visited 12/10/2018)
http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html

Venkateswaran, K., Hattori, N., La Duc, M. T. & Kern, R. 'ATP as a biomarker of viable microorganisms in clean-room facilities.' J. Microbiol. Methods 52, 367-377 (2003)

Zurcher, Anthony 2016: "US election: Is Trump or Clinton going to win?" (last visited 10/10/2018)
https://www.bbc.com/news/election-us-2016-37884603