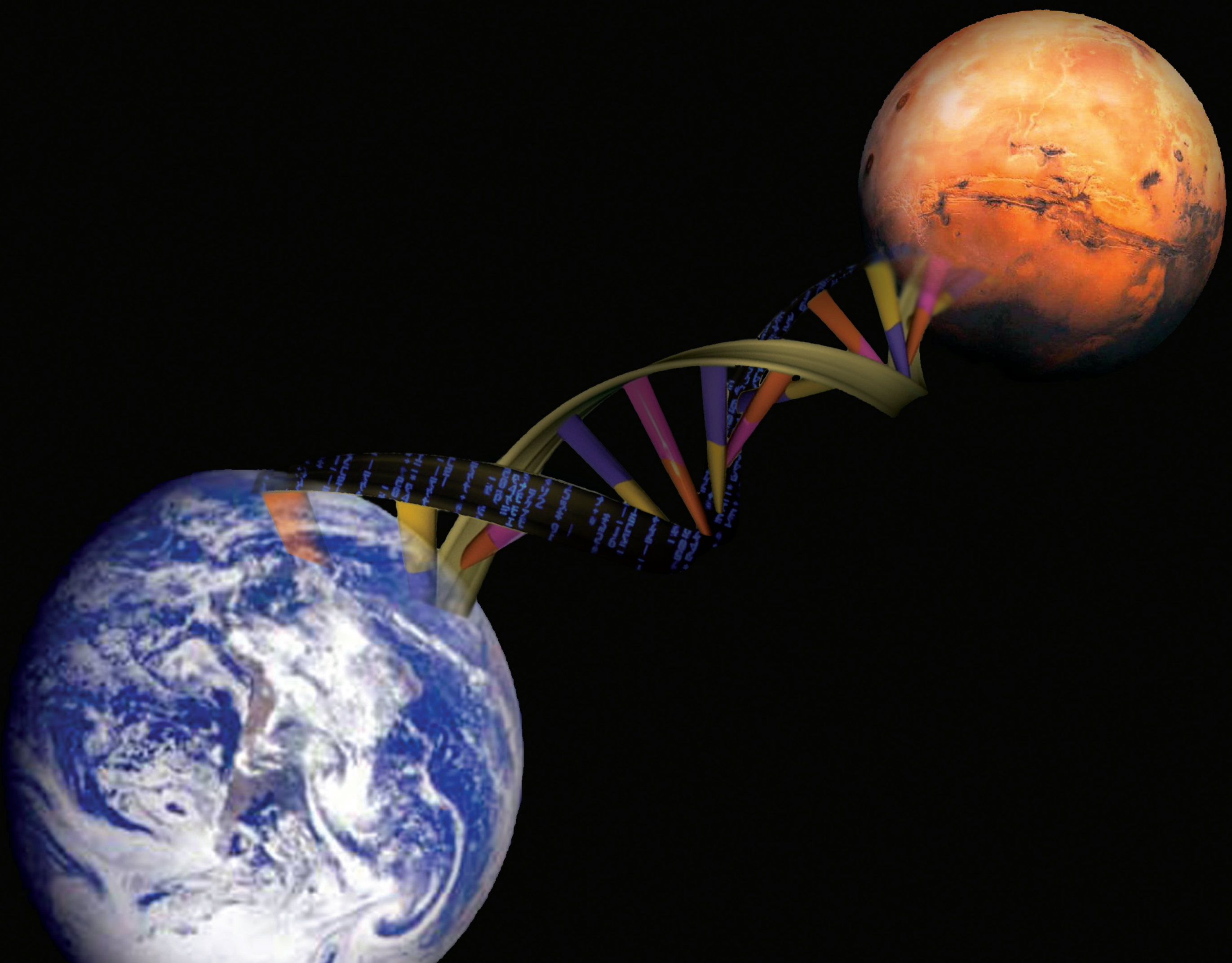
VISYSPHERE MARS

TERRAFORMING MEETS ENGINEERED LIFE ADAPTATION



EXECUTIVE SUMMARY

MSS/MSM 2005

INTRODUCTION

This project is a collaboration of 22 students from the M.Sc of Space Studies and M.Sc of Space Management programs, class of 2005, at the International Space University. The authors came to this project from 6 continents and with backgrounds in 20 distinct disciplines.

This report follows from a comprehensive, critical analysis of the relevant theories regarding the multidisciplinary aspects of terraforming; which is the act of forming another planet to be more like Earth so that humans can live there.

Mission Statement:

"To solve some of the critical issues necessary to establish a selfsustaining system for humanity on Mars by the end of the century, using terraforming techniques in conjunction with engineered life adaptation."

	Terraforming	Engineered Life Adaptation		
	Atmosphere	Biosphere	Technosphere	Noosphere
2000			ISRU on Mars	
2010				Acting for the wellbeing of all sentient beings
2020				Mars convention
2030			Brainwave augmentation and machine learning	
2040		Medical care and immunological treatments	Mechanical counter-pressure space suits	Development authority
2050	PFC production: increase greenhouse effect of atmosphere	Biochips and neural implants	Modular robotic vehicle	
2060				Transhuman philosophy
2070	Asteroid impact: reduce albedo of South pole		Habitat domes	
2080				
2090	Biological seeding: develop atmosphere via an uncontained biosphere	Engineered pioneer microorganism	Wearable life support system	

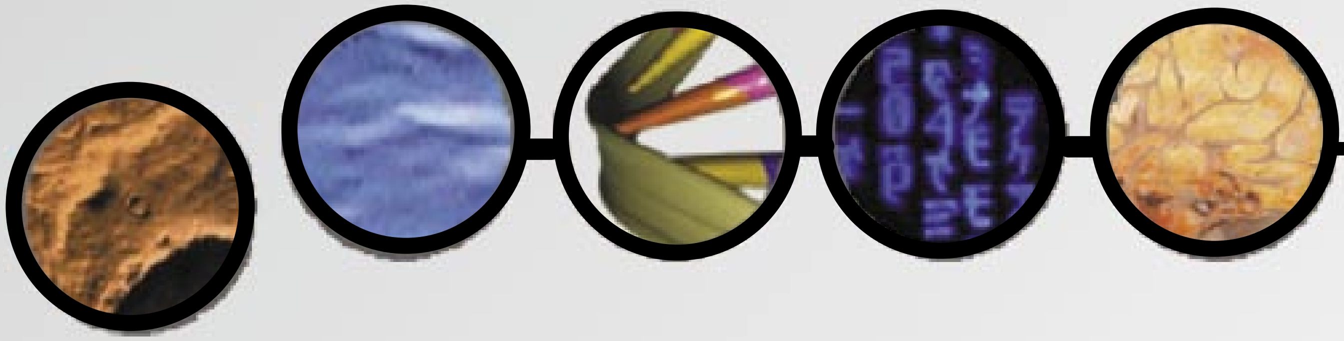
Project timeline

What is a Visyphere?

A new concept, the 'visysphere', was developed by the team to describe a self-sustaining system that could support human life in space.

The concept of the global spheres on Earth, such as the geosphere (areosphere for Mars), atmosphere, hydrosphere, biosphere, technosphere and noosphere, were used to categorize the systems needed to sustain human life. The sum of these spheres is a visysphere.

Drawing upon current technologies and ideas from each sphere here on Earth, this project presents integrated solutions to terraforming and settling on Mars within this century. To allow for in-depth analysis and original work, this project was not undertaken as a general road map to creating a visysphere on Mars. Rather, the authors have focused on how specific areas of current research in genetic engineering, physiology, psychology, biorobotics, life support systems, space suits, habitats, robotic vehicles, cybernetics, socioeconomics, ethics, religion, politics, and law may be combined and applied to starting the terraforming process and meeting it with life adaptation.



AREOSPHERE

Introducing the Areosphere

The areosphere, the Martian equivalent of the geosphere, is the basis of the visysphere considered in this project. Here, the history and physical planetary properties of Mars are described, including the interior, surface, atmosphere and climate, and satellites.

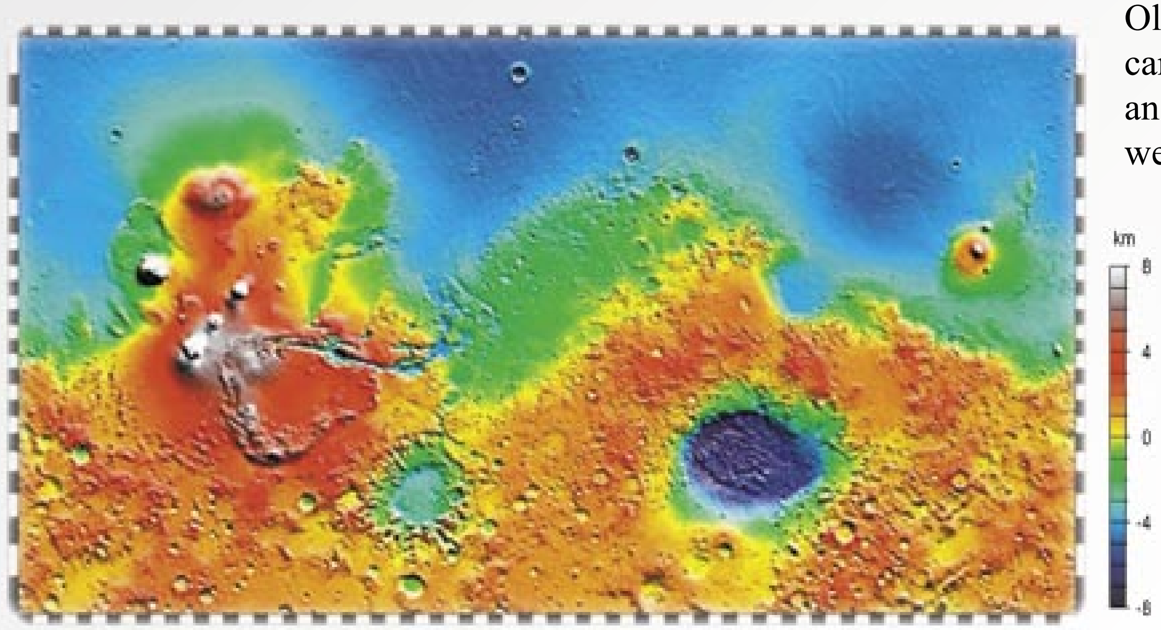
Why Terraform Mars?

- Easiest to terraform
- Earthike characteristics
- Much is known about Mars
- Many resources available
- Economic potential

Mars Properties

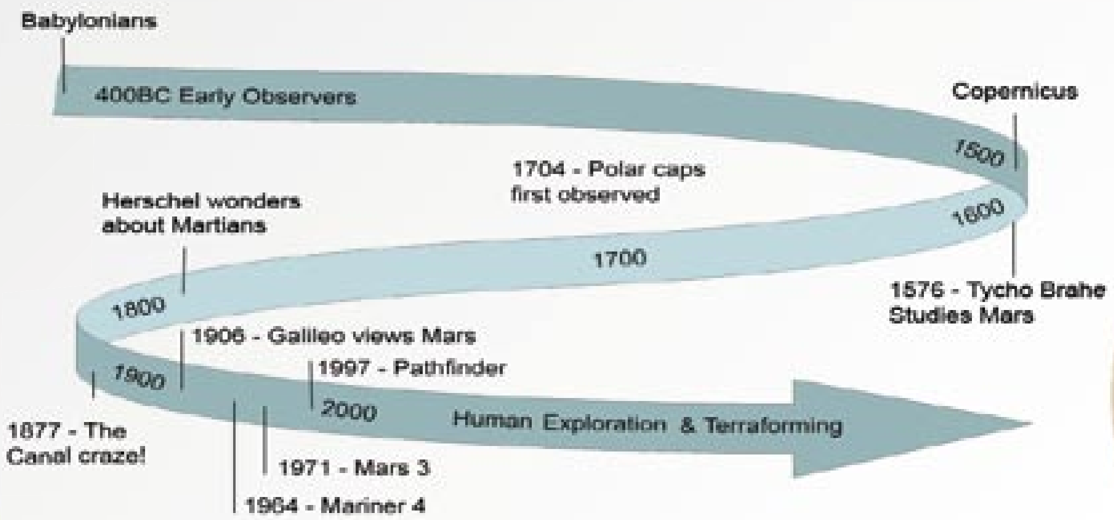
The Martian surface exhibits a dichotomy of highly cratered southern highlands and smoother northern lowlands separated by a scarp that averages 5 km in height. Surface features vary from high peaks like Olympus Mons (26 km high) to the Valles Marineris canyon system (10 km deep). It is suggested that an impact event or early plate tectonic movements were responsible for this large difference in terrain. Mars has dried up valleys and a network of tributaries which give evidence suggesting early surface water activity.

The Martian polar caps are made mostly of water (northern cap) and CO_2 ice (southern cap). The southern cap is believed to be composed of a thin layer of CO_2 frost above layers of water ice and dust. These large reservoirs would provide resources for exploration, terraforming and colonization.



Maps of Mars' global topography

Mars Exploration History



Summary

Mars is a complex and enigmatic body whose properties continue to be discovered. Some of the recent developments include the discovery of methane and strong magnetic bands in the southern hemisphere as well as the possible discovery of large water ice bodies immediately beneath the Martian surface near the equator. These discoveries challenge our previous understanding of Mars and prompt us to re-evaluate our scientific intentions for the planet.

Overall, Mars is still a hostile environment for Earth life. It has an extremely low mean global temperature (220 K) with massive diurnal variations, diminutive atmospheric pressure, negligible radiation shielding and dust storms that discourage the proliferation of life.

Possible Mars Interior Structure

Mars does however, have Earth-like attributes that appeal to life adaptation such as circadian rhythms, a substantial gravitational field, seasons, and water. Our vision of a future terraforming scenareo is outlined in the following sections.

"Mars has intrigued and captured the human imagination more than any other planet in the solar system."

ATMO-HYDROSPHERE

Terraforming Mars

Presently Mars is unable to support life as we know it. Consequently terraforming it will facilitate the introduction and preservation of biological life forms. In order to terraform Mars the following parameters need to be modified:

- Atmospheric pressure
- Global mean temperature
- Radiation protection
- Atmospheric composition

This will be accomplished through a synergetic approach involving various techniques outlined herein.

PFC factory

Warming Mars

Warming Mars will be accomplished by in situ production and release of artificial greenhouse gases. Covering the poles with dark material to lower its albedo will work in synergy to facilitate the adsorbed CO_2. A runaway greenhouse effect will melt the CO_2 deposits at the poles, as well as provide a greater UV radiation protection on the surface. Perfluorocabons (PFC's) will be used as they are

- Resistant to UV light
- Non-destructive to the ozone layer
- Non-toxic at required concentrations
- Long lifetime in the atmosphere (3,000 - 50,000 years on Earth)
- Elements required for their production are present on Mars

PFCs are not only the most feasible method but are also the most flexible method with relatively immediate results and rate of terraforming directly proportional to cost.

Asteroid Impact

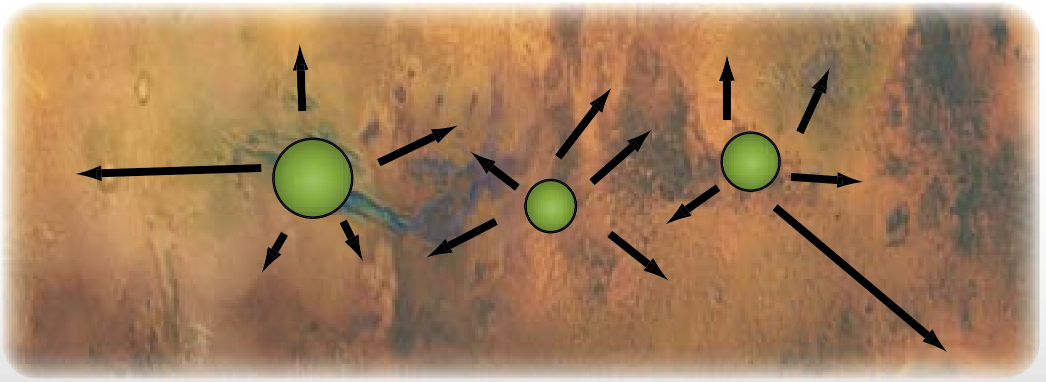
Asteroids gather in the main asteroid belt between Mars and Jupiter, in the Kuiper belt, which extends from ~30 AU out to ~50 AU. Even though comets have water and volatiles, they have eccentric orbits and are loosely packed, asteroids would be imported from these orbits. Current investigations on NEOs (Near Earth Objects), comets, and asteroid rendezvous missions will accelerate development of the technology required. The mission trajectories have to utilize windows of opportunity created between Earth, Mars, asteroids and swing by planets to save on time and propellant. To provide an understanding of the effects of asteroid impacts, a detailed analysis of its atmospheric enrichment, cratering, dust creation and volatile release is considered.

Asteroid impact

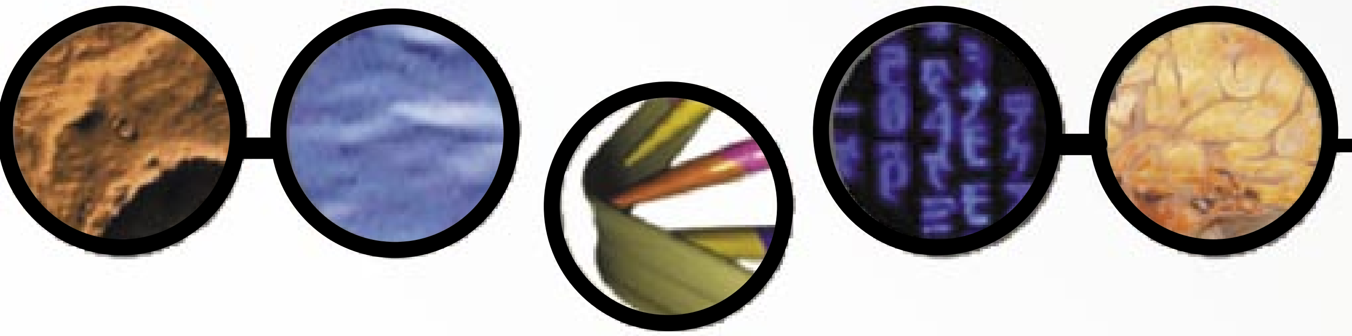
"Terraform to improve the Martian conditions to facilitate artificially assisted life."

Biological Seeding

Biological seeding of Mars would start after warming Mars and subsequent increase in atmospheric pressure towards the end of the 21st century. It would eventually aid in changing the atmospheric composition by raising O_2 levels and lowering CO_2 through photosynthesis. These organisms would consolidate dust and fix nutrients into the regolith, where they can eventually be used by higher organisms. Seeding will take place through the transmission of organisms, using robotic vehicles, from central greenhouse laboratories to sustainable niches.



Biological seeding of Mars



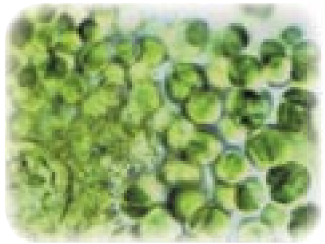
BIOSPHERE

Introducing the Biosphere

The biosphere component of the visyphere on Mars, will contain all the organisms imported from Earth. With human survivability on Mars being the major issue, the authors look into microorganisms that can help terraform Mars and other innovative means of ensuring human survival on its surface.

Adapting Pioneer Microorganisms for Mars

Pioneer microorganisms such as *Chroococcidiopsis caldariorum* can assist in terraforming Mars. Directional selection and genetic engineering can help to increase the growth and productivity of potential candidate microorganisms and can make them more adapted to the Martian environment.



Chroococcidiopsis Caldariorum

The following changes can be made to enchance microorganisms in order to survive on Mars:

- Introduce a DNA repair mechanism
- Increased tolerance to low pH
- Increased tolerance to peroxides
- Increased desiccation tolerance
- Increased metabolic rate
- Increased growth rate
- Introducing regulatory genes to trigger appropriate responses
- Introducing endospore formation capability when nutrients are limited

Low Oxygen Levels

Low levels of oxygen will still persist for many centuries after the initial terraforming stage. Colonists could be genetically engineered to carry more hemoglobin to meet their oxygen requirements during this time.

Low Gravity

Reduced gravity will cause continuous bone loss even after all other physiological systems have adapted to their new surroundings on Mars.
Countermeasures include resistance exercises, prescription drugs and dietary essential amino acid supplements.

Radiation Countermeasures for Humans Colonists

The primary threat posed by radiation to human settlers on Mars lies in the instability of DNA. Possible solutions are:

- The use of telomerase for DNA repair
- Use of drugs to inhibit telomerase activity in cancer cells
- Drugs based on a gene found in *D. radiodurans* that are responsible for radiation resistance help maintain DNA integrity
- The above mentioned drugs can be administered to humans by use of the visychip

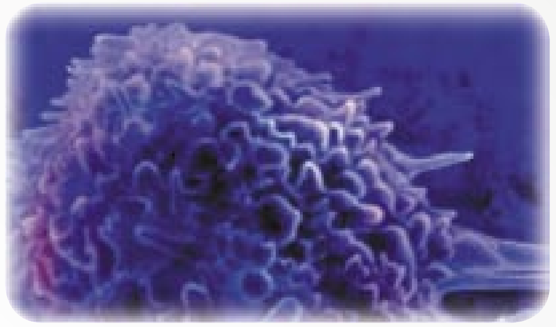
Visychip

The visychip

The visychip combines different microsystem and biotechnologies in a single implantable package. It monitors the internal human body parameters and exterior environment, and detects illness. When abnormal values are detected, the appropriate countermeasure drug is administered by the drug delivery subsystem. To access the information from the visychip, a watch-like device is used. This system emits a signal with all collected data directly to a medical base on Mars and also provides information on the user's location.

"Solutions from the Biosphere can help with both the terraforming aspect as well as human survivability on the surface of Mars."

Immune System for Mars



Human immune cell

The human immune system will need to be enhanced for living and working on the surface of Mars. Genetic engineering techniques will integrate human genes into the genome of simple organisms, resulting in the production of proteins for the immune system. Gene therapy can be used to replace altered or missing genes or add helpful genes to the DNA. Immunosuppressant drugs and monoclonal antibodies would assist the body in accepting implants such as the visychip.

The concept of a visysphere

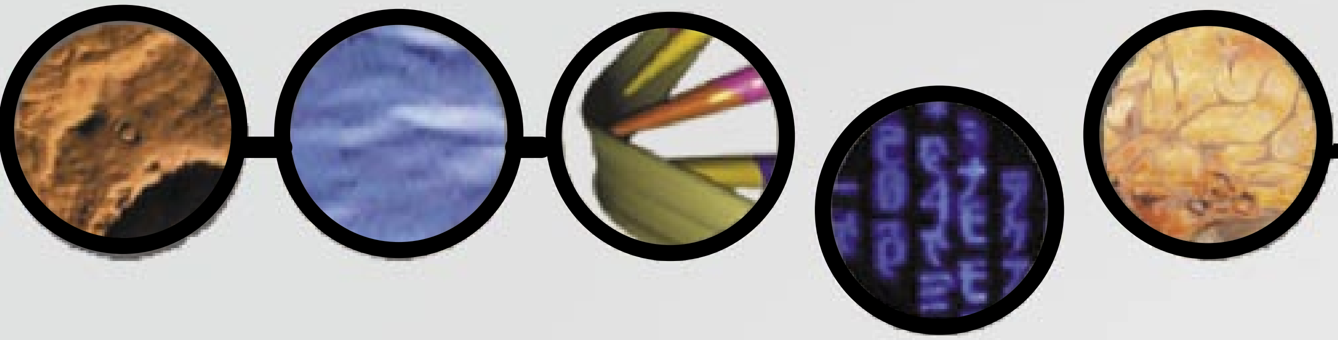
The concept of a visysphere, with its associated technological, environmental, socioeconomic, and political dynamics, will outline solutions to the process of terraforming Mars. This will be accomplished through applying adaptations and reforms to the life and society that will exist there. These efforts are intended to solve some of the critical issues necessary for the realization of selfsustainable colonial settlement of Mars before the end of the 21st century.

Terraforming: A synergic approach

A synergic approach was selected as the preferred solution to produce the runaway greenhouse effect required to initiate the terraforming process on Mars. Perfluorocarbons (PFC) are used to initiate the greenhouse effect while lowering the polar albedo, using asteroid impacts, will aid in further increasing the polar temperature to free adsorbed CO_2 trapped in the ice caps.

Life adaptation

Proposed technological and biological solutions will help colonist deal with the most problematic aspects of the Martian environment. Human survival on Mars will not only depend on these accomplishment but also a Martian synergy of the cultural, social, ethical, legal and moral values of Earth.



TECHNOSPHERE

Introducing the Technosphere

The technosphere is the grouping of all things of a technical nature and the result of their application, all of which enhance and artificially evolve life. By the mastering and manipulation of matter and materials, the technosphere also enables us to explore and survive where one could not otherwise go.

In Situ Resource Utilizaion (ISRU)

Mars' native resources are necessary to create and maintain a Martian civilization. In the initial phase of the colonization of Mars, resources can be imported from Earth, but only on a small scale. If the settlement is to be expanded, materials have to be produced using ISRU possibilities to construct buildings and other infrastructure.

The wearable life support system

Cybernetics

Artificial Intelligence (AI), Machine Learning (ML) and Virtual Reality (VR) can be used to make short-term and long-term changes in human psychological and physical properties by manipulating the normal functioning of the senses and the signals of the human brain. Cybernetics can also offer a solution for communication problems among the humans on the surface of the Mars.

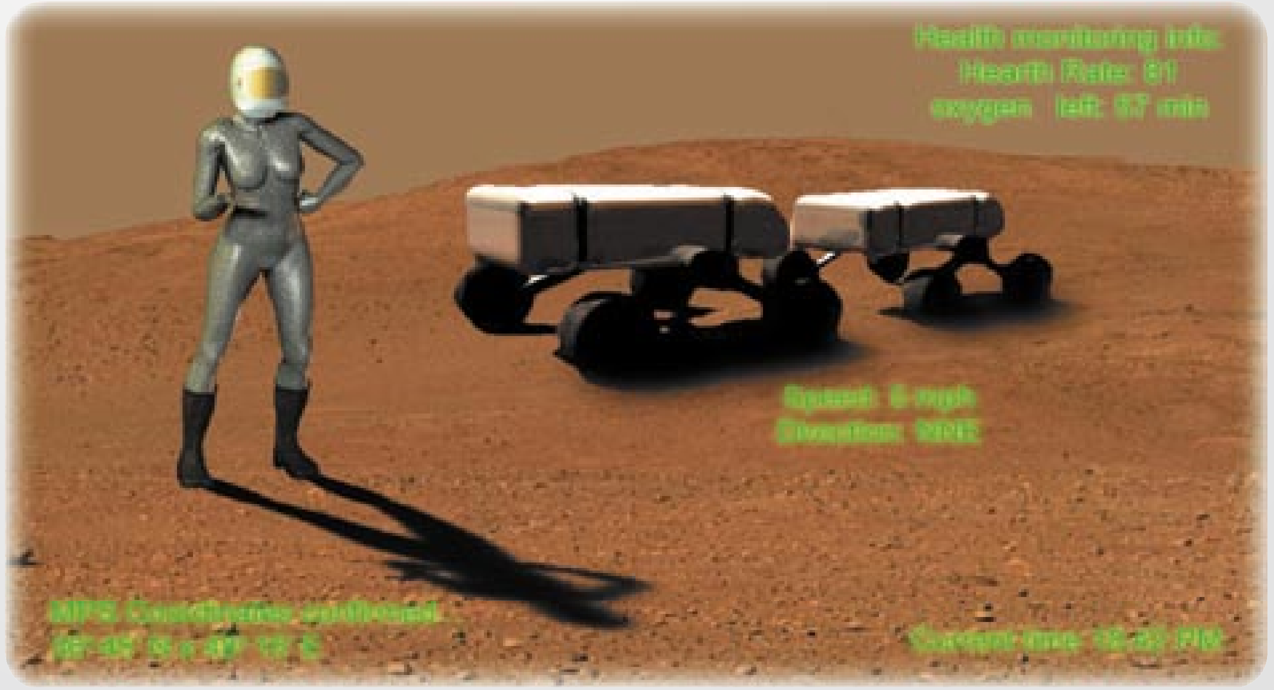
Augmented Reality (AR) units will take the shape and form of common sunglasses and provide the user with important real-time data pertaining to what they see around them, as well as other important safety and survivability information.

Space Suits

The major limitation of existing Extravehicular Mobility Unit (EMU) designs is the use of a pressurized internal volume, severely limiting mobility, and increasing control system requirements. Rectifying these problems for Martian exploration will require the development of the Mechanical Counter-Pressure (MCP) suit, incorporating actively actuating materials in combination with a neck dam system, eliminating the use of oxygen from the neck down.

Wearable Life Support System

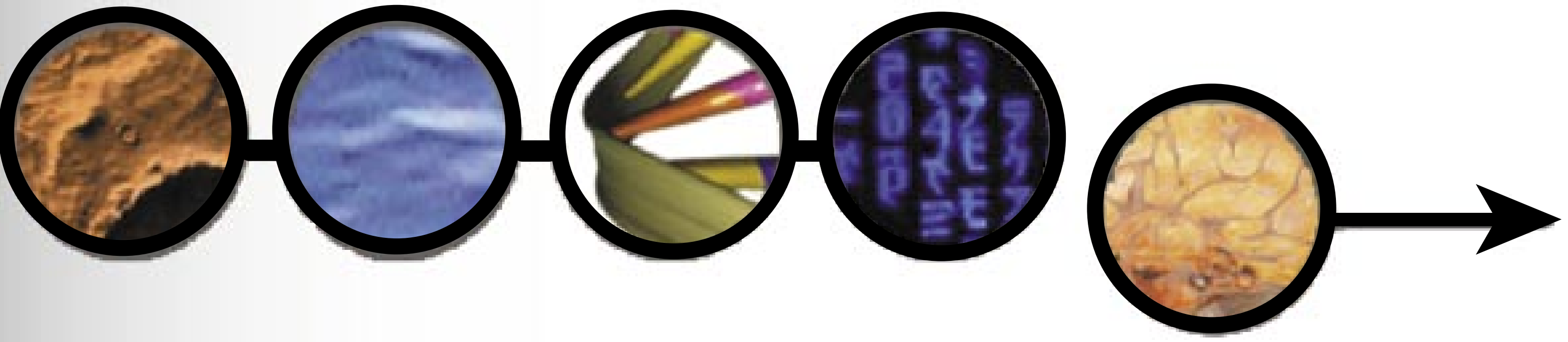
A wearable life support system is a partially open system that would use CO_2 from the Martian atmosphere, and through multiple processes, convert it into breathable O_2, using a combination of natural and artificial techniques. It has the potential to eliminate the need for a breathable atmosphere which is estimated to take thousands of years to create.



The mechanical counter pressure suit with a neck dam system and modular robotic vehicles

Robotics and Robotic Vehicles

Terraforming Mars will require a wide variety of activities. A robotic infrastructure model based on modular design can support humans or perform individual building, science, and exploration tasks.



NOOSPHERE

Introducing the Noosphere

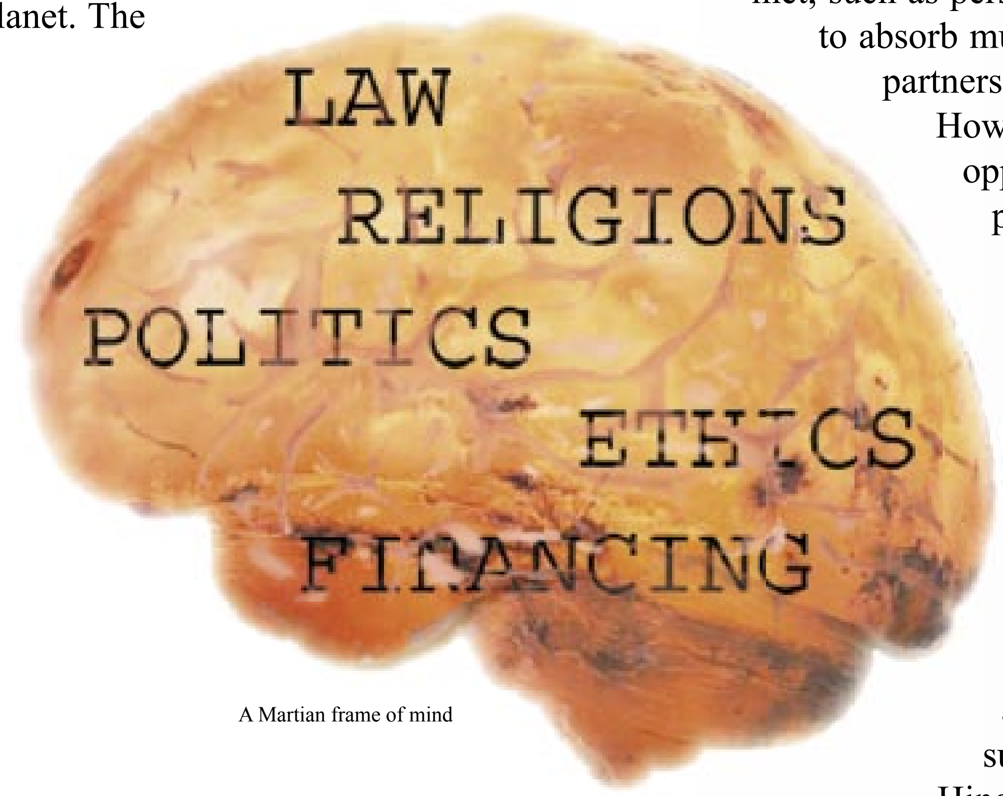
Noosphere from the Greek "nous" (mind) and "sphaira" (sphere). The noosphere focuses on aspects such as the law, ethics and religion imposed by the transformations of the human being and the planet Mars for establishing humanity on the planet. The following aspects are considered:

An Ethical Perspective

It could be considered dangerous to create a new "post-human race", and as such it might be better to create a race that is suited for living on an extraterrestrial planet such as Mars. This may eliminate human identity problems by creating a unique Martian identity. This would also eliminate some of the equality issues, as this new race would not be "better" humans, but better equipped for life on Mars.

The Mars Convention

The Mars Convention contains legal guidelines for the promotion of both space exploration as a peaceful and international endeavour, and a permanent human presence of Mars with some key points to address the regime and organization of the Martian resources. For example, if space is to be considered as the new frontier for humankind, the legal regime regulating the activities of states in outer space should evidently be adapted to a renewed vision of the future space conquest.



A Martian frame of mind

Funding Terraforming

Before a project like terraforming can be undertaken several objectives have to be met, such as persuading space-faring powers with economic resources to absorb much of the initial costs of the project. A public-private partnership is an option if the project leads to social benefits. However, it will also be important to identify commercial opportunities for the private sector. Funding for the proposed technologies is provided mostly by the private sector.

A Religious Perspective

The authors aim to realize a great number of controversial undertakings, including the use of genetic engineering and terraforming itself. We aim to keep in mind the wellbeing of all sentient beings. The terraforming project should gain acceptance from the viewpoint of all religious beliefs, such as Christianity, Judaism, Islam, Buddhism, and Hinduism.

Existing Legal Limitations to Terraforming

The terraforming effort will encounter international conventions that protect celestial bodies from certain activities. Two principles of international space law have to be taken account into: planetary protection and non-appropriation.

The two most important treaties that would have a direct impact on the possibilities of terraforming are the Outer Space Treaty (OST 1967) and the Moon Agreement (Moon Agreement 1979). Terraforming lobbyists will face major legal challenges to modify these international laws in order to legally permit terraforming activities. However, terraforming, seen in a long-term perspective, would impose the negotiation of a new treaty on the international community, as foreseen in the Mars Convention.

"The Mars Convention would make it legal to biologically seed for the purpose of terraforming."

CONCLUSION

Visysphere Mars

Using the concept of a visysphere, which combines areosphere, atmo-hydrosphere, biosphere, technosphere and noosphere, this report has laid the foundations for extensive development of technologies, both intellectual and social, to provide solutions to some of the critical issues in an envisioned terraforming effort. In this respect, the report can be identified as an amalgamation of the critical efforts of all humankind; resulting in not only a technological accomplishment but also a Martian synergy of the cultural, social, ethical, legal, and moral values of Earth.

Terraforming Mars

The terraforming approach addresses how to improve the habitability of the Martian environment before the 22^{nd} century allowing the introduction of engineered life. Utilizing PFC production factories to heat the planet and lowering the polar albedo, it is possible to increase the polar temperature to free frozen CO_2.

One of the issues highlighted is the lack of volatiles on Mars that are necessary for the effective functioning of the biological cycles. One of the few feasible ways to import such constituents, although less practical than using nitrifying bacteria, would be through impacting nitrogen rich asteroids. An icy body imported and impacted on the Martian south pole will supplement the existing inventory while lowering the polar albedo. It should be noted that within this context, terraforming techniques as discussed in this project, can be seen as a clear violation of the two major applicable principles of space law. There is therefore a need to reform the existing space treaties to expand their scope and elaborate on the legal activities of space faring nations before any act of terraforming can take place.

Visysphere Mars

Adapting Life to Mars

Current Martian surface conditions prevent the introduction of terrestrial pioneering microorganisms. However, with the necessary selection processes and genetic enhancements, early introduction and acceleration of the terraforming process is possible. Genetic engineering and drug production techniques also hold vital roles in increasing human adaptation to the environment of a partially terraformed Mars. The concept of the visychip represents one possible solution for combining microsystems and biotechnologies in a single implantable package. Other medical technologies including neural implants can also be used to monitor and manipulate both the physical psychological health of the subject.

Living on Mars

Further development of the Mechanical Counter Pressure (MCP) suit concept will result in a unit able to combat the physical constraints of current EVA activities. Applications such as the Wearable Life Support System, in addition to MCP, would partially or even completely eliminate the need for a breathable atmosphere within the suit. In situ resource utilization will form a skeletal component in producing the required materials to build a colonial infrastructure. In the final colony phase, a whole self-sufficient society would exist.

Humanity's Future on Mars

By highlighting these discrete developments, the project generated several solutions utilizing many forms of technology in their respective disciplines. Combining scientific theories and human intellect the project produced one of the first overall concepts for the interdisciplinary effort to terraforming Mars. In doing so the project provides a guide to the impending needs of future space exploration initiatives whilst identifying critical Earth-based initiatives and technologies in need of incorporation into the space fields. This project therefore stands as a set of solutions for providing substantial human colonization of a partially terraformed Mars before the end of the 21^{st} century.

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Tel : + 33 (0) 3 88 65 54 30
Fax : + 33 (0) 3 88 65 54 47
htttp://www.isunet.edu
Email: publications@isu.isunet.edu

1 rue Jean-Dominique Cassini
International Space University
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" Twenty years from now you will be more disappointed by the things you didn't do than by the ones you did do. So throw off the bowlines. Sail away from the safe harbor. Catch the trade winds in your sails. Explore. Dream. Discover."

Mark Twain

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