# TESI DI LAUREA

a.a. 2020-21, Mars Underground

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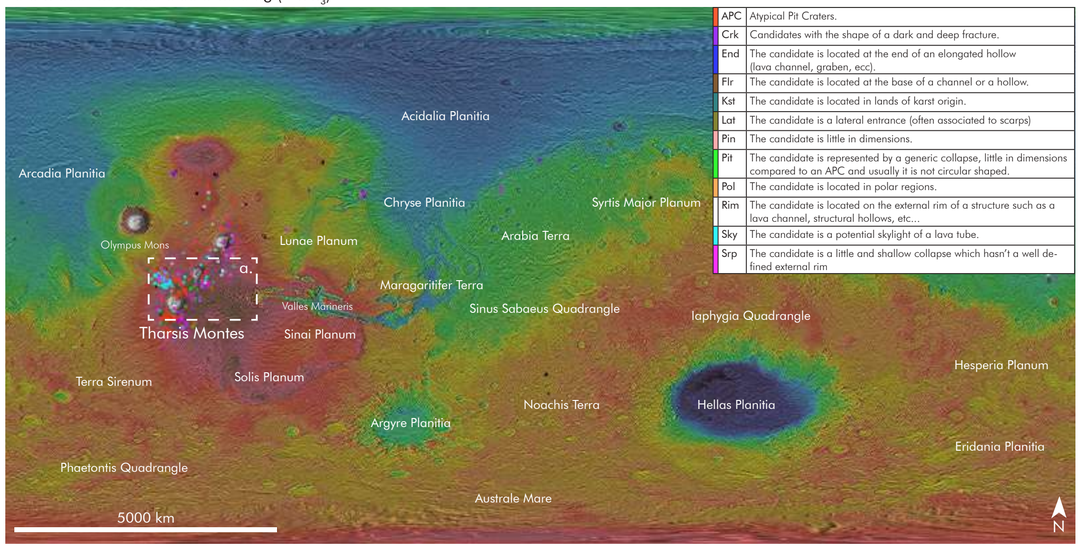
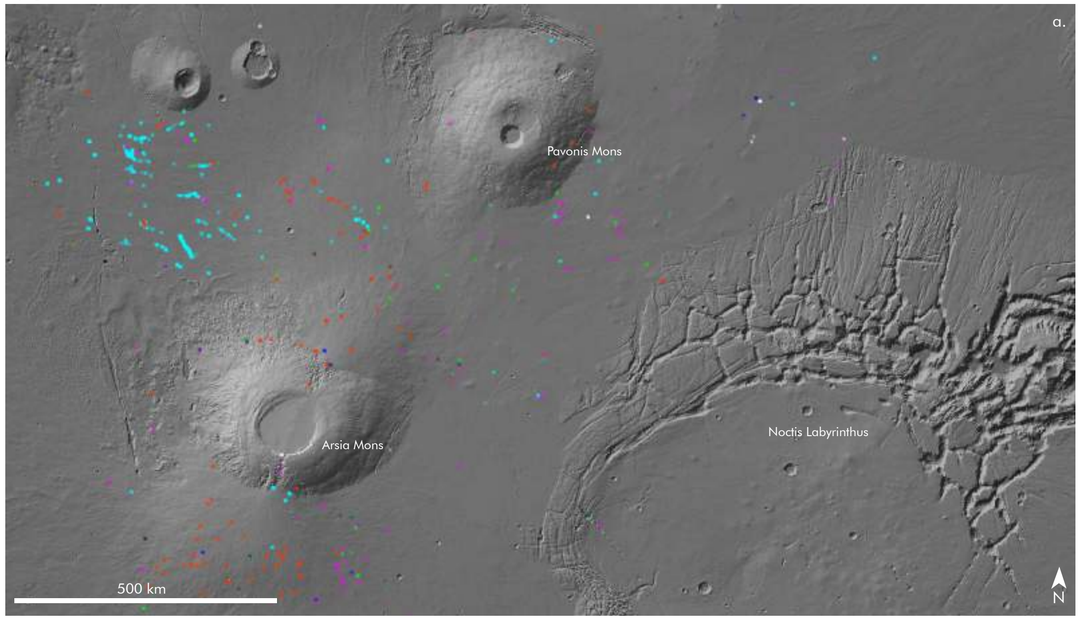
## Mars Global Cave Candidate Catalog ($MGC_3$)




| | |
|---|---|
| APC | Atypical Pit Craters. |
| Crk | Candidates with the shape of a dark and deep fracture. |
| End | The candidate is located at the end of an elongated hollow (lava channel, graben, ecc). |
| Flr | The candidate is located at the base of a channel or a hollow. |
| Kst | The candidate is located in lands of karst origin. |
| Lat | The candidate is a lateral entrance (often associated to scarps) |
| Pin | The candidate is little in dimensions. |
| Pit | The candidate is represented by a generic collapse, little in dimensions compared to an APC and usually it is not circular shaped. |
| Pol | The candidate is located in polar regions. |
| Rim | The candidate is located on the external rim of a structure such as a lava channel, structural hollows, etc... |
| Sky | The candidate is a potential skylight of a lava tube. |
| Srp | The candidate is a little and shallow collapse which hasn't a well defined external rim |

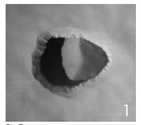
Mars Global Cave Candidate Catalog (MGC3, Cushing et al. 2016) plotted upon Mars Orbiter Laser Altimeter (MOLA, on Mars Global Surveyor) colorized elevation map, 460m/pixel.


## Skylights North West of Arsia Mons



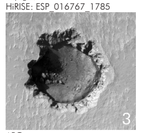

Mars Global Cave Candidate Catalog (MGC3, Cushing et al. 2016) plotted upon MOLA Shaded Relief NW 460 m/pixel (on Mars Global Surveyor; Smith et al., 2001) blended with HRSC MOLA Blended DEM 200m v2.

## Typologies of Caves




Pit Crater,
HiRISE: ESP_014380_1775


Skylight,
HiRISE: ESP_016767_1785




APC,
HiRISE: ESP_033355_1635

### Glossary

HiRISE: High Resolution Imaging Scientific Experiment Camera (0,3m/ pixel) aboard Mars Reconnaissance Orbiter.
MRO: Mars Reconnaissance Orbiter
ESP_xxxxxx_xxxx: specific stamps retrived by HiRISE, always associated to specific coordinates.

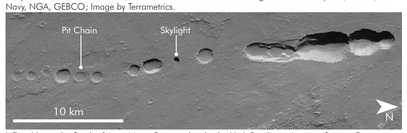
On Mars, numerous caves of different morphologies can be found, due to past volcanic activities. These features are identified and classified in the Mars Global Cave Candidate Catalog (MGC3), an ongoing database curated by the scientist Glen E. Cushing. The data shows that the volcanic region of Tharsis, which comprehends the biggest shield volcanoes of the Solar System, is rich in caves.
The three main categories, related to different genetic mechanisms, are:
Pit Craters, Skylights and Atypical Pit Craters (APC).

- Pit Craters (fig.1) are associated with long narrow fault valleys or grabens that along with associated fissures were once filled with magma and then drained causing collapse and pit formation.
- Skylights (fig.2) are collapses related to lava tubes, which are defined as "roofed conduits of flowing lava, either active, drained or plugged" (Halliday, 2004). These features are of particular interest for human exploration and search of past life signs, providing an entrance to a shelter from radiations, easy access to several resources and water ice (Cushing, 2012).
- Atypical Pit Craters (fig.3) are circular shaped pits which origin is still uncertain (Sauro et al. 2020) and under debate.

## Lava Tubes on Earth and Mars.


Deep inflated lava tube Corona, Lanzarote. Picture taken from Google Earth. Image by CNES/ Airbus.

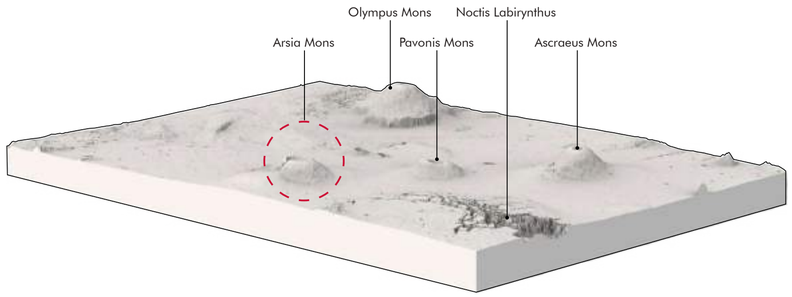

Deep inflated lava tube Corona, Lanzarote. Picture taken from Google Earth. Data by SIO, NOAA, U.S Navy, NGA, GEBCO; Image by Terrametrics.




Inflated lava tube South of Arsia Mons. Picture taken by the High Resolution Imaging Science Experiment (HiRISE on Mars Reconaissance Orbiter) 0,3m/pixel, HiRISE: ESP_011677_1655_RED

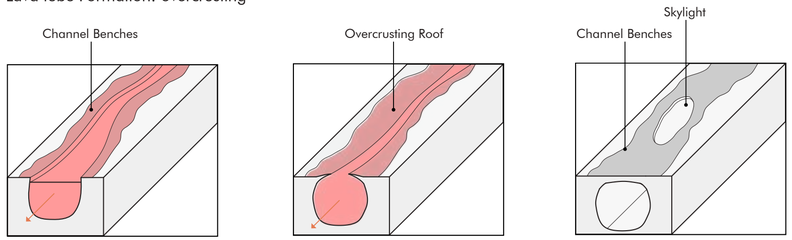

Overcrusted lava tube north west of Arsia Mons. Picture taken by the High Resolution Imaging Science Experiment (HiRISE on Mars Reconaissance Orbiter) 0,3m/pixel, HiRISE: ESP_064568_1770_RED

## Tharsis 3D Model




Rendered axonometric viewl of the Tharsis region, made with the 3d model shared by NASA at: https://nasa3d.arc.nasa.gov/detail/tharsis. The model was rendered with a 6x vertical exaggeration by the authors.

## Lava tube Formation: overcrusting




1. An hot lava flows into an existing channel.

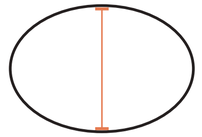
2. The upper layer starts to cool, creating a roof.

3. The flow stops and the lava is drained, leaving an empty tube.


## On Earth

Wd<20m

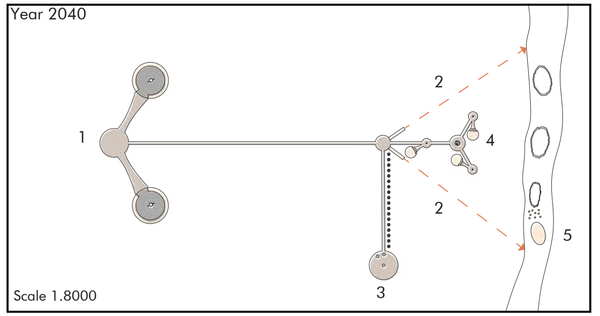
## On Mars

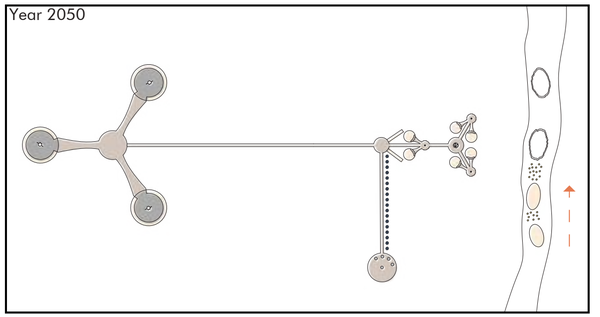


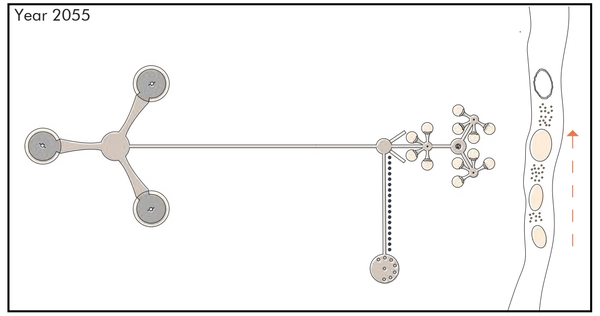
20<Wd<60m

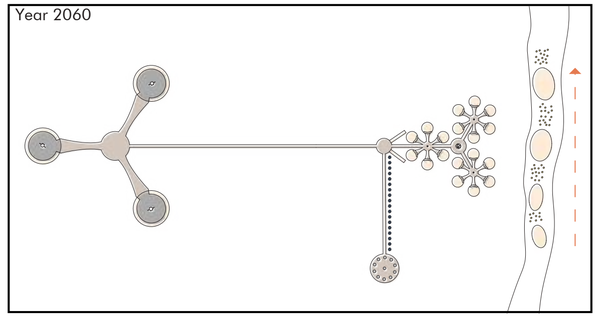

. ESA astronauts Luca Parmitano and Pedro Duque, at Geoparque Lanzarote, in the Canary Islands, 2016. Credits: ESA, L.Ricci
.DAEDALUS Robot entering a lunar lava tube. Credits: Julius-Maximilians-University

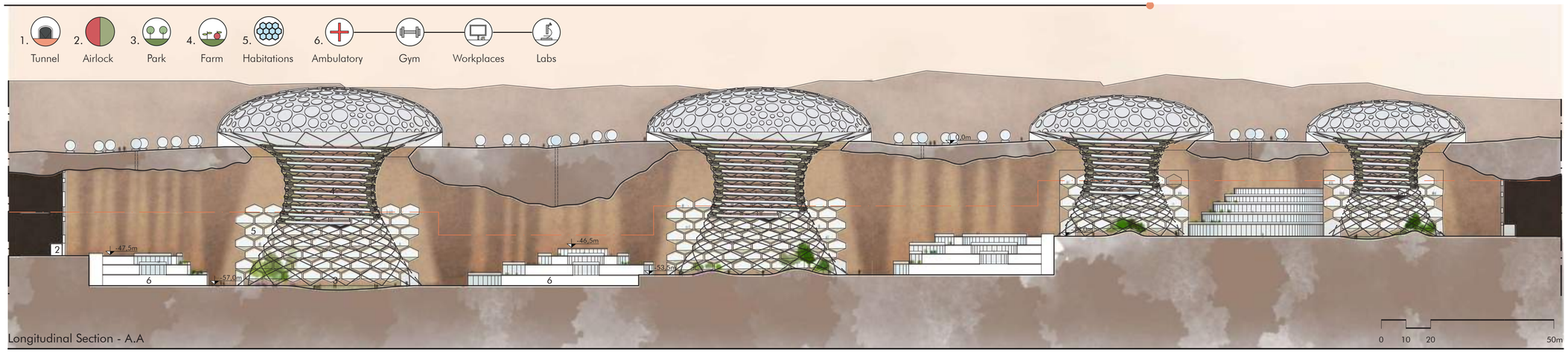

1.Landing Area
2.Tunnel
3.Power Area
4.ISRU Area
5.Cupola
5.Habitat
1
2
3
4
5
0 50 100 500m
N


Year 2040
1
2
2
3
4
5
Scale 1.8000


Year 2050


Year 2055


Year 2060




Longitudinal Section - A.A

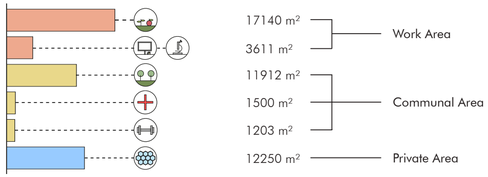
## Habitat Essential Functions:

407 People

1.Human Needs: Park, Farm, Habitations

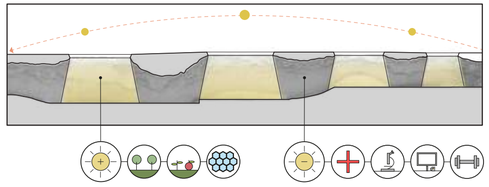
2.Wellness & Health: Gym, Ambulatory

3.Workplaces: Offices, Labs

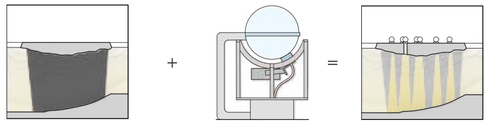



In order to establish a human presence on Mars, it is important to consider the experience that was gained through years at the International Space Station. Long duration missions show that an overall wellbeing and productive environment, is only achieved if the daily routine is balanced between work and leisure time and if the environment is designed properly to increase human interaction within themselves and the surroundings. Being in an underground colony on a desert planet, far from home, demands the creation of a proper habitat and a new landscape.

## Light:



Activities are located in the tube in accordance of their lighting requirements. In fact, researches show that in an underground environment, the connection to the outside is fundamental for an overall wellbeing (Endicott et al., 2020). Functions like habitats, farms and parks have a greater need of natural illumination and for this reason are located near the skylights, the most enlightened places, while other functions like workplaces and labs, have less natural light requirements, so they are located in the darker zones. With the purpose of increasing the natural lighting in this areas, solar concentrators like the "NTU Daylight Harvester" can be used, which collect and relay daylight to the underground.

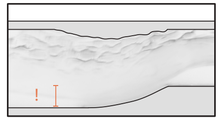



X Less illuminated area

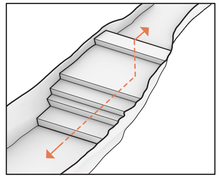
Solar Concentrators

V Illuminated area

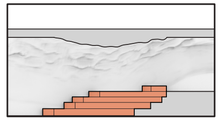
## A new landscape:

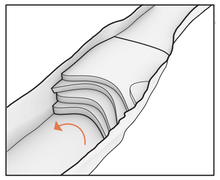


X Not connected

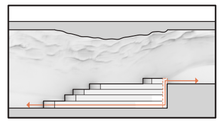


The different sections of the lava tube are located at different heights, but a connection is needed. The solution is to create artificial hills which are partly excavated in the slope of the bottom of the tube and partly printed with the crushed waste rocky material.

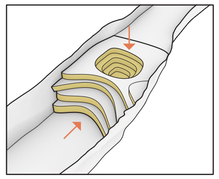




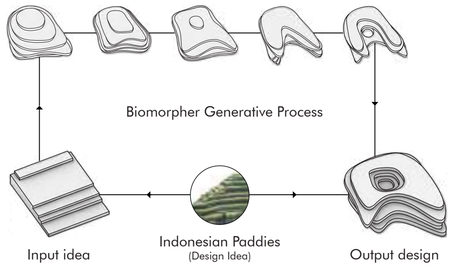
In order to create a more gentle and Earth-like landscape, the hills are modelled to look like organic formations inspired by Indonesian paddies, each one different from the other.



V Connected

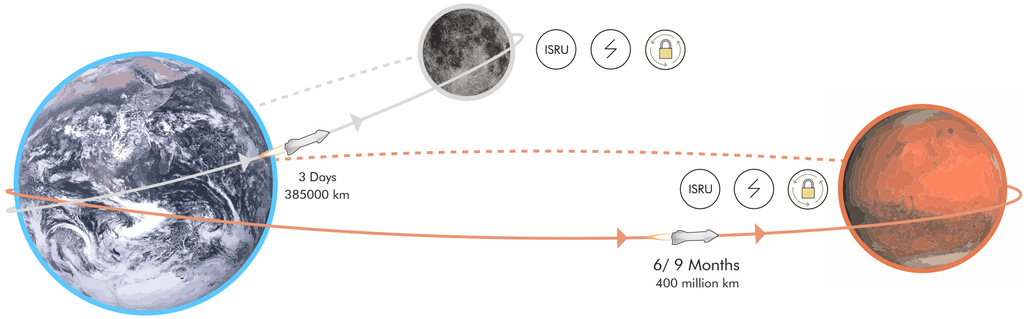


Finally, to improve the overall illumination of the functions located within the hills, light wells are created. The final design provides both an high quality and natural environment and a continuous connection between the centers of the colony.




The design of the hills is obtained through a generative design process with the grasshopper plug-in "Biomorpher", by John Harding. Starting from a design idea, alternatives are generated through a process which mimics natural selection and introduces randomness, providing different outputs. The desired result is then adapted and manipulated into the final configuration.

## Protagonists and Official Timeline for Mars




George W. Bush Administration

*"Our third goal, is to return to the Moon by 2020 [...] With the experience and knowledge gained on the Moon, we will then be ready to take the next steps of space exploration: human missions to Mars and to worlds beyond." (Vision For Space Exploration program, 2004)*


Donald Trump Administration

*"[...] President Trump made the policy of this administration to return to the Moon by 2024[...] Our objective will be to establish a permanent presence on the lunar surface. There we will develop the capabilities to journey to Mars." (Mike Pence, the birth of the Artemis program, National Space Council)*

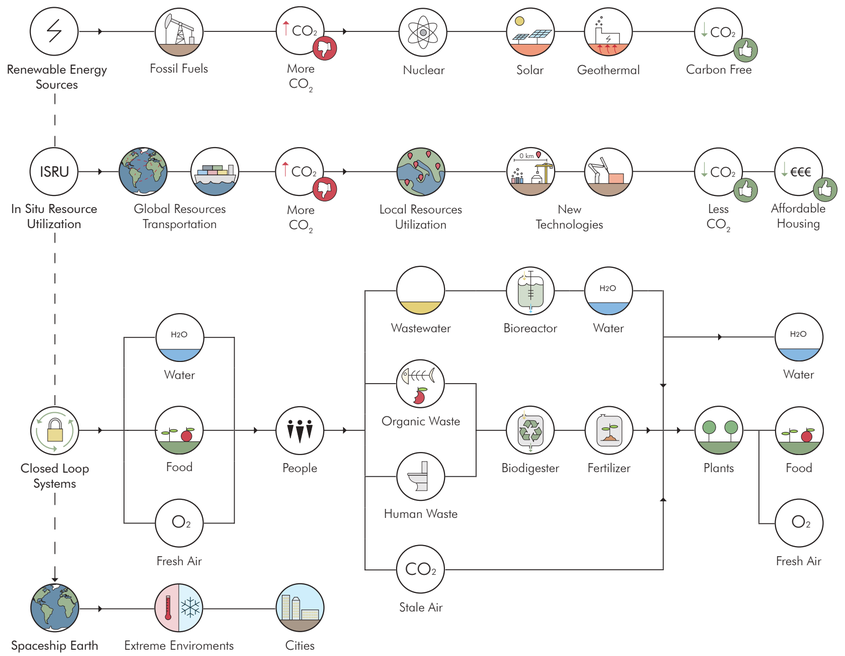
Elon Musk

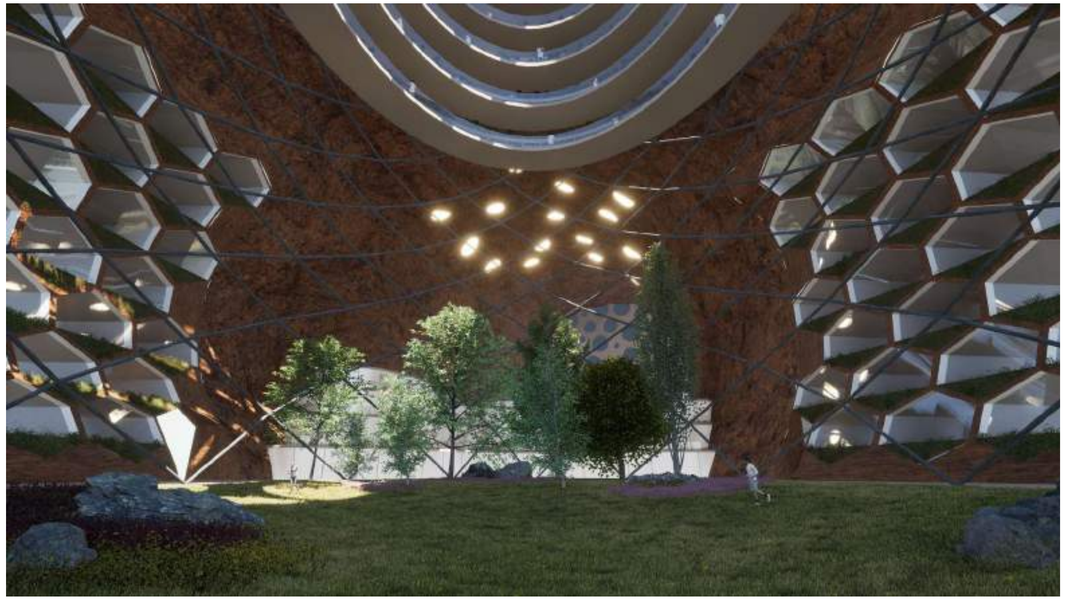
*"If things go super well, might be kind in the 10 year time frame" (The International Astronomical Congress, 2016)*


NASA's Journey to Mars

*"NASA is developing the capabilities needed to send humans to an asteroid by 2025 and Mars in the 2030s" (bipartisan NASA Authorization Act of 2010).*

## Technology Transfer and Terrestrial Applications



The benefits of space exploration and settlement account to many fields. The *International Space Station (ISS)* has demonstrated over the course of more than two decades the benefits that a joint effort has both on research and in the relations between countries. In space, the *"Overview Effect"*[20] seems to change the perception of the world once for all:

*"If everyone could go into space and look at Earth from up there, I am convinced that we would commit ourselves more consciously to the care of our planet, adopting a more responsible behaviour at the environmental level, carefully monitoring the changes we are causing and better controlling the evolution of rivers, lakes, volcanoes, oceans ... of all Nature".*

*(Paolo Nespoli, Italian Astronaut).*

Going to space causes a paradigm shift: it enhances equality, the feeling of belonging to a united human race, but also an environmental consciousness regarding the one and only planet where life is know to exist. International cooperation, equality, sustainable consumption, environmental control are all recognized objectives of the *United Nations Sustainable 17 Development Goals.*[21] Going to Mars can only be achieved together, each nation with its excellences and competences. In addition to that, the concepts that have been developed for Mars can have a synergistic relationship to the ones already known on Earth. For example, *In Situ Resource Utilization* (ISRU) can help to change the mindset about material usage in constructions: innovative science and traditional knowledge can couple in creating a more sustainable present and future. On Earth, the illusion of infinite resources has led to polluting behaviours, but in this sense, the *Closed Loop Life Support Systems*[25] that are currently researched to be implemented for space missions can bring great benefits in buildings and cities, converting waste, wastewater and polluted air into resources again, locally. These technologies are also of a vital importance for less developed counties and extreme environments, where clean water reservoirs and food security are everyday problems to deal with.

Thank you for reading this dissertation.

# lsfE
2022-2023