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A Crossed Look on Space Architecture

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Abstract

Any architectural design is related to an environment in two opposite and complementary ways : first, to take advantage of the natural resources of this environment; and - conversely - to be protected from its threats, or simply from its lack of natural resources. Spatial Architecture pushes this principle to its climax because it must be designed to adapt to all scenarios : possibility of exploiting solar energy (often), have local construction materials like regolith or vital resources like water ice (sometimes), but in most cases having degraded basic environmental parameters (low gravity or no gravity at all, low atmospheric pressure or no atmosphere at all ...), and real major threats for long term inhabited settlements (radiation, micrometeorites, thermal amplitude, presence of abrasive, corrosive or toxic materials, insulation, ...). To address such constraints, Space Architecture requires a multidisciplinary approach, a close crossed look between architecture and engineering, to no longer see - as too often, in popular science-fiction for instance - projects aesthetically appealing but technologically unrealistic, or conceptually realistic but dull and far too austere for a place to live ... For this interactive presentation, we wanted to do the exercise of addressing these questions by cross- ing the eyes of an architect and an engineer, having in common to be former winners of the yearly international competition "Architecture and Design of Space" organized by the Jacques Rougerie Foundation : Sylve Truyman, architect, CEO of Real Dream, a young company focused on innovation for architecture and the space sector, awarded for the projects Solar Spore in 2017, and Selenia in 2018; and Olivier Boisard, independent consulting engineer and space designer at OB-Conseil, awarded for the project of space city for 30.000 inhabitants Apogeios, co-created with Pierre Marx in 2011 (presented at IAC-Naples in 2012, IAC-12-E5.2.1).
In this IP, which aims to be practical and visual, are presented personal projects of each of them, and a new concept of moon base developed in common with the objective of illustrating and popularizing, for the general public, some original ideas using 3d computer graphics and resources like archviz and game engines.
Keywords: Space, Architecture, ArchViz, Prospective

1. Introduction

Any architectural design is related to an environment in two opposite and complementary ways : first, to take advantage of the natural resources of this environment; and - conversely - to be protected from its threats, or simply from its lack of natural resources. Spatial Architecture pushes this principle to its climax because it must be designed to adapt to all scenarios : possibility of exploiting solar energy (often), have local construction materials like regolith or vital resources like water ice (sometimes), but in most cases having degraded basic environmental parameters (low gravity or no gravity at all, low atmospheric pressure or no atmosphere at all ...), and real major threats for long term inhabited settlements (radiation, micrometeorites, thermal amplitude, presence of abrasive, corrosive or toxic materials, insulation, ...). To address such constraints, Space Architecture requires a multidisciplinary approach, a close crossed look between architecture and engineering, to no longer see - as too often, in popular science-fiction for instance - projects aesthetically appealing but technologically unrealistic, or conceptually realistic but dull and far too austere for a place to live ...For this interactive presentation, we wanted to do the exercise of addressing these questions by crossing the eyes of an architect and an engineer, having in common to be former winners of the yearly international competition "Architecture and Design of Space" organized by the Jacques Rougerie Foundation :

- **Sylve Truyman,** architect, CEO of Real Dream, a young company focused on innovation for architecture and the space sector, awarded for the projects Solar Spore in 2017, and Selenia in 2018;
- **Olivier Boisard,** independent consulting engineer and space designer at OB-Conseil, awarded for the project of space city for 10.000 inhabitants Apogeios, co-created with Pierre Marx in 2011 (presented at IAC-Naples in 2012, IAC-12-E5.2.1).

2. APOGEIOS, a space city for 10,000 inhabitants

Project by Olivier Boisard and Pierre Marx

1st Prize 2011 ”Architecture and Design of Space”,
the Jacques Rougerie Foundation,
Institut de France.

Inspired by « space islands » imagined in the ’70s by the American scientist and engineer Gerard K.O’Neill, Apogeios is a concept of a city for 10,000 inhabitants, located at Lagrange point 5 of the Earth-Moon system. Built by robots with extraterrestrial material from the Moon and asteroids, protected from galactic radiation and solar wind, Apogeios offers residents the comfort of a real city and aunique socio-cultural environment. The sun provides all the necessary energy and brings warmth and light to greenhouses for food production and atmosphere recycling. As a prerequisite, an initial program of space industrialization will produce, locally and in large quantities, materials and equipment needed for construction and transportation. To this basic industry will be added later finished products, but highly processed products such as drugs or computer hardware will continue to be manufactured on Earth.

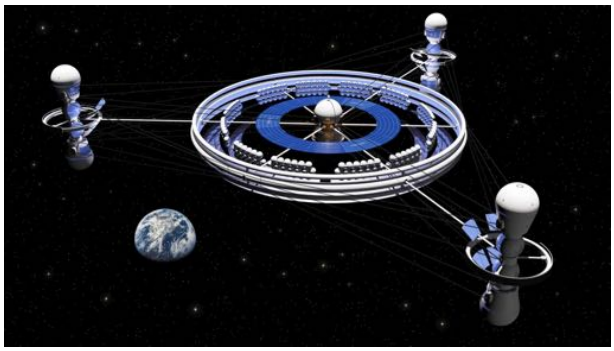


Fig. 1. Apogeios, Olivier Boisard and Pierre Marx

Despite their high automation, minerals mining and processing, and first of all the construction of the city, will require the presence of man in situ. All the processes won’t be remotely controlled. More than « site sheds », real living quarters will be needed. Larger and more autonomous thanthecurrent orbital stations, they prefigure the city to come. Besides their role in the industrialization and the construction, they will qualify number of essential functions such as artificial gravity, culture in greenhouses, recycling of air and water, ecosystem monitoring and safety. Time for such a project has not yet come, but this is more than science fiction according with today’s space technology. Ambitious as it may seem, it is feasible on an international basis and across one or two generations.

3. Marius Hill Moon Base

Project by Olivier Boisard

Marius Hills is a particularly interesting lunar region, characterized by a high concentration of domes and volcanic formations. On this site is located the Marius Hill "hole", a possible collapse in the roof of a lava tube. Because of the richness of its mineral resources, its position on the visible side of the Moon, and the presence of these natural formations, this site is one of the privileged places to establish an inhabited lunar base.

Fig. 2. Marius Hill Moon Base, Olivier Boisard

This project is articulated around an assembly of habitat modules with large panoramic glass windows - whose technology refers to submarine habitats - protected in their upper part by vast horizontal shield filtering the solar and galactic radiations (GCR). The architectural visualization of this project (ArchViz) is realized with the Unreal Engine game engine (see clip above) allowing a virtual visit on a desktop computer, or via Virtual Reality glasses.

4. Lunar Polar Station

Project by Olivier Boisard

The Lunar Night, lasting nearly 15 days, does not allow a continuous exploitation of solar energy. This is no longer the case in the polar regions where, thanks to the low inclination of the lunar rotation axis on the ecliptic, on some peaks or at low altitude, we can find regions lit by an almost horizontal light, rotating 360° each month. Rather than building rotating solar panels, a static tower of 1 km high composed of 3 faces of solar panels arranged in a star shape, provides continuous energy without any mobile structure.

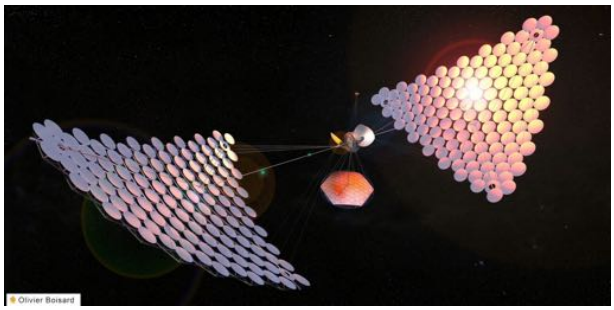
Fig. 3. Lunar Polar Station, Olivier Boisard

This project was presented in ArchViz with the Unreal Engine game engine (see clip above) allowing a virtual visit on desktop computers, or with VR glasses.

5. Sun Arrow SPSS

Project by Olivier Boisard

"Sun Arrow" is a Solar Power Satellite (SPS) positioned in geostationary orbit. Its principle consists in concentrating the solar light thanks to two symmetrical pivoting reflectors composed of circular mirrors (primary mirrors); then the resulting light beam is reflected by secondary mirrors located close to the central axis of the structure, in order to be directed towards a disc called the "sandwich", composed of two "slices": on one face photovoltaic sensors converting into electricity the light collected by the reflectors; and on the other face, permanently pointing towards the terrestrial receiving station, microwave transmitters.



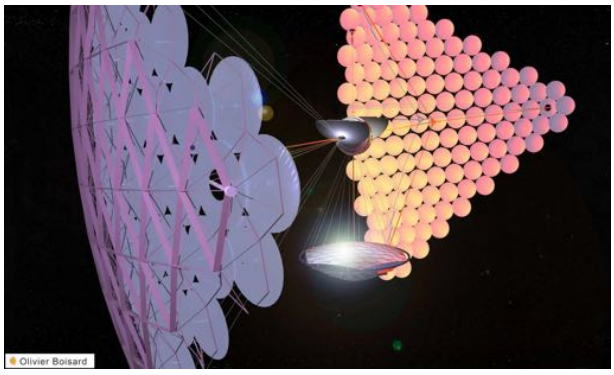


Fig. 4 & 5. Sun Arrow SPS, Olivier Boisard

This project was presented for the 2017 "Architecture and Design of Space" award, the Jacques Rougerie Foundation, Institut de France.

6. Solar Sails

Projects by Olivier Boisard

Concepts of photonic sails, moving thanks to the pressure of the solar light.

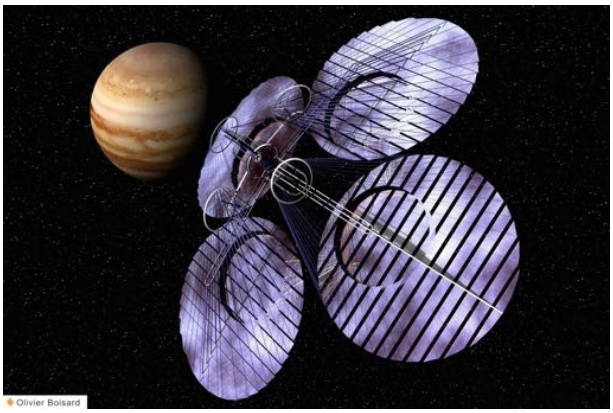


Fig. 6. *Four-leaf clover Solar Sail, Olivier Boisard*

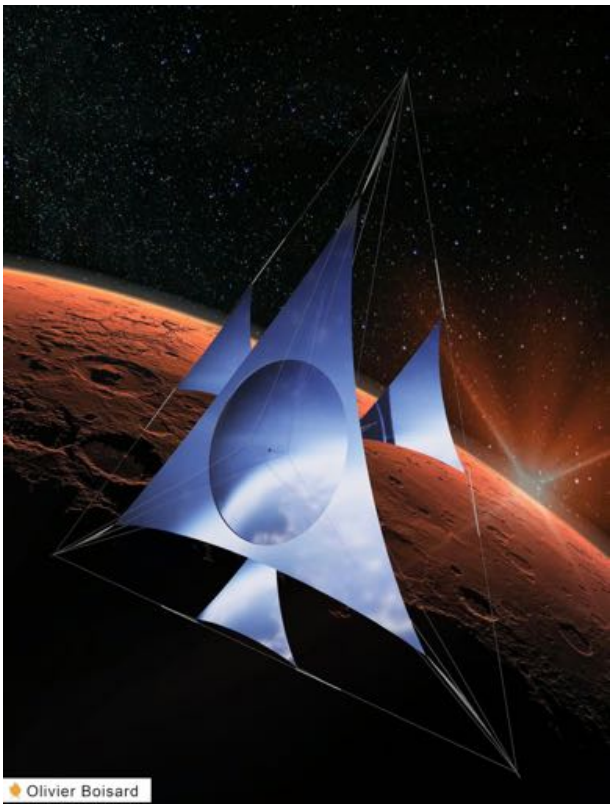


Fig. 7. *Kite Solar Sail*

7. Cosmos Electro Opera

Project by Olivier Boisard

The musical show COSMŎS was conceived in 2018 by Olivier Boisard, intervening as space designer and scientific advisor, with the composer and musician Frederic Bousquet. This "electro opera" performed by the musical group INVENTOR created by Frederic Bousquet, proposes to embark on a journey into space, to the far reaches of the solar system....

Fig. 8. *Olivier Boisard and Frederic Bousquet*

COSMŎS traces a dream story of the space adventure, present and future : take-off from Earth aboard a giant rocket - tomorrow a space elevator -, construction of human colonies on the surface of our neighbor the Moon, then a great journey into the unknown aboard a giant solar sail to the distant planets of the solar system, up to the abyss of the ocean of Enceladus, the icy satellite of the planet Saturn...

Fig. 9. *Moon Village, Olivier Boisard*

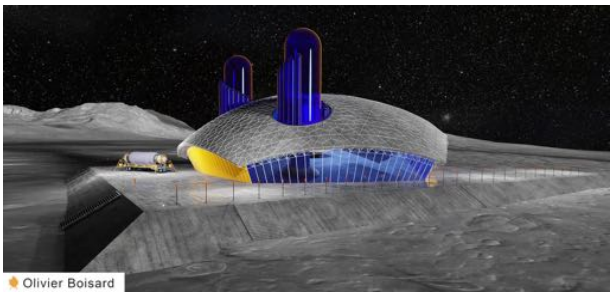


Fig. 10. *Lunar philharmonic, Olivier Boisard*

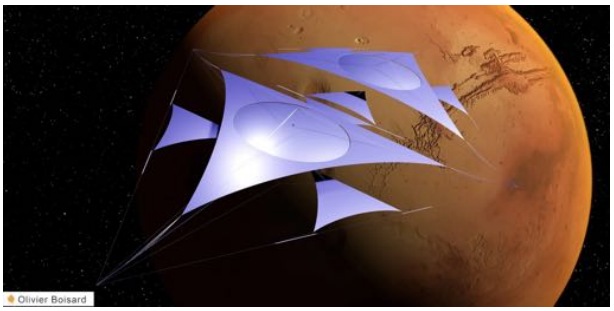


Fig. 11. *Giant Solar Sail, Olivier Boisard*

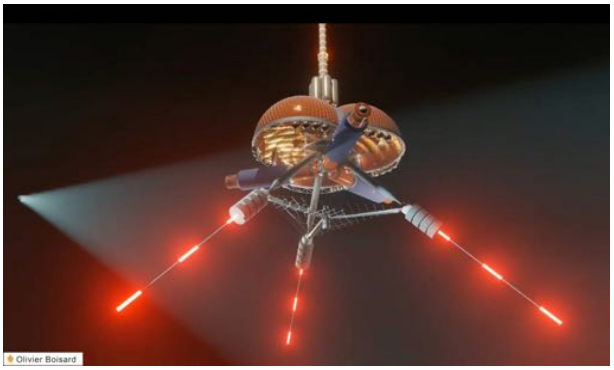


Fig. 12. *Under the ocean of Enceladus, Olivier Boisard*

8. Olympia

Project by Sylve Truyman

1st Prize
MARS CITY DESIGN
competition USA (2019)

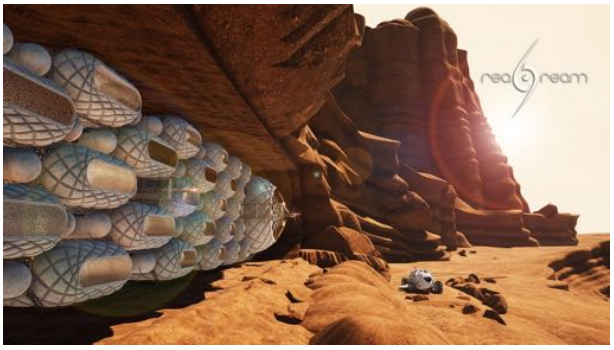


Fig. 13. Mars City Design, Sylve Truyman

Valle Marineris is one of the deepest place on Mars and maybe the best one to land as the atmosphere is thick enough to allow spaceships to brake.
It is where we imagined our Troglodyte Village for Future Settlers. By digging houses under the rock, humans are protected from cosmic rays and radiations. In this first living unit, behind a thick layer of water ice, people from Earth will find a comfortable place to live, work, even exercise on Mars.
We've been inspired by the antic city of Petra, in the Jordan desert. In this place, there is no wood at all to build structures or scaffoldings.


Fig. 14. City of Petra

25 centuries ago, people had to innovate by sculpting their monuments directly in the mountain itself. The first thing to do was to find a way to reach the top of the cliff. Then, to rappel it down to study the rock and finally, find the perfect place to carve from the top to the bottom.
It is an exeptionnal building method which has also been found among Anasazis Indian in Colorado.
In order to get an equivalent result on planet Mars, we think to use rovers to carve and sculpt the cliff before the arrival of the first astronauts.


Fig. 15. Mars City Design, Sylve Truyman

Rovers will cling themselves the cliff and then rappel it down to start the building of the troglodyte house.
As our ancestors did, they will start from the top to the bottom of the cliff. This first uninhabited mission could be fully automatic or controlled from one of the moon of Mars.

This level is dedicated to life support equipment, tanks and containers for water, oxygen and nitrogen. This space would also be used as a garage for rovers and equipments during storms.

Bigger rovers will then be needed to build the village. They will also be used as a transport for the crew when astronauts land on Mars. Such a vehicle has several functions.

For example, it can carry heavy loads such as life modules that will be placed Inside the cave.


Fig. 15. Mars City Design, Sylve Truyman

When humans arrive here, they will be tired by their long journey in space. For this reason, the base will at first be built by machines.
The lower level is dedicated to supply modules, tanks for oxygen, nitrogen and water. Inflatables living modules are on the upper level. Each unit is protected from radiations by a thick rock.
Windows are made of multiple layers of water ice to protect and also provide natural light Inside. It is possible to build an entire city with this unique principle.


Fig. 16. Mars City Design, Sylve Truyman

This work requires that the location have been well studied. Machines and Artificial Intelligence must find

the appropriate topography to spend the minimum of energy and time.

The more a city grows, the more it needs connections. In addition to the horizontal tunnels that are between the modules, we have imagined Ice tubes that connect floors to each others. A need inspired structure that can stand on itself with a lift in the middle. A vertical city will be adapted to the rocky shape of Valles Marineris canyon.


Fig. 17. Mars City Design, Sylve Truyman

A standardized concept that can be adapted into several architectural typologies.
The sports complex with an indoor arena will allow the inhabitants to participate in many compétitions.
Many living modules will be used for sports. With three times less gravity on Mars, human's health is a priority.


Fig. 18. Mars City Design, Sylve Truyman

Let's imagine together this martian troglodyte city, protected by rock and ice with natural light Inside.
Obviously, all of these equipments require a lot of energy. That's why large and flexible solar panels will be deployed by rovers. They could be folded quickly before a storm.

This biomimetic project incorporates many knowledge that both Nature and Antic civilizations have given us to think about the futur of humanity.


Fig. 19. Mars City Design, Sylve Truyman

9. Solar Spore
By Sylve Truyman
Jury's choice
J.ROUGERIE - INSTITUT DE FRANCE
competition FRANCE (2017)

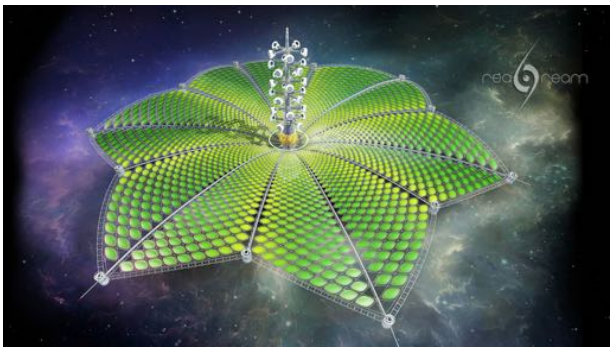


Fig. 20. Solar Spore, Sylve Truyman

Interview of Sylve Truyman (Architect) by the Institut de France

Above all, tell us about yourself in a few words: Where do you live, study or work at the moment?
We are a french team based in Paris. Sylve whose father Pierre Jacques is an engineer is an architect and a concept designer. Sylve works for ten years in architectural firms in Paris. We had planned to design a project together for a long time.

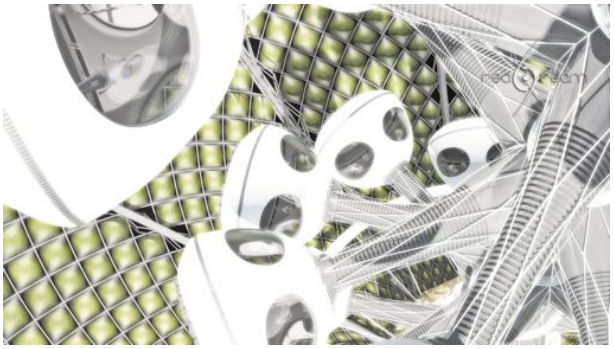


Fig. 21. Solar Spore, Sylve Truyman

One sentence to tell us about your project:
The J.Rougerie Foundation invited us to think about architecture and space : two fields that fascinate us. So we have imagined an orbital solar power plant similar to a seed : it can travel throught space and open up like a flower.

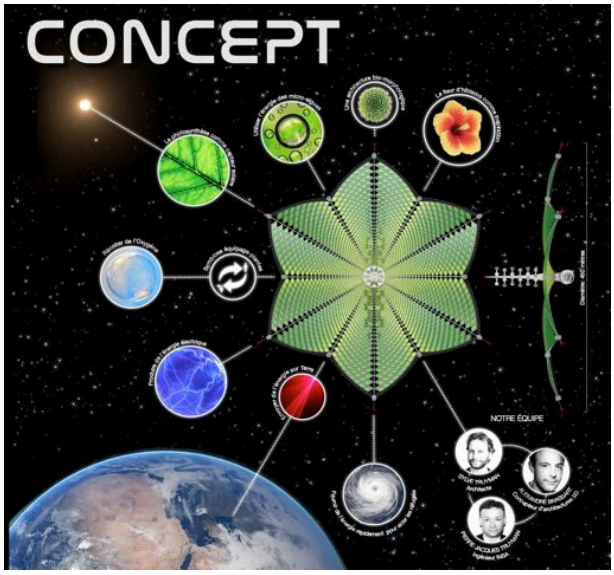


Fig. 22. Solar Spore, Sylve Truyman

Was does your project mean to you?
Above all, we wanted to design a project that blends innovative technologies and inspired by Nature. As it is an inexhaustible source of inspiration.
"We consider Nature as High technology."
All the technologies and inovations of the Solar Spore project already exist. We have combined and mixed devices present on Earth or in the International Space Station. It is important to us that most of the technical aspects are possible and that those who see our images understand that these dreams are within reach.
"Each of our conceptions is a « Real Dream » that our children or grandchildren will see. It has nothing to do with utopia or fiction."

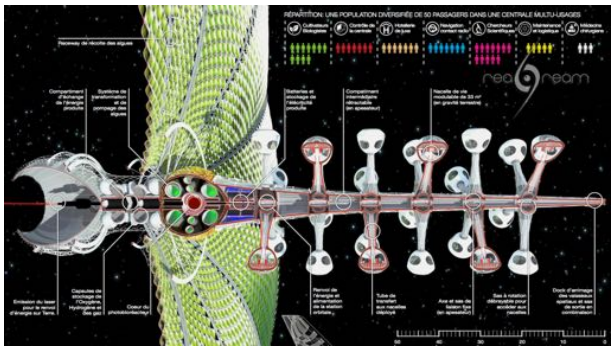


Fig. 22. Solar Spore, Sylve Truyman

What challenges did you face during the creation process of your project?
First we realized it was difficult to send it into space. That is why we asked for the help of sylve's father, Pierre Jacques. Together we designed a large rocket to send Solar Spore into space in one go. This project is designed as a living organism just like a plant, it can open easily, almost naturaly. We could imagine a lot af them and send them in the solar system.

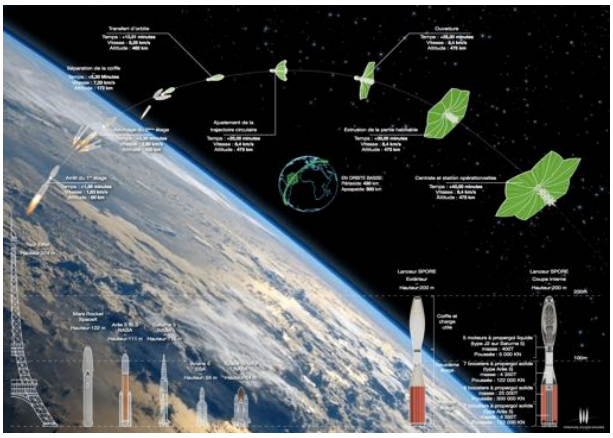


Fig. 23. Solar Spore, Sylve Truyman

How does it feel to try to be one of the most visionary architects in the world?
We do not pretend to be so ! However we became interested in the thought and the approach of a visionary architect: Jacques Rougerie. In 1988 there was a phone conversation between J.Rougerie and Jean Loup Chrétien, an aquanaut Under the sea calling an astronaut in the Mir station. We discover it on the internet and it had such an effect on us.
They made us aware of the tremendous possibilities that these two worlds offer together and separately. Seaweed is the domain of the sea, so precious to Jacques Rougerie and exporting it in space was also a tribute to his work.


Fig. 24. Solar Spore, Sylve Truyman

Do you think the Foundation played a crucial role in your project's advancement, visibility?
By entering the competition of the Foundation we had a feeling of freedom. It was a fulfilling and enriching experience. We were both surprised and happy to win the « jury's choice » Prize. This allowed us to validate our approach and continue in that direction. Now we know we are both able to win a competition by ourselves and also to make an original project incorporating ideas that are important to us.

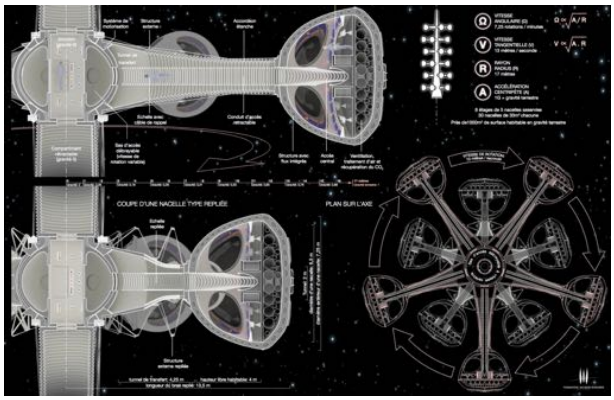


Fig. 25. Solar Spore, Sylve Truyman

10. Selenia
By Sylve Truyman
Special Mention
J.ROUGERIE - INSTITUT DE FRANCE
competition FRANCE
(2018)

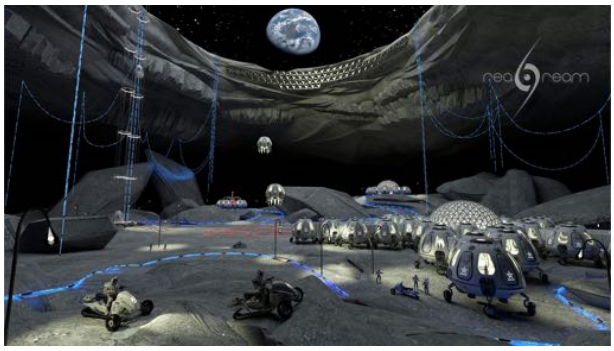


Fig. 26. Selenia, Sylve Truyman

Learn from history and ancient civilizations.
1150 years BC, the situation was critical for the city of Pi-Ramsès: the green banks of the Nile river have turned into an arid and barren desert. Fortunately Ramses II, his builder, had it all figured out and so this city could be fully rebuilt stone by stone. So it was rebuilt 40 kms to the west and renamed Tanis. A feat made possible because the city had been designed so from the beginning.

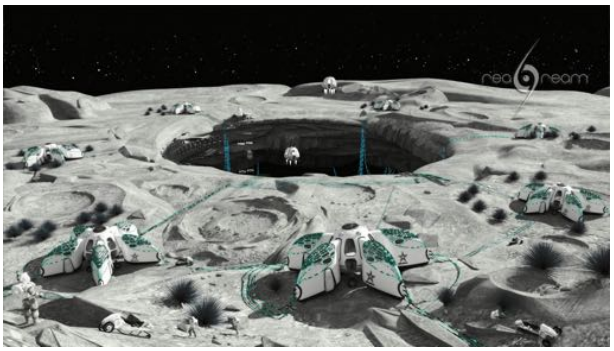


Fig. 27. Selenia, Sylve Truyman

Caves on the Moon, how to be protected from cosmic radiations?
In 2017 The NASA LRO probe discovered holes on the Moon that led to former lava tubes of several dozens of kilometers long. An opportunity that solved recurring problems faced by several space agencies : how to protect future lunar inhabitants from lethal radiations, micrometeorites and strong temperature variations?

Fig. 28. Selenia, Sylve Truyman

Biomimetism: inspired by the nature.
They will be joined to each other such as the cells of plants and so the village will be able to adapt itself and evolve by following the uneven outlines of our satellite on the surface as well as in lava tubes. It can be compared to a starfish moving at the bottom of the sea. It will be enlightened by a Bioluminescent PhytoplanktonSeveral ones could be placed in the first version of the future NASA rocket SLS.

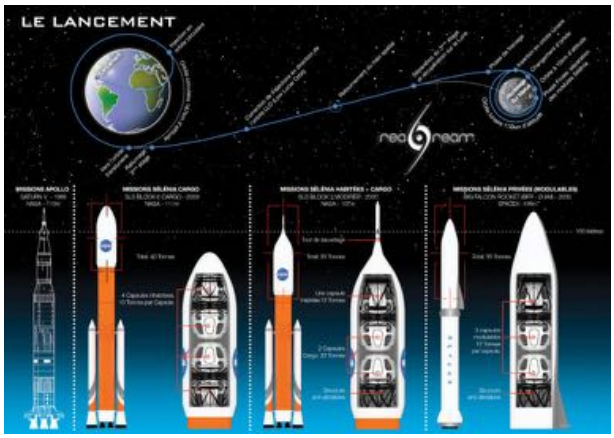


Fig. 29. Selenia, Sylve Truyman

A tribute to Stanley Kubrick and Jules Verne.
Half a century after Stanley Kubrick's movie « on 2001 the Odyssey of the space » to which we wanted to pay a tribute to it by creating our sketch. A century before him Jules Verne imagined in his novel « De la Terre à la Lune » a journey in four days. The inhabitants on the moon were called the Selenites. A name that comes from the Greek goddess of the full Moon: Séléné. In memory of this novel which informed my entire childhood and that of my father and also inspired numerous projects, we gave the name Séléna to this village under the Moon.


Fig. 30. Selenia, Sylve Truyman