FOUNDATION

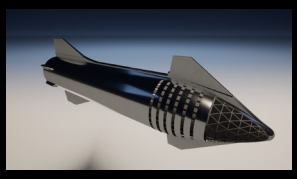
SPECIAL EDITION

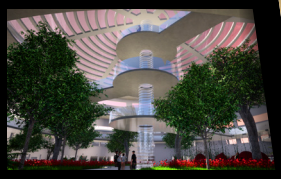
>>> SPECIAL PUBLICATION N°25

PLANETSCOPE

SCIENTIFIC SOLAR SYSTEM NEWS

>>> WORLDS STUDIES





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Living together, the Martian way.

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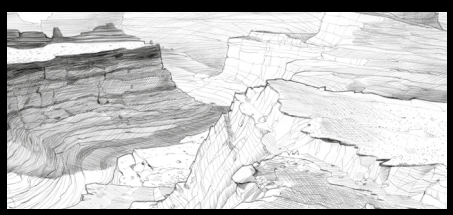
ARKADIA/SURYA

A DREAM COME TRUE

...AND PRESENT IN EACH PART



LUCIE'S NOTEBOOK
OUR REPORTER'S VISION

Website

1.
LIFE SUPPORT SYSTEMS
BETWEEN SUN AND ICE

The Foundation City-State regroups two main settlement poles and a smattering of small settlements approximately aligned on the 170° West meridian. The two settlements, Arkadia and Surya, often described as the city of water and the city of the sun, are linked by the Meridian Way, a 2,200 km long road that is the backbone of the Foundation City-State.
Arkadia, located in Arkadia Planitia is the oldest human settlement on Mars. It developed from the first inhabited base on Mars, chosen for easy access to large amounts of water ice.
Surya is a younger settlement, located in Nicholson crater near the Equator, and its location was determined by a favorable combination of sunshine, good views of the central peak and the presence of water ice in the nearby Medusae Fossae region. The construction of Surya was held back until a compromise was reached concerning the rules of Planetary Protection. The new settlement, with its own spaceport, has practically reached the size of Arkadia.
The two settlements benefit from a fairly low altitude, respectively -3798 m and -4423 m, providing an atmospheric pressure of about 1 kPa.

The Suryan settlement tends towards a greater adaptation to the Martian environment when compared to Arkadia. Surya' investment in solar energy is highlighted by the use of surface greenhouses and space mirrors for food production, rather than the use of underground grow rooms and bioreactors. The architecture is also based on spaces that are more open to the outside, with a more relaxed attitude towards radiation, rather than the initial reliance tunnels and massive shielding found in Arkadia.

Lucie's notebook

Arrival at Arkadia

"Of all the questions I asked myself before leaving Earth, the most heady, the simplest and the most important was undoubtedly the one concerning "these other humans": Would these brothers from another planet accept me? Now, I find myself dreading their look. It's silly, but that's what I feel as we approach Mars. In the imminence of a landing on it's crazy spaceport, my heart is racing, thinking of all the intrusive questions that I will have to ask, all these avenues of human civilization that I will have to walk in search of an answer. I will have to understand what is the pride of Arkadians and Suryans, the inhabitants of this strange City-State known as Foundation, where each new green plot of "land" has ben won at the price of efforts and ingenuity, bringing life to a planet which was devoid of it. The steam clears from the tarmac. The airlocks opens and a new smell reaches my nostrils. I am on Mars." ■

THE FOUNDATION SOCIETY : ON THE ROAD FOR THE ECOPOIESIS PROCESS

The first human settlements on Mars were the results of public-private partnerships, whose governance was ensured by consortiums of one or more Earth nations. Their rules were necessarily complex and often poorly adapted to local conditions. he requirements of daily survival on Mars highlighted the need for rapid and collectively accepted decisions, and irresistibly called for the independence of Martians. The natural arrangement of the martian settlements into cities gave rise to a planet wide civilisation of sovereign City-States, made of one central city or a coalition of cities.
Foundation is the largest and most famous of these coalitions, and to most people on Earth, it is basically Mars.

Mars Congress

At the planetary scale, a consultative body, called The Congress of Mars was quickly established. It emerged to set up and run the Mars Planetary Rescue Force, nicknamed, with a certain irony, the Red Helmets. This organization first administered the contributions of each city (field hospitals, suborbital hoppers, staff) then became the privileged place for discussion on other global themes.
The main topic of discussion at this level concerns the terraforming of the planet, which is still in its infancy. A challenge system has been established and is based on bonuses won by the first City-State to achieve an objective linked to the ecopoiesis process. This healthy competition, which some call the "Olympic Games of Mars" is followed throughout the solar system and the subject to a whole betting system. Its winnings are used to finance the prizes and the compensation for prejudices to settlements penalized by the terraforming process.
The Congress of Mars also functions as an arbitration court. If coexistence and cooperation are the watchwords of diplomacy on Mars, there is definitively a certain competition for access to resources, and relations between City-States are not free from disputes, and even conflicts.

Use of weapons and the "Balance of Prudence"

Even if the means to produce weapons are available, there is little incentive to build them and use them. Using a weapon on Mars leads to the risk of rupturing the habitat walls, an act seen as an abject crime against ▶

Humanity and the Ecosystem that sustains it, and deserving of the most severe punishment. In a similar way that the use of atomic weapon on Earth is restrained by the "Balance of Terror", even if no text explicitly prohibits the use of weapons on Mars, each State knows that endangering a habitat, even in "collateral damage", would lead to all the other States allying against the perpetrator. No State has betrayed this tacit agreement, which is commonly called "Balance of Prudence".

Political organization of Foundation

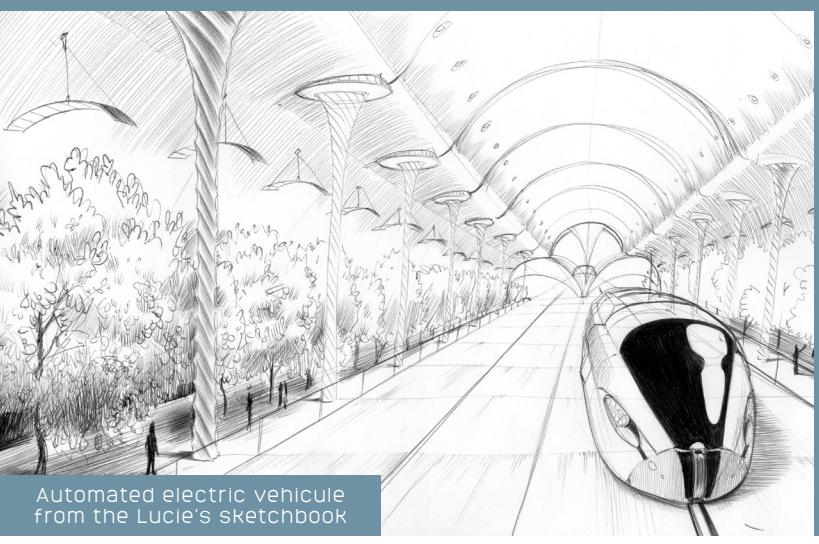
Each Martian City-State is organized in a different way, with different entities representing the legislative, executive and judicial powers. Foundation operates as a direct democracy. Most public decisions are submitted to referendum by universal suffrage. Votes are electronic and authenticated by blockchain. Citizens' solicitations are permanent, most of the votes relate to relatively local decisions and the participation rate is generally low. The discretionary power of political staff is thus very limited, and it is sometimes necessary to resort to the drawing of lots to appoint officers. The Terran lobbies have regularly declared themselves bewildered by the lack of interest of politicians toward their precious advice.
The political organization is based on the principle of subsidiarity, aiming to delegate the level of decision as low as possible. The basic level is that of the district, a tightly defined set of habitats serving of the order of 10,000 people, but which is in practice very variable. This district is administered by a mayor and municipal councilors. Each higher echelon has its officers elected by universal suffrage. Unlike on Earth, it's observed that favorite public positions are the lowest and local ones.
Subsidiarity is particularly important for the judiciary and executive powers. For example, in Arkadia and Suria, if a crime is committed in a district, the judgement and the sentence are carried out at this level. If the crime concerns two districts, officers of the next echelon are mandated to solve the problem.

The Right to Life Support

The most famous constitutional principle of Foundation is called "the Right to Life Support".
Despite its economically open-market culture, the Foundation society implements many costly social protection measures, which are readily accepted because they are subject to the rapid sanction of public control and direct democracy. Education, measures promoting birth rates, medical follow-up for all are considered inalienable public services. As is the Right to Life Support, which includes air, a minimum amount of water, energy and minimal housing. Indeed it is impossible to live outside the system on Mars.
This highly decentralized but highly interconnected governance has enabled intense technological development, stimulated by the permanent emulation between districts and City-States. It has led to the selection of organizational methods derived from agile methods, but applied to the development of districts, cities and rule-making. The increase in productivity that resulted from this organizational revolution was comparable in magnitude to the revolutions of Fordism and project management techniques of the Second World War, but this time without the drawbacks of cultural standardization and exclusion from the decision process. These developments were paralleled by high population growth, stimulated by the birth rate but also by immigration.
This is the Foundation society, very representative of all Martian societies: coalitions of hundreds of small districts, fiercely watching over their independence and uniqueness, but never hesitating to exchange information, and to vote for everything. ■

AUTONOMY AND LIFE SUPPORT SYSTEM, **A ROOM IN THE HUMAN IMAGINATION TO INVENT NEW CITIES**

Living on Mars is not without risks, but the design of the life support systems, and its continuous improvement, has reduced the risks to that of a well lived life on Earth. Life on Mars is no longer the one of a crew in an Antarctic station, but the one of a citizen of a comfortable, mid sized cosmopolitan city.
This could be achieved thanks to subsidiarity being taken as the fundamental governance principle. In terms of town planning, this results in maximum autonomy for the district of about 10,000 inhabitants. It has many advantages; it effectively ensures the empowerment of each citizen vis-à-vis the maintenance of the manufactured biological ecosystem that keeps him alive, as well as the sharing of practices between the different districts which leads to healthy competition. In addition, compartmentalisation, maximized, ensures that a local accident does not compromise the whole of the city, which will then be able to come to the aid of the stricken district. Thus each district is as autonomous as possible, both physically and in terms of production, but also in the management of public affairs. The principle of autonomy implies a second one: maximizing the proximity of the different areas necessary for the life of a citizen. Combining residence, work, shops, social and community areas into a single habitat is common practice. This principle, combines as well with the fact that agriculture and the maintenance of ecosystems is one of the main activity of the inhabitants of Foundation, since it is the most labor-intensive. It is therefore necessary to reduce the distance between agricultural and urban areas.
In this way it is possible to favor pedestrian displacements within a district, The journeys between the districts are made by a system of automated electric



Automated electric vehicule from the Lucie's sketchbook

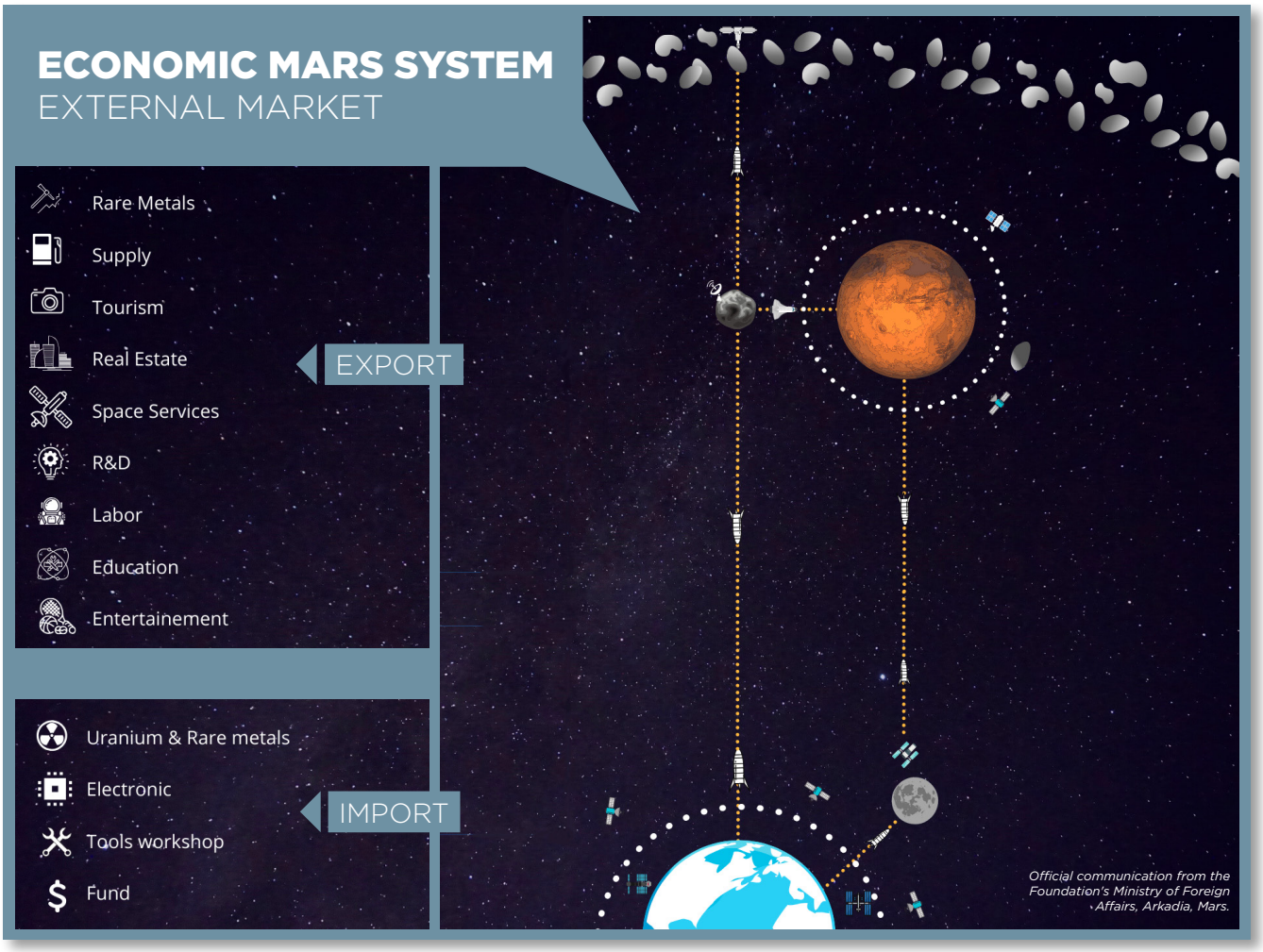
▶▶

vehicles, rolling beneath the pedestrian walkways and through tunnels, integrated in the pressurized enclosures or themselves pressurized, depending on design.

Solar energy farms occupy a large area outside of the city (several hundred of square kilometers, depending on local energy mix). They are organized as standardized "solar islands", in which solar panels surround a central industrial sector, which include all facilities dedicated to solar panel manufacturing and maintenance, alongside with plants dedicated to methane/oxygen energy vector production and storage (for more details, see our article on energy).
Finally, the systematic use of the building information modeling (BIM) methodology for the design and operation of the city made it possible to optimize costs thanks to the creation of digital twins.
There is room in the human imagination to invent new cities. And what better place than on Mars, where a city must be, by necessity, a mosaic of autonomous villages where each inhabitant, adult and child, is the gardener of the ecosystem that supports them. ■

2.
FOUNDATION SERVICES AND PRODUCTS
HOW IT WORKS ?

Economic measures taken by Foundation during the last 20 years as well as the future projects of private and public actors on the planet.



Note: G$/yr stands for billions of United States dollars per Earth years.

TOURISM - 11 G$ / year

Residence offered with premium services:
- For scientists, engineers and others, on missions financed by the Earth.
- Tourists on the experience of a lifetime.
- Adventurers & Pioneers from the whole Solar System,
- Health, Cures for retired people, or anyone else: Extension of life expectancy by reducing stress on the heart and arteries by lower gravity.

Excursion to the surface on emblematic places:
- Marineris Valleys, the largest canyon in the solar system.
- Mount Olympus, the largest volcano in the solar system.
- The Ark of Tartarus Colles.
- Visit of a belt asteroid aboard an X33.
- Stellar cruise to Saturn aboard a Starship.

Mars welcome more than 50,000 visitors per synod !

REAL ESTATE - 69 G$ / year

Licensing:
Foundation offers licenses to exploit and explore the riches of Mars. A company is authorized to explore and extract mineral resources; in exchange it has a 30-year ▶

property right and it must participate, via subsidies, to the extension of the city. It can also rent the operating site to other companies.

Real estate investment:

- It is the core job of each Martian settler to build a new world, it is obvious that Mars would be the new Eldorado for construction and real estate financing, compared to a saturated Earth where competition is fierce and profits tiny.
- Investments in Foundation currently represents a 28% growth share in the solar system property market.
- Average price per m^2: 10 k$.

And remember, it is not a question of demolishing a planet to cover it with concrete, but of greening Mars!

KNOWLEDGE ECONOMY - 5 G$ / year

EDUCATION

The Mars Institute Technology (MIT) has designed a training offer focused on a high level of excellence in the following fields:

- Agronomy,
- Sociology and Psychology,
- Engineering according to specialization,
- 3D printing,
- Robotics and AI,
- Circular Economy and Recycling.

MIT has concluded research and development contracts with private companies on Earth.

The universities of Mars teach the Earth' elite thanks to professors having taken part in the colonization of Mars.

R&D AND PATENTS

Mars is a harsh place, and inventiveness is a necessity to survive. Innovation is t the core of Foundation economy. Thanks to its R&D, Foundation draws profit of this for the benefit of Terrans

It offers patent exploitation licenses for the following sectors:

- Medicine (cancer treatment, life extension, cardiovascular treatment, procreation assistance and many others,
- Food industry (GMO, above-ground, soil treatment),
- Climate and environmental control,
- Engineering,
- Circular economy,
- Recycling and reuse of materials,
- Dry extraction of resources,
- Water Management,
- Energy.

The example of Earth ISRU:

Today the technologies developed on Mars to make steel from the regolith are sold under license to Earth and allow the production of high quality steel at a competitive manner directly from low-grade ores. Foundation collects 5% of royalties on the patent exploitation licenses on steel, this generates for Mars revenues of 40 billion $ / year. The patents related to the highly automated Foundation solar farms are nowadays best-sellers on Earth.

All of Foundation university and patent revenues are placed with Bank of Mars. The interest of 5% is used to finance the extension of the colonial projects of Mars.

SPACE SERVICES - 5,1 G$ / year

EQUIPMENT AND LAUNCH

The Martian space industry is booming. Today it competes with Earth for the supply of space launch and equipment. Currently, Foundation offers the following services:

- Production and launching of geostationary satellite thanks to the advantage of ΔV compared to Earth.
- Design and launching of orbital stations
- Asteroid drilling and mining equipment

Lucie's notebook

The Foundation Space History Museum

"That will be all for us, madam. To answer your concerns, no quarantine will be necessary - the journey is long enough!"

It is a graying medical control doctor who concludes her only spoken sentence by waving me away with a gesture. I am allowed out of the glass office with a few drugs in a cellulose bag and a long list of recommendations. Faster than I imagined, after 4 months in weightlessness.

It is now 5 days since I landed on Mars and severe leg pains remind me of the kilometers already covered in the streets of Arkadia. The slight gravity of Mars has helped me get used to the vertical station again, but my ungainly gait betrays my origin. My timid little steps and my uncontrolled leaps earn me smiles! I have not yet managed to imitate the long slow and elegant strides of the native Martians.

The local chapter of the Mars Society gave me an interview this morning and provided me with a guide, Adhémar. I have been thoroughly briefed with safety drills and practices and am free to move around. Adhémar offered to accompany me to a speech given by the Minister of Culture on the anniversary of the founding of Arkadia. We have to walk to get there. Again. Arkadians vigorous walking habits relegate the marathon runners of Earth to simple hikers. Everyone walks here. But I expect I'll get used to it soon.

The Grand dome of the History Museum finally covers us. It is the most visited attraction on the planet. The speech is held in front of several hundred people. The majesty of the space allows me to listen to a rather inspired and fortunately brief speech (my feet are killing me!). Adhémar shows me some of the dome' treasures. I find myself facing the modules of the first Martian base, preserved intact. It is here, in the center of the city of Arkadia, that the first elements of the colony were set up. Further along, Adhémar, stops in front of a rather incongruous sculpture. For Adhémar, it is the object of a certain emotion: during the early manned tests of the first Martian built space vehicle, a team of astronauts decided to bring back to Arkadia the mannequin Starman at the wheel of his Tesla Roadster. Indeed, a few day after the Falcon Heavy launch, to the question "if I can recover it, can I keep it ?", Elon Musk, founder of SpaceX and owner of the vehicle had answered "Yes". The Martians have apparently taken up the gauntlet. ■

- Exploration probes to the outer planets and the asteroid belt.
- X33 in commercial or government version
- Space Internet
- Telecommunication equipment

Costs to orbit examples:
- LEO: $ 150 / kg
- GEO: $ 180 / kg
- Moon: $ 200 / kg
- Belt: $ 100 / kg

SUPPLY

Foundation offers an extensive infrastructure for supply contracts for the Moon, orbital stations and the Asteroid Belt. As well as extended trips to the gas giants.

Here is a non-exhaustive list of possible supplies:
- Food,
- Carbon, nitrogen, hydrogen and other light elements,
- Consumables and basic necessities,
- Tools and Machines, some as simple and as essential as toothbrushes,
- Propellant,
- Space habitats.

As an indication, the annual supply to the Moon, populated by 100,000 people, brings in 1.6 G$/yr only to compensate for life system losses..

LABOR

Foundation provides the Asteroid Belt with the manpower necessary for the development of the mining industry.
All trades, from the most intellectual to the most manual are sought after.

Mars Services, the umbrella-organization for the management of extra-Martian workers, is responsible for:
- Providing qualified personnel,
- Organizing Mars transport - Belt,
- Providing supplies and consumables,
- Certifications - Payroll management,
- Health coverage.

There are currently more than 10 000 workers in the Asteroids Belt. And yes, they call themselves Belters.

RARE METALS - 1,2 G$ / year

Foundation in collaboration with MarsProof, the most influential Miner' Guild of Mars which is behind the first Martian service station, takes care of extracting, refining and delivering metals essential to your industries.
MarsProof offers a diversified catalog of metals, including rare Earth minerals, gold, platinum and copper and offers a direct route from the belt to Earth. MarsProof take a contribution of 5% in materials for Mars and 5% in cash in order to take care of the transportation, and the security of the transporter.
Mars also offers deliveries of metals to all human settlements in the solar system.

ENTERTAINMENT - 7,4 G$ / year

Foundation offers various services in the entertainment, games and multimedia sector:
- Annual tourist lotteries.
- Bets on the winning city of the Terraformation prizes (Mars Olympic Games).
- Sale of broadcasting rights for sporting events
- The Grand Rally of the Marineris Valleys

For example, the Red Sands Lottery, one of the numerous dedicated lotteries on Earth is set up with $100 tickets. Every two years, the lottery draws ten winners for a two-year "all inclusive" trip to Mars. The lottery generates a very high margin which is devoted to the development of Mars. ■

INTERNAL TRADE

Monetary system

Foundation chose to abolish the fiduciary system widely used on Earth. The goal was to gain energy because there was no need to produce physical currency on the spot.
During the early development of the economy of Arkadia, a standard system was put in place. This was based on a raw material stored in Foundation with the blockchain (MTC) as a distribution vector. With the development of methane strategic stockpiles for energy storage and as a precursor for industrial activities, methane progressively gained a tremendous importance in the Martian economy. The methane standard enabled the economy of Foundation to remain independent in the face of Earthly fluctuations in the financial markets, and is now used in all martian City-States. As a result, one of the most useful organic compound is produced and stored on Mars as would be gold on Earth. Accumulation of organic matter, a major step of Mars terraforming, is at the core of Mars financial system.

Trade Road

Each settlements has developed both a fiercely protected general production capacity and a few specialities for inter settlement and intercity state trade. Arkadia is an industrial center for large scale production of industrial goods using cheap nuclear power. Surya developed its solar industry. The Meridian Way serves as an exchange route between the settlements, creating ties that bind the two parts of the Foundation City-State together.

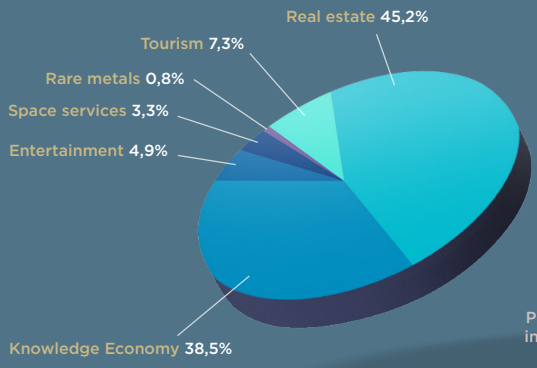
Banking services

Service revenues, patent royalties and immigrant money is placed in a bank on Foundation and is loaned to Earth and Martians with interest. Interest is used to finance colonial works. The bank of Foundation thus became the first space bank. Banking is currently expanding to fund expansion in the belt.

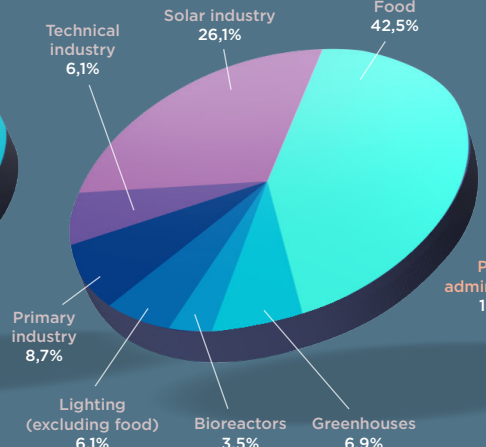
Bonus Malus

Mars has implemented a Bonus / Malus system based on the positions taken by each and each group in order to promote mutual aid and sharing. ■

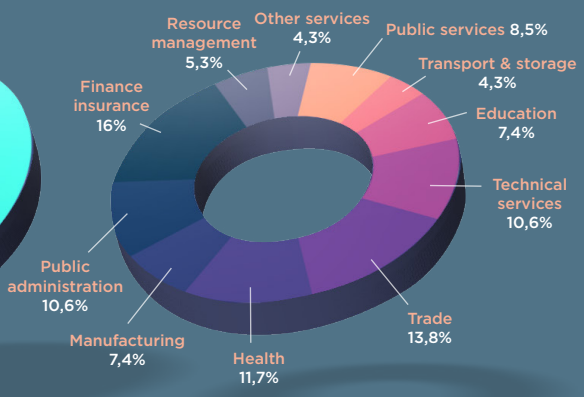
EXPORT

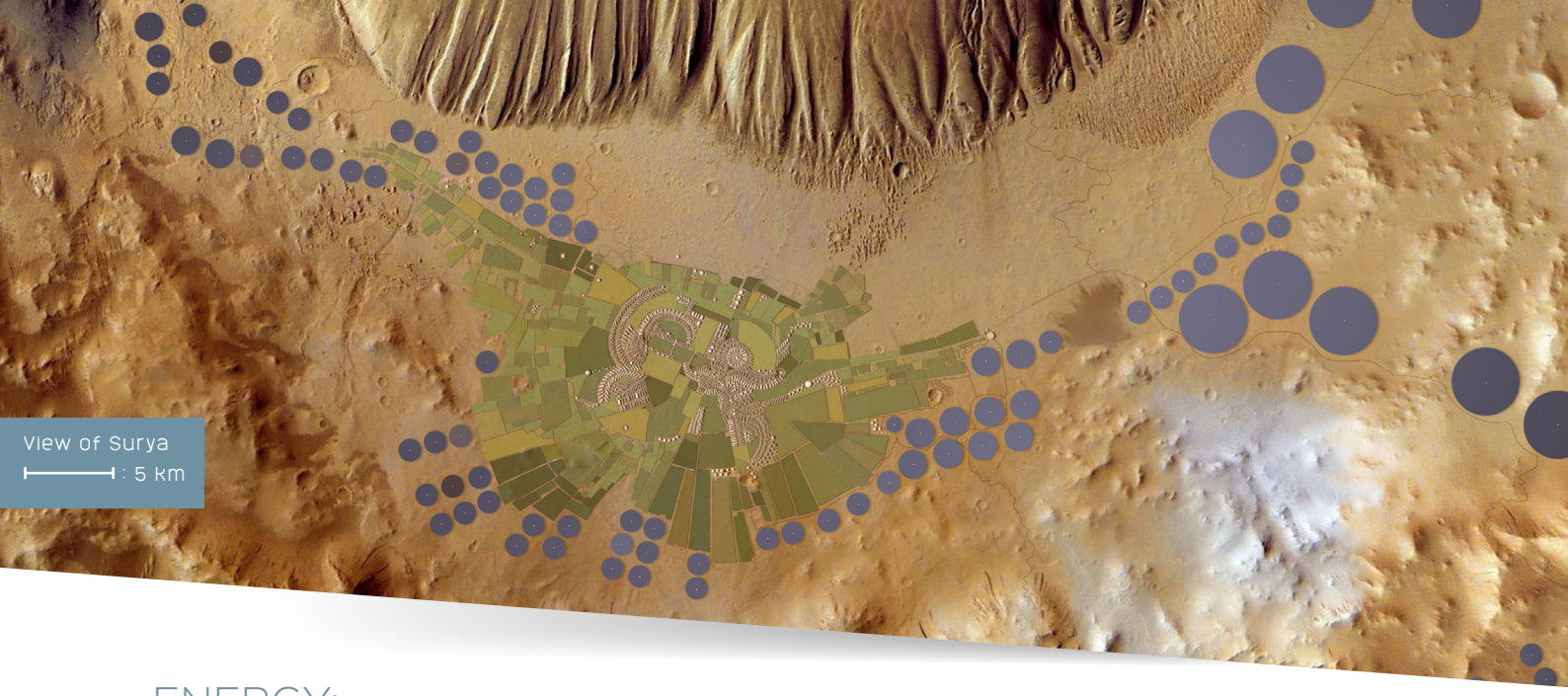


ENERGY REQUIREMENT OF INTERNAL TRADE



FOUNDATION BUDGET





ENERGY:
THE NUCLEAR AND SOLAR ENERGY MIX

Energy is a fundamental subject for Martian societies. It is not the most labor intensive sector (but certainly the one that attracts the most attention). Some essential points: civilizations on Earth developed from the exploitation of wood from forests, as fuel, but also as building material. It then moved on to the formidable fossil fuel reserves. The Terrans have thus benefited from a colossal converter of solar energy, the Ecosystem, fruit of billions of years of evolution and stockpiling huge amounts of energy. However, on Mars, civilization and a mature ecosystem can only emerge from a system of energy production *ex nihilo*.

Foundation was developed on the basis of a nuclear and solar energy mix. The low density of the atmosphere of Mars makes wind power uneconomical and no significant underground heat source has been found for geothermal energy to be developed on a City-State scale.

Solar energy on Mars today ensures near complete independence from the Earth

Nuclear energy offers the possibility of a continuous supply of energy. The preferred technology is that of fast-neutron MSR (Molten Salt Reactor) with in-line fuel reprocessing. However, the absence of usable uranium deposits on Mars makes the planet dependent on natural uranium extracted from the oceans on Earth and imported at each synod. This departure from the rules of autonomy is made out of necessity, and has led to the creation of a strategic stockpile of ten years worth of nuclear fuel. Exploration continues in the hope of finding local uranium that could compete with solar energy.

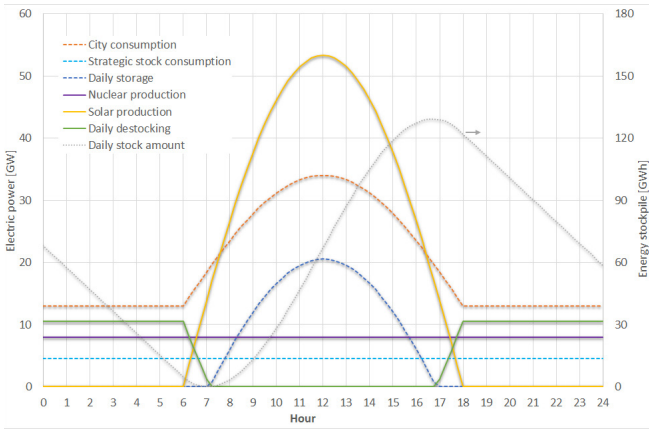
Solar energy on Mars today ensures near complete independence from the Earth, but also between each location. The technology of inkjet printed perovskite photovoltaic cells dominates the field. They are installed in concentric strips approximately 5 m wide and up to several kilometers long, around central dedicated manufacturing plants. Specialized rovers print them, clean the surface of dust, move the strips when needed and recycle them if they are damaged.

Solar energy is sensitive to natural variations in sunshine: daily variations, seasonal variations (induced by the obliquity of the axis of rotation of Mars to which are added variations due to the ellipticity of its orbit, where the sunshine is more than 40% stronger at perihelion than at aphelion) and dust storms. These regularly plunge the colony into the dark for long periods, with planet wide storms every six years and many smaller ones.

Energy supply being the condition *sine qua non* of survival on Mars, these conditions make the management of energy stocks extremely strategic. To meet the challenge, Foundation uses three generic technologies: batteries for short-term storage, pumped storage hydroelectricity (PSH) for short and medium term storage when available, and a fleet of methanox thermal power plants for strategic "long-term" storage.

The two main settlements observe the principles described above, but put into practice different energy mixes. Arkadia has a balanced energy mix of 45% nuclear and 55% solar (in energy produced), while the sunshine in Surya (combined with a fierce desire for independence) has enabled the implementation of a much higher fraction of solar. In addition, in Surya, a massive PSH stores energy (see box on this subject).

Daily energy mix of Surya settlement



	Arkadia	Surya
Nuclear	17 GW	8 GW
Solar	39 GW	53 GW
Batteries	2 GW	15 GW
Thermal (methane)	17 GW	15 GW
PSH	0 GW	5 GW

Energy consumption on Mars is 1600 GJ / year per person. This may seem huge versus 220 GJ / year per person in North America, or 120 GJ / year / person in Europe but it is, at least in part, an illusion: on Earth, a gigantic fraction of the required solar energy is hidden in agricultural production, which is not included in the balance sheets. On Mars, all the energy is counted and tabulated. Nothing is free.

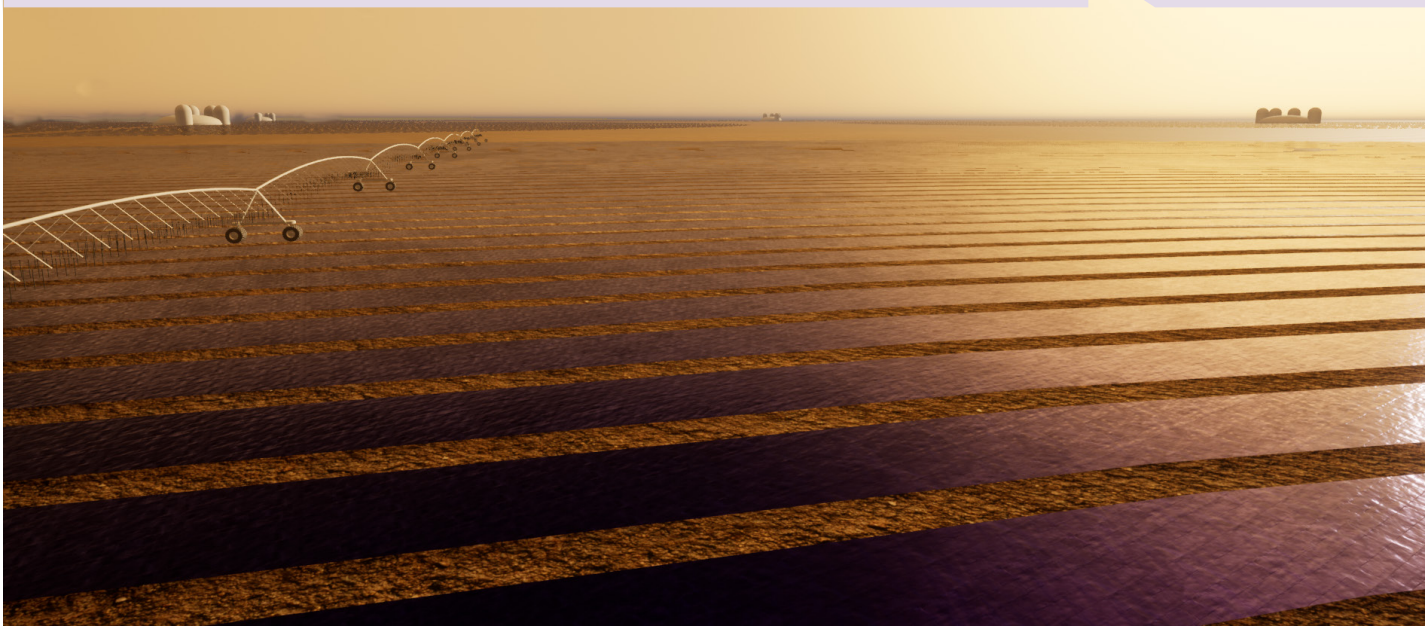
Box 1: Nicholson PSH

The city of Surya is located at the equator, in Nicholson crater. This crater offers elevation differences of over one thousand meters and has proven to be a prime location for the construction of a massive pumped storage hydroelectric (PSH) station of 5 GW and 200 GWh, partly dedicated to daily storage and partly to seasonal storage.
The principle is as follows: Two lakes hold 300 million m^3 of water each (4kmx3kmx25m and 3kmx2kmx50m). One is located at the bottom of the crater and the other in a natural hollow near the central summit. They are connected by pipes. To keep the water in a liquid state, the lakes are covered with hanging plastic sheets and maintained at a pressure of 0.1 bar. Thanks to the greenhouse effect and additional light provided by orbital mirrors, the temperature is kept above 5° Celsius. During the day, large fields of solar panels supply electrical energy to reversible turbines which bring the water up from the lower lake to the upper one. Depending on the needs, day and night, the water can run down the pipes and reverse the turbines, driving electrical generators.
Thanks to a maximum total flow of 2000 m^3/s and a cumulative elevation of more than 1000 meters, the electric power is potentially 5 GW (efficiency of 70%) and the storable energy is around 200 GWh. ■

Lucie's notebook

Visit to the solar fields

"Arkadia is surrounded by hundreds of square kilometers of strips of solar panels whose role is to provide local, abundant and cheap power. These are manufactured and maintained by autonomous factories which tirelessly roam the great expanses of Mars to extend the surface of energy collection. These robots are themselves manufactured in fully automated factories (which they call autofabs). I discover that Adhémar, for his part, works in one of the master factories that manufactures the components of these autofabs. After a 3-day petition and an expensive Hawaiian restaurant, Adhémar announces that he is taking me to see the solar panels. Joy!
Leaving early, he finishes his first rotation and picks me up around 11am at the "Domer" station. It's meal time and we'll start with the cafeteria. Like a foreigner recently arrived in Dodge city in the American Far West, I attract attention. I end up exchanging the usual banalities that bring strangers together. While we share a bowl of farmed salmon Poké, several workers ask me, in various ways, how I manage not be afraid, on Earth, without a protective enclosure above my head. I find that my answers remain unconvincing to them. Knowing me to be a journalist, Mayra, Adhémar's partner, pushes him to take me to see one of the roaming factories, something inaccessible for a lambda newcomer as it requires putting on a mechanical pressure suit. I struggle into the tight suit and we take off on a small wheeled vehicle. No walking this time! We three drive for many kilometers between the long strips, until we reach one of these famous roving factories. I feel very small at the foot of this huge quasi sentient machine, it's bulk enhanced by an enormous roll of film which it carries on his back.
A number of subunits wheel around, and the printheads slide back and forth over the strip.
I contemplate the immense expanse of panels, while in the distance a wide rolling robot, rather like a linear irrigation machine, cleans the solar panels. Adhémar explains to me that this is how the inhabitants of Mars have managed to drastically reduce the price of energy, to the point that it is this same process, under Martian patent, which is currently implemented in some deserts on Earth.
Confronted with this very real scene, an emotion overwhelms me without warning. I understand something essential here: What forests and fields do on Earth by converting sunlight into organic matter and multiplying by seeds is exactly what these replicating robots are doing on Mars: transforming rock into an environment favorable to the emergence of life." ■



3.
DUAL SYSTEMS OF MARS
A DELICATE BALANCE

TWO TYPES OF WORK TO KEEP A BALANCE

According to Foundation Law, every citizen is entitled to a Right to Life Support, which includes a breathable atmosphere, housing, access to electricity, water and canteen service. The counterpart of this right is the obligation to perform free civic service. In the territory of the Foundation, work-related activities are divided into two categories: unpaid civic work, intended to produce basic goods and services linked to survival on Mars, and private activity intended to generate the income necessary to buy goods and services. The separation between basic and leisure activities is an important object of democratic debate. It varies between districts, however it is systematically observed that civic service includes the following goods and services: maintenance of the atmosphere, management of the water, energy and waste, ecosystem maintenance, health and education - in particular by companionship during civic service. While some neighborhoods refuse to do so, the majority of them also include the production of minimal free social goods for food, clothing, housing and connection - providing a minimal safety net that is unattractive but sufficient in the event of eventual hardships.

work-related activities are divided into two categories: unpaid civic work and private activity

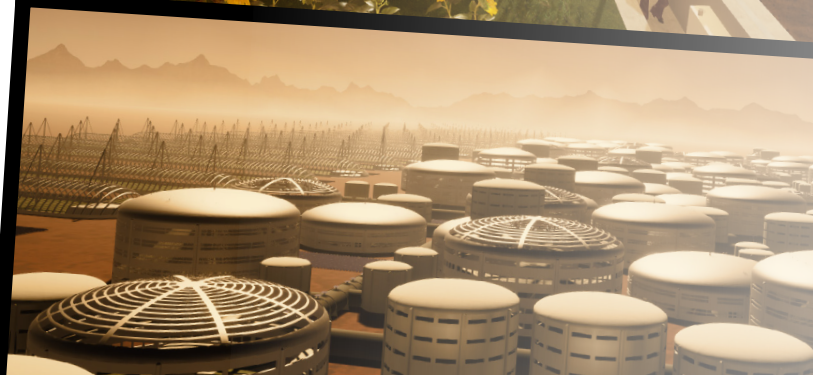
The rest of the economy is the object of private activities, the supervision of which remains minimal and generally registered in the form of a business. The difficulty and complexity of survival in the non-forgiving environment of Mars, as well as the long work of making the ecosystem (ecopoiesis), fosters an empathetic state of mind and favors complex thinking, allowing this system of dual types of work to keep a balance - which does not prevent heated debates on the location of the tipping point.

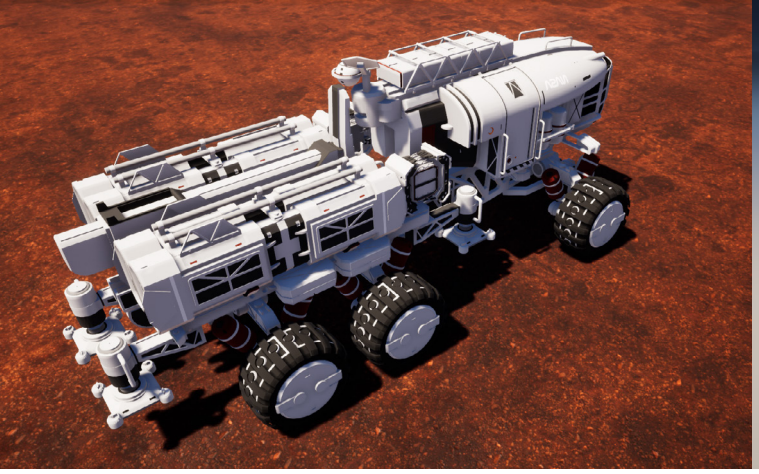
The vital systems of Martian cities require consistent and permanent maintenance. In practice, the settlement of Mars requires very large human resources and manpower is more often scarce than the reverse. As a result, children are mobilized very young on ecosystem maintenance activities that are most suitable for them. In this logic of early empowerment of the Martian citizen, the age of majority is fixed at 15 years.

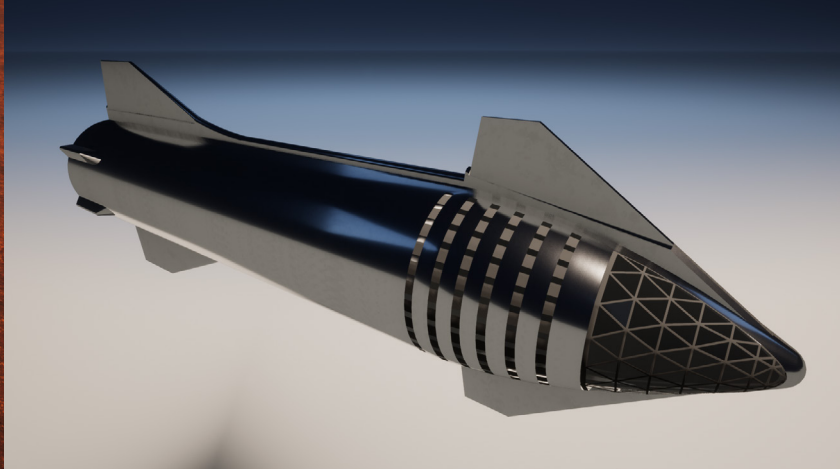
The permanent labor shortage for teleworking, piloting drones and artificial intelligence development pushes the martians to find solutions at home. Foundation and the City-States implement an active policy intended to encourage a high birth rate, with in particular the following measures, decided according to the votes of the different districts: free crèches and shared childcare, home support by retirees and family, free education, priority for housing and medicine, or tax reductions.

Indentured immigration for a service of two, four or six years, paid by companies is also common. Some telepresence is possible from Earth, but in very limited circumstances due to transmission delays,

Automation has increased productivity to unheard heights and made the Martian GDP per individual the highest in the solar system. ■







SPACE AND GROUND TRAVELS: **A STATE OF PLAY**

Transportation between the various human settlements on Mars is carried out by land, air or space vehicles. They generally draw their energy from the methanox sector (mixture of methane and oxygen), benefiting from a historic pooling of infrastructure and know-how with energy storage systems and methalox space propulsion.
Certain City-States have developed alternative energy vectors based on solid fuels; aluminum-oxygen or magnesium-carbon dioxide (the latter being taken directly from the atmosphere), included in a regeneration cycle, in particular by solar oven. These latter sectors, however, remain in the minority due to the cost of generalizing the infrastructure.

A complete range of vehicles

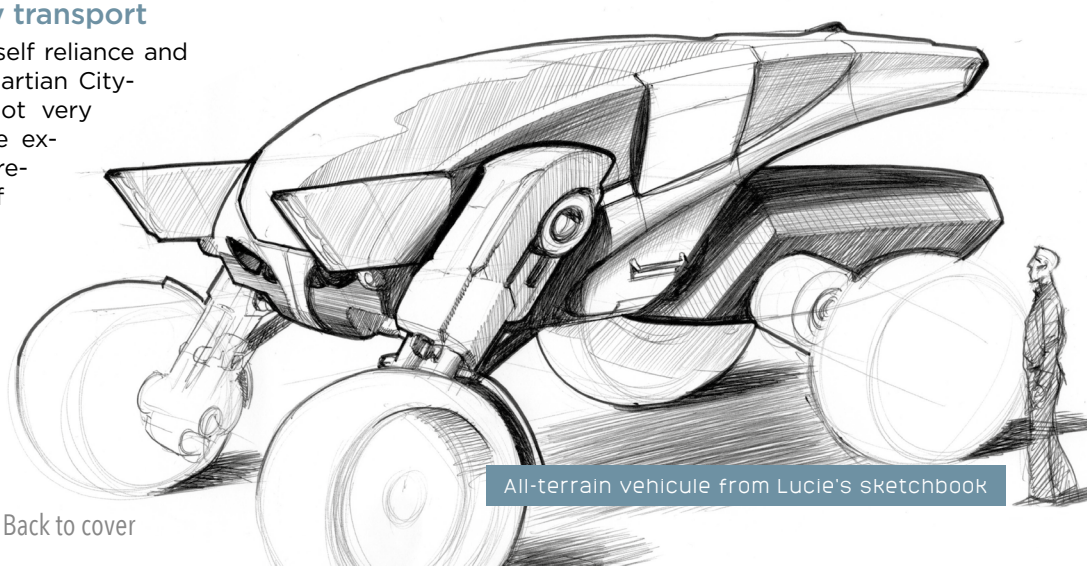
Land vehicles are of all kinds. For the longest journeys, they have life support systems that make them more like large motorhomes than cars or trucks. They can be all-terrain, but most of them are built for travel on the flat surface of the Meridian Way. In order to maximize safety, vehicles often run in convoys with departures at fixed times.
Point-to-point space travel between distant cities on Mars is common. This type of transport is generally carried out by interplanetary vehicles, which are not used between each launch window. The transport companies prefer to operate them in the meantime, and sell a ticket at a reduced price, the vehicle already being amortized by the sale of interplanetary journeys. The recent demand for orbital mirrors for the Surya development has put a strain on this infrastructure. There are a few specialized suborbital vehicles reserved for institutional applications - for example the Mars Planetary Rescue Force, with hoppers in each city, able to intervene on the whole planet in less than an hour.

Low intensity planetary transport

Because of the doctrine of self reliance and autonomy favored by the Martian City-States, these are usually not very specialized, which limits the exchange of products and therefore transportation. Most of the transport is intended for the youngest and less autonomous settlements, generally small mining villages. In addition, many prospecting or scientific expeditions criss-cross Mars regularly.
The movements of people between City-States are also rather limited. The lower costs of transport between locations on Mars, as well as the absence of constraints linked to the launch window between Earth and Mars every two years, in principle make it possible to offer golden bridges to the best professionals of another city. However, rigorous management of human resources and skills is a key point of the long-term survival strategy of each City-State, leading to administrative obstacles and a kind of self-restraint by recruiters.

Tourism, an important user of transportation

Tourism occupies a large place in the local economy. Indeed, Mars is not stingy with natural splendors - who has not dreamed of seeing the sunrise from inside a pressurized chalet built at the edge of the caldera at the top of Olympus Mons ? Some major architectural works are counted among the Wonders of the Solar System, among which Foundation offers the Tower of Arkadia and the Botanical Garden of Surya.
Tourism is the business of the Martians themselves, but also that of many Terrans. Some of them are wealthy tourists who have come for two years, usually on a mixed business and leisure trip, and others are retirees who have saved their whole life for this purpose, Mars adds to its marvels the effects of a reduced gravity, than can be beneficial for many cases, with the proper medical supervision. Tourism is not only the affair of the rich; many lotteries on Earth offer prizes of Mars expeditions. These draws are very popular, to the point of occupying today nearly a third of the world market for games of chance on Earth. Some commentators welcome the fact that this sector is being used for a more constructive purpose, namely the greening of Mars. We will not blame them. ■

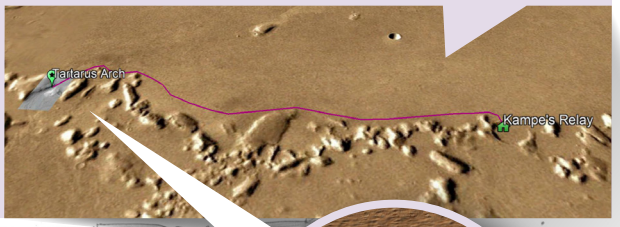


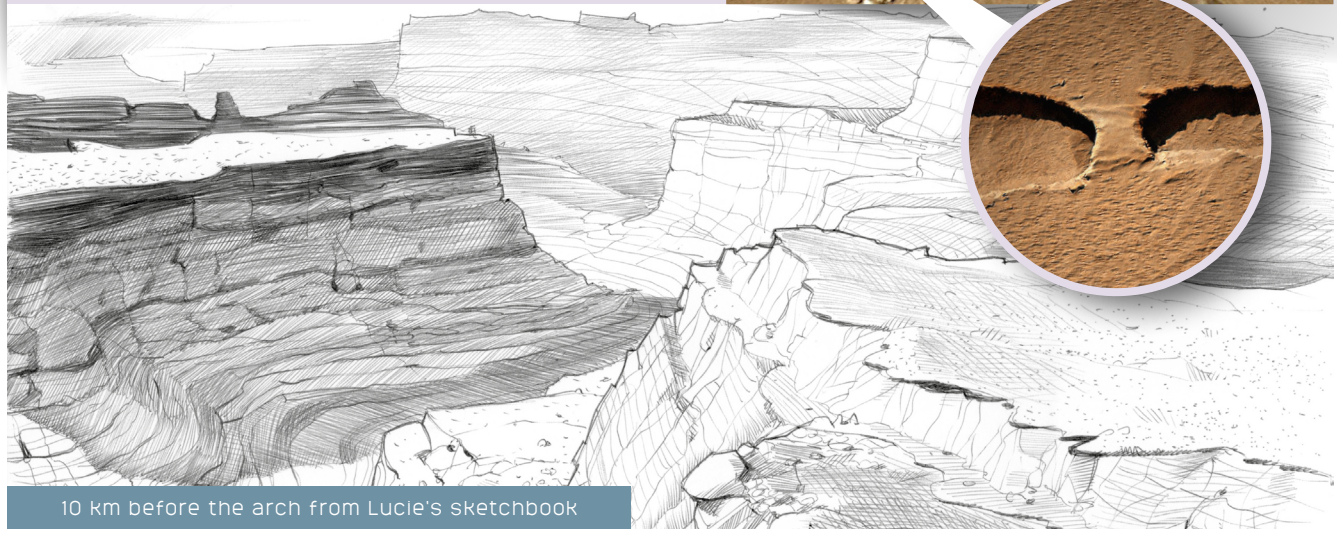
All-terrain vehicule from Lucie's sketchbook

Lucie's notebook

A trek to the Arch of Tartarus

"My first year on Mars is coming to an end and I'm preparing to go on to the other objective of my trip: Surya. Only, I had not expected to leave friends behind, without any hope of seeing them again. Cruel. I embrace Mayra, I breathe the smell of her shoulder to engrave it in my memory and tear myself away from her presence and wave my hand as a farewell. Adhémar accompanies me on this trip and comforts me as best he can. He embarks with me on a kind of night train or a bus, I do not know or care anymore. Throat clenched and eyes clouded, I watch the lights of Arkadia fade away. After a quarter of an hour we reach a convoy of vehicles, mainly trucks, which will follow the track of the Meridian Way to the south.
I decide to sleep the first hours.
I wake up as we stop at the Kampe Relay, close to Tartarus Colles, a third of the way to Surya. We get into a smaller vehicle. Its driver, Antonio, smiles at me and says that his job is more pilot than driver. I understand the nuance as soon as we start our trip, we cross the plain at 140 km/h, a dizzying velocity for off road displacements. Along the hills, the suspensions stir in all directions, the huge tires rumble, stones hit the cabin walls; but the cabin itself barely trembles. Definitely an adventure! I did not expect such a journey here.
"A trek," corrects Antonio, smiling again. The landscape, which undulates around us, seems to observe us; and succeeds, for a short moment, in making me forget the beloved faces that I left the day before.
The elaborate GPS system of Mars places us with precision on our itinerary. We gradually enter a canyon made of ocher, red, gray and orange under a magical salmon pink sky. Then, suddenly restrained by our safety straps, we stop in an opaque cloud that surrounds the rover while Antonio, standing on the brake, signals us by a triumphant "here we are", the presence before us of the famous arch of Tartarus. Unbelievable. "This natural sculpture was detected for the first time on November 15, 2006 by a probe called Mars Reconnaissance Orbiter", Adhémar tells us.
We stay here a few hours, Adhémar and I, walking about in our spacesuits, exploring this natural sculpture which attracts some other curious people, such as this young Californian, on a four-year study trip to the University of New Jakarta, a budding City-State located at the foot of Olympus Mons. It's truly surreal to speak through a communicator to a stranger in such a place. Believe me, I am enjoying my luck, to be here, at this time." ■





10 km before the arch from Lucie's sketchbook

AGRICULTURE
GROW ROOMS, GREENHOUSES AND BIOREACTORS

Agriculture, and more generally the maintenance of ecosystems in Martian districts and settlements is one of the primary activity of Foundation. Its importance also determines in a large part the size of the production of material and energy systems, and if it appears disproportionate by the standards of the Earth' economy, it is due to the fact that on Earth, the ecosystem is self-sufficient and preexisting to civilization. Its work is "free" and is not counted in the economy; the closest equivalent to the situation on Mars are, on Earth, the increasing costs of repairing environmental damage.

An agricultural mix in evolution

The lower sunshine of Mars, combined with more mar-

ked seasonal variations, as well as the long night caused regularly by dust storms, has led to a relatively ineffective historical approach and the development of local solutions: on the one hand underground grow rooms and breeding chambers with artificial lighting and on the other hand bioreactors, massively producing low price proteins, often used in animal feed. The production mix has a relatively low yield. However, it has made it possible to safely produce a large amount of organic matter (including the synthetic methane from the energy sector). The progressive accumulation of this organic matter is indeed the fundamental issue of the development of life on Mars, and a very significant amount of resources and technical developments have been devoted to it (notably in the energy field).

The grow rooms are optimized to maximize the use of space. The cultivated species are diverse and mixed: cereals, soybeans, fruit trees, especially for the latter in urban gardens. Livestock mainly concerns fungi and insects, which are fed with bioreactor products, and the insects are then used for fish farming and breeding (fish, poultry, rabbits). Finally, some of the illuminated surfaces of the city are covered with green algae inserts, particularly in Arkadia.

Surya greenhouses

A recent development in Surya, the construction of very large surface greenhouses is an approach more suited to the Martian environment. These greenhouses are highly transparent, using locally developed technologies, and have little or no need for artificial lighting as illumination is enhanced by orbital mirrors. This development, which is less energy intensive but more intensive in terms of land area, has been made possible by the increase in industrial productivity as well as the reduction of the cost for the access to space. Flexible curtains of vacuum insulation reduce night time heat losses.

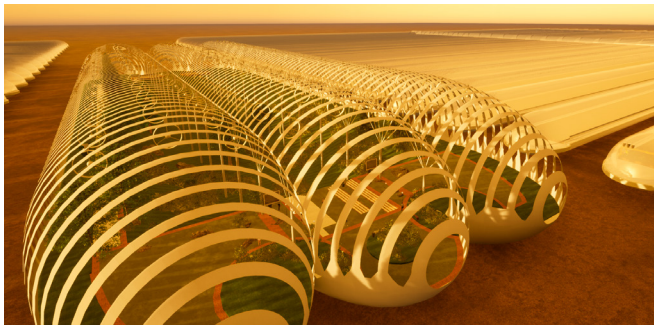
	Arkadia	Surya
Grow rooms area	50 km²	32 km²
Greenhouses area	0 km²	90 km²
Bioreactors area	13 km²	8 km²

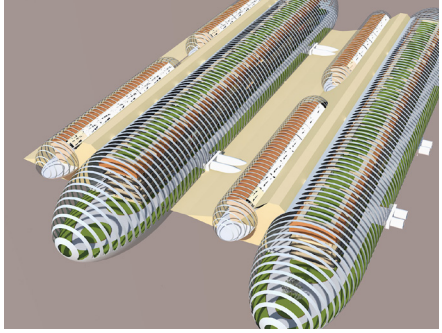
Orbital mirrors

Orbital mirrors are a new development. Thousands of low flying mirrors in highly eccentric orbits focus light onto the Surya greenhouse areas, increasing the light levels to those of the Earth. These light balloons, usually 150 m in diameter but just a few hundred kg in mass, are made of reflective mylar sheets and provided with a minimum station keeping system. They focus a mirror area five times larger than the surface areas they illuminate, to create optimum growing conditions at very low cost. Martians SSTOs have found here a new market for their capabilities.

"Made in Mars" gastronomy

While the consumption of meat from small animals is frequent on Mars, red meat, for example bovine, remains an extremely rare and expensive dish. However, a whole chain of cultured meat production has developed on Mars, which is enjoying growing success today. Some Martian chefs cooking "artificial" meat have ended up being recognized by Michelin stars and have had a meteoric career on Earth, where the price of animal meat has also experienced a strong surge in cost. Indeed, patent negotiation for this type of product is today a major export issue for Mars. ■





4.
MARTIAN COMMUNITIES
HOW DO THEY LIVE TOGETHER?

The natural environment of Mars is deadly for humans and more generally for all living terrestrial species. The atmospheric pressure is a quasi-vacuum, about 1% of the pressure at sea level on Earth. The temperature rarely exceeds 0 ° C in summer, its average is below -50 ° C, and it can approach -100 ° C in winter on the territory of Foundation. The thin atmosphere allows a level of irradiation from solar storms and cosmic rays of over 300 mSv / year in an unprotected environment, nearly ten times the usually prescribed maximum dosage for workers of the nuclear industry.
Architecture thus takes on a particularly critical dimension on Mars, because the buildings must ensure flawless protection of the people and of the ecosystems that they shelter. To this end, Martian architects commonly divide habitats into three spaces, each with its own constraints: the Exterior (deadly, where one only moves in spacesuits or in pressurized vehicles), Living Space (public, enclosed space, containing the ecosystem), and Chez-soi (private space).
The atmospheric pressure of the habitats is generally fixed at 0.7 bar, of which 0.26 bar is oxygen, the rest being made up of an approximately equal mixture of nitrogen and argon (called "argonitrox"). These values are historic and derive from a need to reduce the stresses on the structures, to reduce the work required to produce inert gases while guaranteeing perfect health and physical condition for the inhabitants.
The buildings respect historic standards of protection against radiation, fixed during the construction of the first bases on Mars. They allow anyone who wishes to do so to spend their entire life in areas identified as guaranteeing a level of irradiation set at a maximum of <100 mSv accumulated over 5 rolling years, in line with the rules for the protection of nuclear personnel on Earth by the International Commission on Radiological Protection (ICRP). These standards are accompanied by meticulous medical monitoring. However, the strong feedback accumulated by several hundreds of thousands of cumulative lives in this environment has led to the confirmation of the weak effect of low radiation doses, as observed in the Ramsar region in Iran on population exposed to a high level of natural radioactivity (up to 260 mSv / year), almost comparable to that of Mars. In particular, with the exception of outside workers, citizens do not wear a dosimeter, and no one, apart from Terran tourists, loses any sleep over the time spent in open spaces without direct protection. People from the equatorial city of Surya, more accustomed to vast open spaces, are more relaxed in this regard than people from the northern city of Arkadia.

the structures must be built to resist bursting rather than crushing

Protective architecture

The construction of buildings on Mars is, to a large extent, reversed with respect to Earth. The stresses on structures produced by internal pressure are much greater than those of gravity: the structures must be built to resist bursting rather than crushing.
In Foundation, the pressure structures mainly consist of flexible cylindrical envelopes, intended to ensure gas tightness and resist both hoop and longitudinal stresses. Stainless steel is usually prefered, although other assembly have also had some success. An intensive research

▶

Lucie's notebook

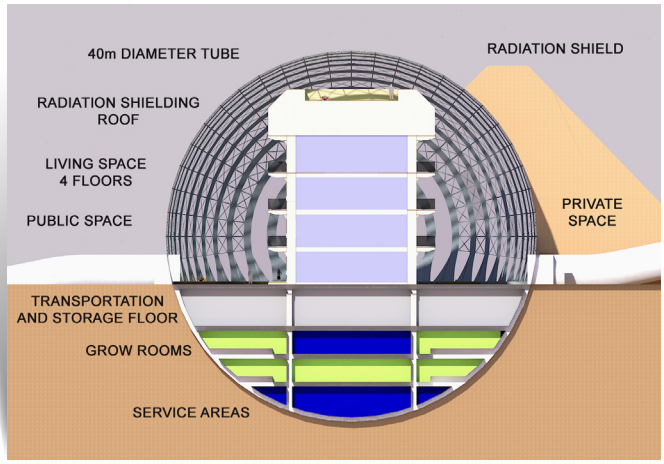
An evening at the bar

"Absorbed by an article in sociology, a persistent ringing breaks through my bubble. Mellibée, a young student with whom I spoke yesterday afternoon, invites me to go out. I have the strong impression that the wisdom of this interruption lies in the benefits of the socialization yet not recommended of alcohol. I finally accept and find myself in a place quite in keeping with the memory I have of a student bar. Mellibée introduces me to her friends and happily advises me on the culinary specialties. I confess to him that I have not yet eaten despite the late hour and his friend Geoffroy makes me roar with laughter by advising me the "mattdams" or "mattdammons", the local name for fries. Obviously, the novel and movie, dating back to beginning of the XXIth century, has persisted until this sparkling generation. The evening's discussions mainly revolve around the exhibition of the controversial "Lollere", an unclassifiable artist whose works show a critical eye on Martian societies and who is starting to gain attention on the global network. Constance hates, Mellibée adores. Nothing can convince either of them, obviously. Geoffroy proposes a game of "flare", a game that looks like darts but takes place in a 20 meter corridor, played with luminescent projectiles. I finally understand that throwing the dart to the edges created a color which apparently brings back points. Feelings of tiredness and thirst making themselves more insistent, I leave my hosts of the night at an alley which leads to my "sub", cheap apartments installed in the basement of the habitats. The group is meeting me tomorrow to go to the Lollere expo. I do not know yet if I will have time, but this lucid and hopeful youth is beautiful to see." ■

effort has led to significant improvements in flexible glass, leading to a material with high transparency, high resistance and low intrinsic energy, the 300M "AresShield". This allows for the creation of spaces that are as open and bright as possible, lighting up dwellings that might otherwise have been suffocating. This design using a continuous pressure enveloppe removes most of the forces from the foundations. These modules can be joined in many configurations to enlarge the space, usually at the cost of some radiation protection, as can be seen in the larger parks in Surya.

The dimensions of these enclosures follow the historical evolution of the Foundation cities, towards more industrial capacity and comfort: the center of Arkadia is made up of Mk1 cylinders of 9 m in diameter, surrounded by Mk2 cylinders of 18 m in diameter. The most recent constructions of Surya reach 36 m to 40 meters in diameter, approaching the practical limits of such constructions. The orientation of the tubes is then a matter of choice, with clearly marked architectural differences between Arkadia, favoring vertical cylinders and Surya that favors horizontal ones.

Radiation protection is provided according to available materials and technologies, with the aim of keeping lines of sight as open as possible. It is usually made of regolith; sintered, compressed, bound with various cements. Walls and roofs are thick and heavy, adding their mass to the radiation protection. So light enveloppes, enclosing heavy buildings.



Public architecture

Foundation urban planners seek to create open spaces, while breaking the monotony that an entirely artificial environment might, in principle, create. They look for curves when possible by varying the internal environments, and architectural diversity is encouraged by multiple artistic competitions. Over half the average grade space is occupied by vegetation, walkways, squares and parks, maintained by neighborhood associations. Reminders, if such was necessary, of the love of Martians for gardening.

The cities are spread over several levels: the most pleasant surface urban spaces bring together dwellings and shops in a vehicle free environment, while the underground spaces hold the grow rooms, light industries, technical and storage areas and pod transport systems. This arrangement reduces spatial extension, and therefore promotes walking and health, while ensuring close proximity to open and pleasant spaces. They also make it possible to passively reduce the dose of radiation for much of the working day.
Many underground spaces also serve as shelters in the event of an accident compromizing the integrity of a pressurized surface enclosure. The regulations require that sealable underground areas must meet the basic needs of the population for a month. Sometimes in difficult but bearable living conditions, while the elements destroyed in the event of a major disaster can be rebuilt and relief organized by. other districts or City-States.

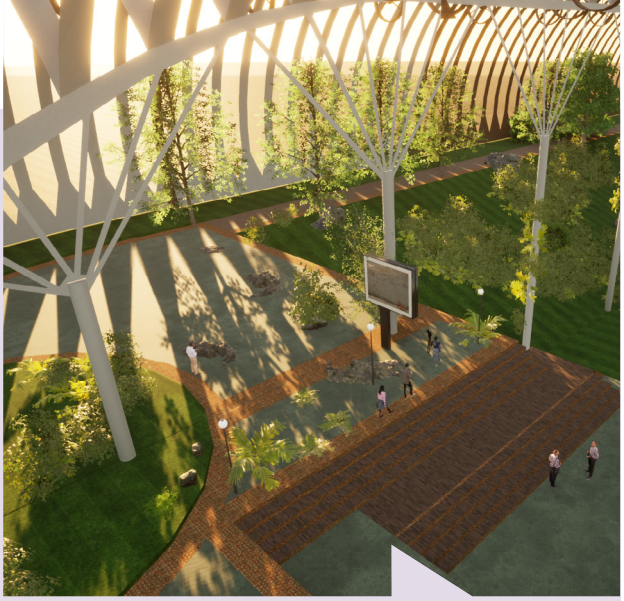
Interior architecture

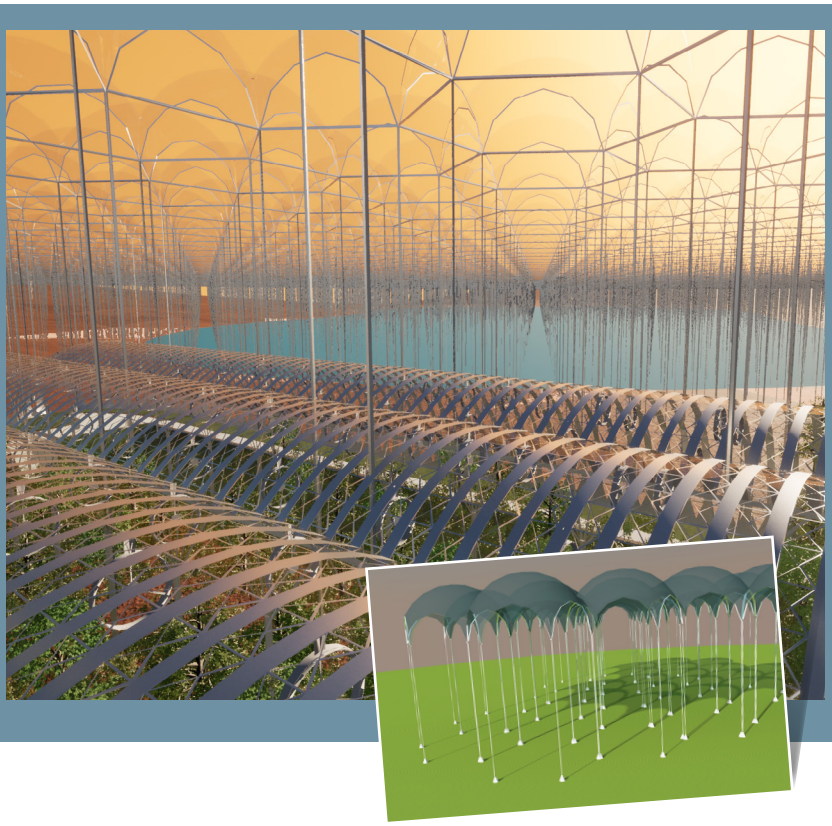
The interior of the buildings are generally modular, so that the size of the apartments can be quickly adapted to the size of each home. The Martians' way of life is generally more communal than that of the Terrans: it is not uncommon for sanitary facilities and kitchens to be shared between several homes, although this is more common in the older districts of Arkadia. ■

Lucie's notebook

Visit to the botanical palace

"Some microorganisms live under the ocean at a pressure 400 times greater than the one we live at on dry land. A whale hears our heart beating when we approach it underwater and a dragonfly flies at 100 km/h while spending only 2 Watts and can stand up to 30 Gs".
I listen to the words of Mathilda Kampf with the delight of a child enjoying a fairy tale. Jumping up from her desk, Mathilda, a seventy-year-old curator and researcher in aquatic ecosystems, takes me through a series of corridors dotted with fragrant plants and punctuates our walk with an uninterrupted flow of anecdotes. I am swallowed by this gentle tornado and suddenly stop in front of a huge aquarium. On Earth I didn't really care for them, but here it has been 8 months since I've seen water in close proximity in such large quantities. It's a miracle. An aquarium without fish, but still. Mathilda joins me in my enchantment and explains to me that the botanical gardens begin by questioning the visitor about this thing that is life. These seemingly empty aquariums, for example, contain the two things that gave birth to humanity: liquid water and phytoplankton, basis of the oxygen and carbon cycles. "Striking, isn't it? "
I recognize the acuteness of this question and let Mathilda continue on to a crescendo of wisdom that I am not soon to forget: "The concept of this dome goes further than that of a museum and it was not easy to work out, on a purely ethical level, as our initial wishes touched on the principle of ecopoiesis, that is to say, ultimately, succeed in reproducing an ecosystem in its entirety."
Concentrating on the words of my new teacher, I enter a large wooded area. It smells so good! I am overwhelmed by nostalgia for Earth and it's forests. But why? Aren't they already here? Further on, there are clearings and small savannah that we cross through in glass corridor. My host pointing her finger upwards, showing me a light structure high above our heads. We are under a gigantic transparent tent, and the tube keeps us from the inadequate air pressure outside. Inadequate to us, but not to plants, and not for water. A vista onto an immense surface of water open up, the lower reservoir of the Nicholson pump-storage power station.
I question Mathilda: "Why do you absolutely want to reproduce the entire Earth ecosystem? You know it's impossible, right? "
"Unfortunately, we felt that we have no choice", retorts Mathilda. Bending down to pick up a small insect on the ground, she puts it up high onto a branch and continues: "if only for the simple reason that Earth needs Mars, just like a computer needs backup. It may seem presumptuous to you, but think about what we can learn from such an approach as the Earth gradually loses its biomass diversity. Water and phytoplankton put man on Earth, man will have put water and phytoplankton on Mars. At best, it will stir up the pride of Terrans and at worst, it will make a copy that may take several thousand years to make; but it is worth it." Mathilda finishes the visit with me, and leaves immediately with a young man in a white coat, popping out of nowhere to drag her away to conference rooms. Stunned by information overload, I realize that it is on Mars that I am learning to really understand my own planet." ■





THE TENT CONCEPT

The tent is a new concept on Mars, using domes and tension structures for the creation of arbitrarily large spaces. The design is based on a flexible membrane made from the new 300M flexible glass, held in a mesh of steel cables. These cables are fixed to foundations that are either driven deep into the martian soil of ballasted to keep the tent in place.

The theoretical maximum height of the tent is a few kilometers, the weight of the cables would then exactly compensate the internal atmospheric pressure, without requiring anchoring. In practice, the height of the tents is dimensioned by the cost of the cables and the pressure inside the tent. A first attempt using very low atmospheric pressure was built successfully for the Nicholson hydro station and may lead, eventually, to having plants growing directly on the planetary surface. ■

SPORT AT 0,38 G GRAVITY, **THE REAL DIFFERENCE**

On Mars, sport is important, both because it is necessary to work hard to maintain proper muscle tone and health, and because it offers novelty to Earth. A gravity of 0,38 g changes both endurance and strength, as well as changing some games beyond recognition. Football, in both American and European styles has lost some of its appeal on the red planet, where anyone can kick the ball from one end of the field to the other. So it has been re-invented by the Martians.
Vehicular sports have found a niche, exploiting the endless landscape. We have, for example, the motorized trek, inspired by the Paris-Dakar and the 4L Trophy: each year teams leave in all-terrain vehicle of home-made manufacture (approved and properly tested, of course) and embarks on a journey of several thousand of kilometers. This event, broadcast every year on Earth, is appreciated for its adventurous nature, its covering genuinely unexplored spaces, but also because it is a pinnacle of motorsport, where the vehicles must be perfect to adapt to the terrain, have huge endurance and also provide security in the harsh martian environment.
Other sports, such as climbing, have also experienced a gain in popularity. Indeed the low gravity on Mars has made it possible to exceed the limits of the discipline, and the climbs of the walls of Valles Marineris are impressive.
Regular sports activity on Mars exceeds even the well known dedication to fitness of Australians. Mars, despite all the architecture, is not Earth, and the human body is not perfectly adapted to it. Whether it's in a gym, through team sports or individual sports, and particularly through walking at every opportunity, martians exercise continuously.
A few years ago a special edition of the Olympic Games was held in Arkadia and was an interplanetary success, with a whole new set of possibilities setting new records in practically every field. A strong contrast to the regular olympics where progress is now practically non existent, or measured in milliseconds.
The dance disciplines, especially aerial dance, have experienced a significant boom and the possibilities given by the low gravity have allowed the creation of ballets of incredible intensity, which have propelled some Martian choreographers to status of interplanetary stars. ■

Lucie's notebook

Foundation's arts

"Ranjan stands and raises his hand excitedly; he wants to open up the competition to the other districts. Freina, moderator for the evening, asks him to sit down while asking the assembly to vote. She suggests that we adjourn till the next competition, so that everyone has time to think about it. The 63 people present vote by show of hands. They will keep the competition closed to "outside" for this year.
This Thursday is a district meeting and it's not only nice things that the exchanges are about. The formality of the debates, however, usually leads to constructive decisions. Such as a moratorium, decided following the announcement of the construction of the Arkadia tower, which seems questioned at the time when I write these lines, or the creation of a link direct between botany and decorative gardens following the problems of cultivable area in the Vankuist district. Each week, a theme thus preoccupies an assembly and this week it is the competition of bas-reliefs for 6 facades of the district.
A meeting to discuss an artistic competition... Don't they have better things to do? It was after this meeting that I became interested in the subject of Art on Mars. What place does it have in a seemingly hyper-utilitarian universe? I then realize, a posteriori, the number of exhibited works that I have come across in my walks and the full scale concerts seemingly improvised in public spaces.
Unlike Earth, artistic expression is not separated from social and professional life, and it's quite confusing. Schools give the arts a preponderant place, and they show up in CVs and elsewhere. I have the impression, however, that some aspects of this escapes me, like a word missing in a sentence. Adhémar, present at the famous meeting and capturing the wide-eyed interrogation of my puzzled face, explains.
On Mars, inventiveness is a question of survival, nothing more, nothing less. To encourage this, Foundation grants the individual the possibility of finding their own mode of expression from an early age. And at all stages of his life, a person on Mars will be able to enhance his existence by traveling in his deep "self" thanks to this medium, in particular. A way of cultivating one's true identity in the service of the whole, "one" first for the "multitude" then. Beyond the words, I feel a deep impact from his speech, a shock wave that resonate in me. For Adhémar all this seems obvious, but for me, it is a quest. By working on oneself, by mixing this loose and mysterious material, one may create by capillarity an acceptable living-togetherness. I find myself doubting the success of this turn of mind on the scale of a city, while having the proof before my eyes that people on Mars seem to know who they are much more than I know myself." ■

A facade from Lucie's sketchbook

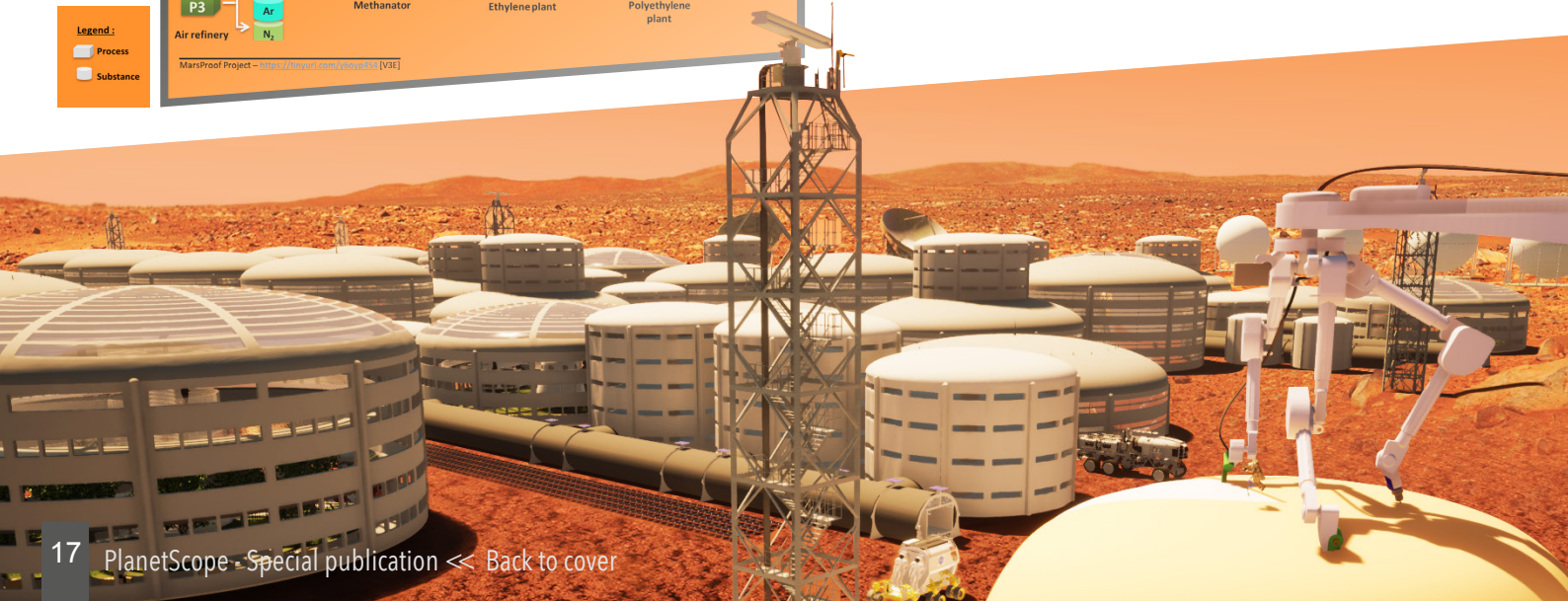
5.
THE LIVING MACHINE,
MARS' INDUSTRIAL ECOSYSTEM

The allocation between the industrial products made on Mars and those which are imported from Earth is influenced by two factors: the price of interplanetary transport and the Foundation doctrine of autonomy. To summarize, most products whose production price is significantly higher than $ 500 / kg are imported, with the exception of those which appear on the list of critical products. The latter is established by democratic vote on the basis of compromises between the price level, the need for the product and the human resources available for starting a new industry.
As a result, the vast majority of the industry in Mars relates to relatively low-tech products when compared to Earth standards: production of primary resources, the construction sector and the manufacture of heavy and strategic equipment. A gradual rise in the technological level has occurred, sometimes for initial reasons of image. In this register, the success of the Foundation's X33M "Albatross" is very telling.
Note: this section will not deal with the case of agricultural products and energy production, sectors which are the subject of specific articles in our dossier, and to which we refer the curious reader.

The raw materials industry

The main raw material produced on Mars is water. For the most part, it is extracted from large surface ice water open-pit mines. This water ice is abundant in Arkadia and also present near Surya, in Medusae Fossae, but with a much higher level of contamination.
The treatment of ground up regolith resulting from the water extraction process makes it possible to produce other raw materials: sintered regolith bricks, concrete, structural steel and cables, glass AresShield, and other products used in industry. External concrete uses sulfur as a chemical binder, but the availability of some calcium silicate deposits favors the alternate minerals. As a Martian will tell you, nothing smells quite as bad as wet Sulfur concrete.

Large atmospheric processing plants separate the main gases from the atmosphere. Carbon dioxide is separated first, by compression and cooling, to be used for the production of methane using the Sabatier reaction. Alternatively, carbon monoxide production is intended for the reduction of iron oxide into iron and steel.. Nitrogen and argon, in approximately equal parts, are used for the atmosphere of the habitats. They are mostly separated out independently and locally from the CO2 process using an energy efficient adsorption process, as the propellant production no longer provides sufficient inert gases for the build-up atmospheres of the fast-growing habitats. An important part of the nitrogen is used in the production of nitrates intended for fertilizing crops (via, for example, Haber-Bosch reaction and newer plasma based processes). Water vapor is also recovered, but the production of water by this way is tiny compared to the needs of the colony.
A wide variety of plastics are produced from methane. Plastic is however avoided if possible, because its resistance to ultraviolet light is poor its energy cost is significant, and methane often turns out to have more cost effective uses.
The production of raw materials from local resources using principles of In-Situ Resources Utilisation (ISRU) has been from the start of the settlements on Mars a a rich research vector, which has produced both local successes and processes applicable back on Earth. Some ▶



of these initiatives have been able to yield significant dividends, others have been open-sourced, such as the MarsProof ("Tough enough for Mars!") project by the association Federation Open Space Makers and which is at the origin of to the well known miner's Guild of today. Indeed, the label "Earth ISRU" has appeared in reaction to the advantages, demonstrated on Mars, of small locally produced runs of high technology fabricated products using fabs and 3D printers.

Table production volumes

	Tonne / yr*	PJ / yr
Food	1 100 000	360
Biomass	1 200 000	360
CH^4 propellant	72 000	6
Water	75 000 000	40
Structural steel	1 000 000	40
Construction concrete	8 000 000	20
Habitat services	-	120
Solar panels	150 000	150
Others	-	500

A very active construction sector

The nature of Martian housing, light pressure vessels subject to high tension loads and massive construction elements to absorb radiation, creates an important need for construction materials and operations. Combined with the strong growth of the Martian population, this leads to making the construction sector one of the main industrial sector of Mars.
Just as the production of solar panels has been streamlined as much as possible, the production of protective enclosures has been the subject of a great optimization: automatic concrete batch plants, stone yards, transporters, metal spinners and fab units. This optimization has always been subject to the respect of the architectural principles aimed at the greatest versatility of modular elements, to allow creativity to express itself at the local level, and to prevent any risk of monotony in an artificial environment.

Recycling, at the heart of human activity on Mars

Recycling of materials is intensive, because Martians are acutely aware of the value of raw materials and of the energy benefits of recycling planned from design. Don't they drink recycled water and breathe in equally recycled air?
An interesting anecdote concerns the choice of stainless steel as the standard grade for habitat manufacturing. This choice was made in line with the choice of the SpaceX Starship hull material, with the aim of recycling end-of-life vehicles. No source of materials has been overlooked to reduce the costs and efforts to build this new world.

The equipment industry

Industry is largely dominated by the needs of the agricultural sector: cultivation and hydroponics equipment, light sources, and more generally the needs related to production, distribution and energy storage.
District workshops include small, versatile productions units: plastic, metal or ceramic 3D printing, rapid prototyping and other automated machining equipment, making small series production economically possible. In addition, a substantive activity is related to construction and robot maintenance. The use of open source models is encouraged whenever relevant to reduce engineering costs. A certain emulation exists between makers on Earth to produce equipment usable on Mars, because it is a consecration to see one's model selected by many districts of the Red Planet, even for free.

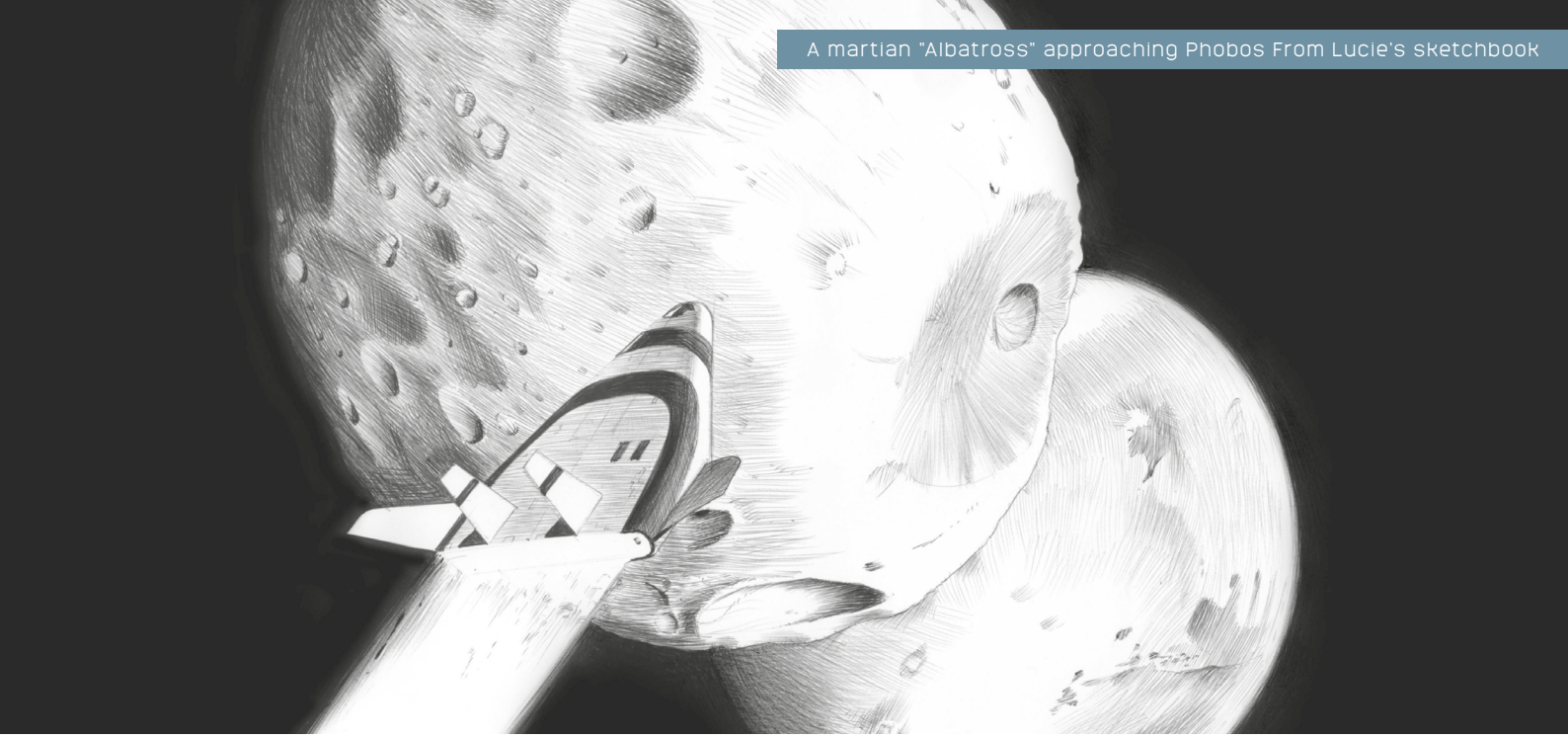
A turning point towards high technology

Industries on Mars are gradually diversifying their production, and gradually reducing the planet's dependence on high technology from Earth. Foundation has recently succeeded in making reliable and deploying a local production of integrated circuits, using Minimal Fab type units.
The production of SSTO type interplanetary transport vehicles such as the "Albatross" series is also a great source of pride, as will be explained in our next article. ■

**yr is for Earth year.*

X33M, **A SPACE INDUSTRY MADE IN MARS**

In the early stages of the settlement, interplanetary transportation was carried out by terrestrial companies such as SpaceX, with their own vehicles. However, the moons of Mars were eventually proven to harbor underground ice, as predicted by Fanale et al, in the 1990. This made for a paradigm shift for Earth-Mars transportation. With industrial production starting in earnest on Mars, local investors created a single stage to orbit (SSTO) rocket, built on Mars to compete with Earth suppliers. The design of the rocket was inspired by the futuristic but ill fated X33 Lockheed Martin SSTO prototype.



A martian "Albatross" approaching Phobos From Lucie's sketchbook

The first Martian built SSTO "Albatross"

Length	21 meters
Width	25 meters
Dry mass	30 tonnes (with descent shielding)
Main propulsion system	LCH4 and LO2, specific impulse 319s.
Total propellant	240 tonnes
Payload	20 tonnes
DV	5500 m/s

A spaceport was built on Phobos to produce propellant to refuel the Martian SSTOs. This extended their range to many destinations in the solar system, including Earth orbits, the lunar orbital station, and the asteroid belt, where they provided the lowest transportations costs for the growing asteroid mining companies. Mars benefits from much lower deltaV requirements than Earth, and can supply consumables to the asteroid belt at a competitive rate.

Earth-Mars transportation optimization

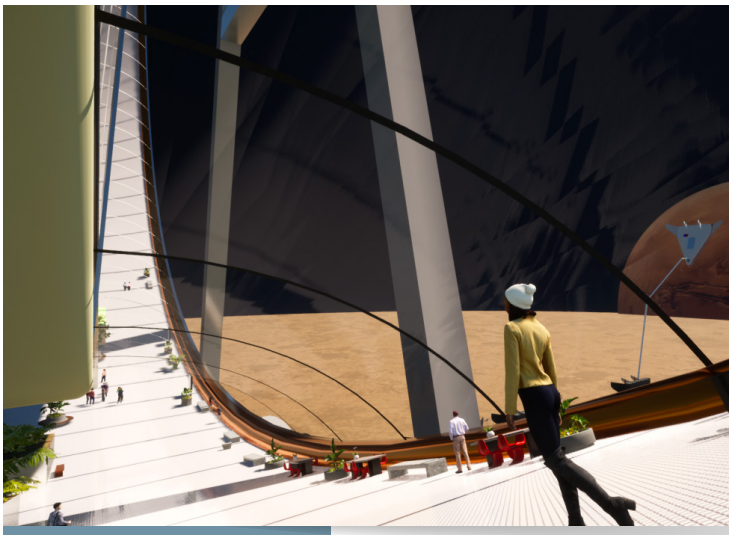
For Earth-Mars transportation, numerous spaceliners (giant vehicles with more than 100 passengers, like SpaceX' Starship) make the round trips. The stop at Phobos allows an important reduction of costs as well as an improvement of safety. Most manned spaceliners do not reach Foundation soil anymore, passengers are now transferred in Phobos Station to the winged Albatross SSTO that will handle the descent, allowing for simplier, safer and more comfortable landing procedures. Then spaceliners refuel with methane and oxygen and returns to Earth. As they arrive in Earth orbit with half filled tanks, only 2 refueling missions are needed instead of 5 for the next interplanetary transit, which cuts the cost by a factor of 2. In addition, thanks to the elimination of the descent and landing on Mars, the payload capability has been increased and the reusability rate has been tripled.

Profitability of the "Albatross" SSTO vehicles:

Martian SSTO such as the Albatross have made Foundation the leader for delivering satellites to geostationary orbits.

The Albatross SSTO has some important advantages over Earth spaceliners:

- For the descent to the Martian surface the shape of the vehicle allows for efficient aerobraking in the atmosphere. The landing can be either vertical or horizontal. Horizontal landing is used as a backup strategy. The touchdown velocity for horizontal landing is about 600 km/h, which is quite high but then, the landing runway are very long.
- It is a robust and fully reusable rocket. With appropriate maintenance, it can be reused up to 500 times without extensive refurbishment.
- It is a single block. There is no need to assemble different parts for the launch.
- Thanks to the low gravity of Mars, the spaceship is quite small and light. The dry mass is only 30 metric tons. In comparison with Earth rockets, the Albatross can be assembled, moved and set up for launch using much simple equipement. ■



View from Phobos station

6.
MARS IDENTITY
WHEN YOUR LIFE DEPENDS ON OTHERS

The autonomy doctrine is based on the assumption that Mars should be able, as soon as possible, to survive and thrive even in the case of a global disaster on Earth that would jeopardize supplies. The idea of Mars as a backup of the Earth underlies many of the Martians' decisions. This leads to some specific industrial choices, based on risk analysis and mitigation rather than profitability. And it leads to endless public debate, of the sort Martians are so found of.
An overarching Martian identity rose up remarkably fast, tempered by a fierce local pride that feeds the many district's and City-States civil life. The people of Foundation are proud to be part of the oldest and largest state on Mars. However, this pride has never deteriorated to nationalism thanks to the shared experience of life on Mars, where every second of your life depends on the work of others, on the careful and attentive maintenance of equipment, systems and ecosystems that must work flawlessly for you and yours to survive. The Martians really are "All in it together".

The idea of Mars as a stepping stone to space and eventually to the stars, even more than the idea of a backup plan for mankind, has proven attractive to millions of Martian settlers. Mars is populated by pioneers and the children of pioneers, people who feel intimately that they are building something new, and something big. Mars' quest to green itself is seen by many as a quest for meaning, the transcendence of Humanity, from a dying world into a vibrantly living one, and the first step to an even grander plan of spreading life throughout the universe. ■

Lucie's notebook

A new start

"This is my last day on Mars."
It took my fingers several minutes before they could type that sentence on my keyboard. 2 years and 9 days crisscrossing the surface of a red pebble floating in space. In a few hours, I will leave everything. Leaving Adhémar is hard. I will also have to leave my gang: Jeremya, Pelemon, Juan, Melibée and Mayra. I can only bring my 40 kg of accumulated belongings, the maximum allowed per person. The images of the next few hours pass before my eyes: Fly up to Skyreach Station on Phobos aboard an "Albator", Then, arriving near the rotating torus at the heart of the base, our little transport will be caught by a capture arm which will dock us next to a huge Starship, waiting patiently for its return journey cargo. We will stay in transit while we trade propellant, food and exchange crews. I will spend the time thinking about Mars and its people. I will look feverishly through one of the portholes at the red planet, looking for a thin shiny line linking two tiny green spots. I will put my fingers on the glass, thinking that I am stroking Adhémar's face as the vibration caused by the moorings snapping open signals the end of a great adventure.
But I haven't left yet, and I am waiting for the taxi at tube 28. For the moment, I smell that odor of air conditioning mixed with that of enclosed plants that I've grown so used to. This fragile, manufactured air. I know in my heart that the future is playing out here, that human endeavor is taking on another scale with the rebirth of this planet. Mars was once covered with water, someday...
Journalist, it wouldn't be so bad here.
The media on Mars are becoming more and more crucial to the communications between the City-States.
The next flight to Phobos is in 3 hours... and I think to myself:
"There is still time to stay." ■

References

THE **TEAM**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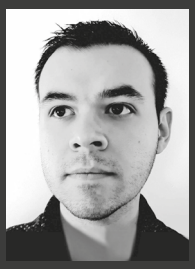
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Some organization are cited for story convenience in current text (Mars Society, SpaceX, Michelin Guide, Lockheed Martin), but the opinions given are those of the authors and cannot be attributed to these organization other than by coincidence.