"A gas strategy for space settlement"

Rel. 1.10 – May 30th 2021

Adriano V. Autino, Space Renaissance International, adriano.autino@spacerenaissance.org

[co-author(s) ----------

- Alberto Cavallo, Space Renaissance International, alberto.cavallo@spacerenaissance.org

3 SYMPOSIUM ON SPACE PHILOSOPHY AND OUTREACH, 3.1 A conceptual timetable for the founding steps of Space Settlement

☒ this paper was not published before

☒ I agree that Space Renaissance International will publish this paper on their websites and publications

ABSTRACT

We have to choose our future very quickly now: before 2030 we should bootstrap civilian space development, or the civilization will be scrapped. Climate extreme events, pandemics, economic recurrent crisis, unemployment, resource wars, big migratory flows, are the multiple crises which are jeopardizing civilization, and all together could soon close the "launch window", should the world remain closed, as Gregg Maryniak told us during an interview we had few months ago. To open the high frontier and start a space settlement agenda, we do need a strategy, what we call a global expansion plan, starting in Earth Orbit, progressing to the Moon, the Cislunar region, Mars Orbit, and beyond. Jeff Greason, in his speech at the 2017 ISDC, explained a strategy for settlement, that could work greatly: progressively mining the Moon, the Near Earth Asteroids, the Mars Moons and the Asteroid Belt, we can produce fuel in space, to be supplied in Earth Orbit, Cislunar Space and so on. Each global infrastructural level we will build, thanks to space fuel, will reduce the cost of missions and investments, making space more and more affordable for private enterprises. All of the stakeholders, the whole civilization in first place, will immensely benefit of such a cosmic renaissance. This paper largely refers to that Greason's speech, and other key contributes he gave during past years. The paper also reviews a bunch of case studies, related to big projects of the history, which required serious strategies. Some alternative strategies for space settlement are considered and compared, advocating a more collaboration among competitors, some kind of coopetition. A feasible and sustainable strategy is finally sketched, based on the fundamental fact that a fully reusable space vehicle is on its way of testing and integration.

PAPER

1 Premises

1.1 Background

We have to choose our future very quickly now: before 2030 we should bootstrap civilian space development, or the civilization will be scrapped. Climate extreme events, pandemics, economic recurrent crisis, unemployment, resource wars, big migratory flows, are the multiple crises which are jeopardizing civilization, and all together could soon close the "launch window", should the world remain closed, as Gregg Maryniak told us during an interview we had few months ago.

To open the high frontier and start a space settlement agenda, we do need a strategy, what we call a global expansion plan, starting in Earth Orbit, progressing to the Moon, the Cislunar region, Near Earth Asteroids, Mars Orbit, Asteroids Belt and beyond.

1.2 Some history

- 2002 Elon Musk founds Space X
- 2004 ScaledComposites wins the X-Prize, birth of the New Space industrial segment, kick-off the downsizing of cost to orbit.
- 2011 1st Space Renaissance Congress – analysis and proposed strategy: space tourism as strategical development line for the opening of the space frontier
- 2015 kick-off reusable rockets
- 2016 2nd Space Renaissance Congress – analysis and proposed strategy: civilian space development, geo lunar space industrialization.
- 2017 SpaceX leads the global launch providers, lowering the launch cost of one magnitude order
- 2018 Space Renaissance focuses on enabling technologies to allow untrained civilians to travel, work and live in space, launch of the Civilian Space Protocol initiative
- 2020 Space X kicks off the development of Starship, the first fully reusable space vehicle, targeting $20/Kg cost to orbit
- 2021 Covid19 Pandemics operates a total reset on global economy, NASA chooses Space X to develop the Artemis Moon Lander.

1.3 Some competing strategies for space settlement, and possible coopetition

- Elon Musk: City on Mars
- Jeff Bezos: Building geo lunar space infrastructure, move heavy industry in space, living in space cities, according to G. K. O'Neill's model
- Krafft Ehricke: Selenopolis, cities on the Moon
- Bob Zubrin, Bruce MacKenzie – Mars colonization and terraforming, Mars as the gateway to external solar system
- Isaac Arthur: alternative propulsion technologies: aneutronic nuclear fusion
- Gregg Maryniak, John Blincow, Jerry Stone: following up Gerald O'Neill model
- Arthur Woods, Mike Sneads and others: Space Based Solar Power as a strategy to feed Earth civilization growing energy needs
- Jeff Greason: mining the Moon and Near Earth Asteroids to produce fuel in space

Each of the above strategies have something good, and doesn't need to remain the one and only, making the other strategies to disappear. Some first steps are being made: Elon Musk, by his side, is doing an essential part of the above: realizing a fully reusable space vehicle. His strategy is focused on settlement on Mars, which in our vision could take place later, but what he is doing is essential and no one else has practically started to do the same, since the orbital launcher of Blue Origin could be maybe a competitor of Falcon 9, but not of Starship. Astro-electricity, or SPS, proposed by Mike Snead and Arthur Woods, is great as well, but it only can work if included in a global expansion strategy. Using it for supplying energy, both to Earth and space customers, will be sustainable only when we will be able to collect raw materials on the Moon and the asteroids, and fabricate the solar panels directly in space. Richard Branson, and the space tourism entrepreneurs patrol, are doing a great work, since they are facing the big issue of transporting untrained civilians in space. But they are very late and the first private orbital crewed mission will likely be performed by SpaceX instead. Suborbital tourism run the risk of becoming outdated before starting, while orbital tourism can be targeted soon – as soon as the Starship will be operational. Space tourism should take advantage of other advancements to develop quickly towards reaching orbit and, at the same time, contribute their civilian requirements to more ergonomic, safe and comfortable characteristics of the new space vehicles. Even if each solution has its own downsides, the settlement agenda can work only if all of these initiatives will be integrated with the other good solutions or, at least, to take each-other into account. The efforts for putting in service a fully reusable launcher will be precious for Moon and asteroid mining as well as for the development of space tourism, even if these launchers were initially conceived to reach Mars as soon as possible skipping all of these developments. The solution shouldn't be "take my solution and reject all of the other ones", in a sort of "religious" choice among several different faiths. We should promote and support an alliance among good solutions: Bezos and Musk to keep on fairly competing, and the two of them to listen to Greason's strategical view. Fair competition should focus on being first, avoiding to create obstacles on the road of competitors. The governments to adopt space friendly policies, abandoning the current concept of military like space missions performed by air force officers.

The role of governments of Planet Earth, of UNOOSA and COPUOS, should be the one to encourage a methodology of national and international cooperation among different strategies, or at least each one to take into account the other ones, while developing their own roadmap. That doesn't need, of course, to suppress competition. We believe that Earth has still enough resources, and we're not constrained to flat every efforts all together: we well know the superiority of working in parallel, wrt putting intelligences in series[1]. The "only"

thing we need is that governments, and the UN, setup their mind toward civilian space development… Missing that we, as a space advocacy movement, will however keep on supporting the efforts of the good willing individuals and enterprises, recommending them a bit more coopetition!

A general strategy should be draft, defining main milestones, and asking all of the entities engaged to realize space settlement to acknowledge it, propose changes and improvements, considering it as a source of general requirements, when developing their projects: a kind of *a standard*. Standards exist, from a methodology point of view, in quality management, project management, risk management, and other processes well known to designers and managers world-wide.

2 Why we do need a strategy

Nothing serious was ever done, in human history, without a strategy. Aegyptian pyramids needed a strategy, looking forwards years and decades, to win the giant problems posed by such an enterprise. Putting together the work power, identify the materials – limestone huge quantity, of different qualities, for internal and external construction, mining and square the materials, transporting them, designing the engineering, and managing the whole projects, over several generations of engineers and workers. Some other samples follow below. Btw, surprising recent historical research shows that the workers were not slaves. They were motivated by prizes. There is documentation about the existence of teams being rewarded for the progress they made, in competition with the other teams. And they did strikes when they were not satisfied with food and salary. A full documentation about a strike and the relevant negotiation, the "papyrus of the strike" is preserved in Turin Egyptian Museum[2].

2.1 Sample: history of the Nineteenth Century Mercantilism

Though the expansion of civilization into outer space will be quite different from the historic colonialism – mainly because in the solar system there are no populations to rob nor oppress – it is worth, from the point of view of a strategy, to refer to some of the main issues, related to such history.

Colonization epics, conducted over the seas since 1400 to late Twentieth Century, by Portugal, Britain, France, Spain and many other Countries, required strategies. In Nineteenth Century steam vessels were the main carriers of the mercantilist policy (mainly controlled by Britain), moving colonists and goods over the seas. It was not convenient nor possible to move such a large amount of people and goods bringing all the needed fuel (carbon) from home. Soon the colonist companies and powers understood that having refueling stations on the road was essential, for the good result of their trades and enterprises. The Portuguese empire, with its center in Goa, consisted of a series of coastal bases in Africa, India and Insulindia, of a strategic value for stopping and supplying ships. The British Royal Navy ensured the availability of high quality steam-coal at British overseas stations, for naval ships and its transportation overseas[3]. Such a condition is related to the coal age only: Britain's rivals failed to achieve the same control over fueling in the age of the coal ship, during which Britain mercantile system profited of an undiscussed primacy. Such a primacy ended with the beginning of the oil age. In the case of the space epic going to start, it will not make any difference what will be the evolution of the fuels – methane, oxygen, helium 3, other -- the leading factor will be the capacity to produce fuel from extraterrestrial in situ resources.

2.2 Sample: history of World War II USA strategy

Jeff Greason[4], in his speech at the 2017 ISDC[5], referred to the USA strategy during World War II. Such a strategy was based upon the progressive establishment of basis in the islands of Pacific Ocean. Only following such a strategy the Americans were able to reach near the Japan coasts, and complete the operations that lead to win the war. Such a strategy was called the "island hopping" strategy[6]. The term "Hopping" was sued because some islands were deliberately skipped, even if they were occupied by important Japanese bases. The idea was that those bases, left isolated, would be more a burden than an advantage for the Japanese. American bases were made where it was more convenient for fueling the advance.

2.3 Sample: the Transcontinental Railroads in North America

Since 1870 to 1900, 170,000 miles railroads were built, across the United States, mainly the transcontinental railroads. Four of the five transcontinental railroads were built with assistance from the federal government through land grants[7]. Getting grants by land owners was a critical process. Social conditions of the huge crews who took part to the construction were quite hard to be managed as well. Not to mention the many natural geographical features, including rivers, canyons, mountains, and desert.

The railroad opened the way for civilian settlement in the continent, provided immense economic opportunities, stimulated the development of town and communities, and generally contributed greatly to unify the country.

A rather evident similitude can be sketched between the American Railroads construction epics and the building of the Geo-Lunar infrastructures: to most Americans the West was as remote as the moon, its terrain as alien and forbidding[8]. Like the moon project, its conquest required immense resources. The building of the railroad was undertaken by private interests, after Congress passed legislation to favor financing of the work.

The incessant lobbying of the involved companies led to the Pacific Railroad Acts of 1862 and 1864, which provided several forms of assistance, right-of-way, land grants, government bonds. Each company could also issue its own first mortgage bonds for the same amount as the government bonds, relegating the latter to a second mortgage. It was clear that money could be made from the railroad itself (when completed) but from its construction too. Proper companies were formed for the construction.

Two were the main competitor companies: the Central Pacific and the Union Pacific Railroad. May we think nowadays about SpaceX and Blue Origin? Without forgetting the traditional ones: ULA, and the non US competitors, China, Russia, and India mainly.

The railroads constructors needed to use in situ resources, mainly wood, iron, cement. Therefore to create infrastructures to process raw materials along the path. In the same time, the railroad, up to its progressing development edge, was used to transport construction materials for the continuation of the works. We can imagine that giant work as a moving yard, proceeding alone the railroad path, processing the materials, providing the necessary semi-worked components: iron for the tracks, wood for the crossbars, carbon to move the locomotives. It needed General Grenville Dodge, a hero of the Union Army, to take control as chief engineer, to the Union Pacific finally begin moving westward, in 1866. They had to face the attacks by Native Americans, who were threatened by the progress of the white man and his “iron horse” across their native lands, not to speak about the habits of the workers, producing the enduring mythology of the “Wild West.” The good news: there are no Native Lunars nor Belters, nor Martians!

The physical construction of the rail line was a job with an enormous scope[9]. The construction crews had to cut grade, build snow-sheds, blast through hard rock and lay track through snow. An enormous amount of tools, materials and supplies were required. Each mile of track required 100 tons of rail, about 2,500 ties and two or three tons of spikes and fish plates. Some of the tools needed included wheelbarrows, horse drawn scrapers, two-wheel dump carts, shovels, axes, crowbars, blasting powder, quarry tools and iron rods. Locomotives, wheel trucks, switch mechanisms and foundry tools were needed as well. All supplies for the Central Pacific came from the East, and the Panama Canal shortcut did not exist at that time. All material, rails, rolling stock and machinery was shipped around Cape Horn on the southernmost tip of South America, en route to California. River steamers then took the material upriver to Sacramento, where it was offloaded to platform cars and hauled up into the mountains. If a shipment didn't leave the East Coast on time (and this happened frequently) or if an accident occurred in the shipping, the resulting delay could create a great hardship. The Union Pacific's construction materials were sailed up the Missouri or brought in by wagon. Their biggest difficulty lay in getting railroad ties, since there were few natural trees as were found in the Sierras. They had to import the ties until the Chicago & Western railroad line was extended to reach the Black Hills of Wyoming and the Wasatch Mountains of Utah.

Both companies laid track essentially the same strategy: a combination of progressive exploration, establishing outposts, settlement, construction. When suitable wood was available, ties were made in situ. When not, they had to procure proper materials from distant locations.

All of the above appears like a serious strategical commitment, by the US Congress and by the investors and companies, towards the construction of the national railroads. Ultimately railroads paid off their government debt in full. From the first, the government also received another payment in the form of reduced rates on its troops and freight carried by the roads. Before the building of the Transcontinental Railroad, it cost nearly $1,000 dollars to travel across the country. After the railroad was completed, the price dropped to $150 dollars.[10]

2.4 Different conditions today vs. past history cases

A common trait that all of the case studies mentioned above had to face was social issues. Some historians report that social conditions of the laborers constituted the worse problems, and were cause of hard delays and financial discrepancies. Workers were unhappy, and often had to fight against local inhabitants.

Some meaningful differences, and incomparably more advanced technology conditions we have nowadays:

a) **computer science** and technology, allowing to design and produce directly on the edge of the road

b) **additive manufacturing** 3d printing technology, allowing to produce tools, components and machinery directly in situ, processing in situ resources

c) **robotics and artificial intelligence**, that will support human laborers, mitigating social issues.

3 Current situation

3.1 Sectarianism of space advocacy

“There's a small number of people very passionate about the details of space policy, and they are so passionate about it, that if you're not 100% in agreement with them, they think you're 100% wrong.” Said Jeff Greason in his already mentioned speech.

This is particularly true, unfortunately, among the different space advocacy, and even inside each single organization: we definitely need to learn how to join our efforts on shared concepts and goals, putting aside the things we don’t agree.

We should understand at least the following facts:

1. often singular searchers and organizations deepen great concepts and knowledges,
2. each developed concept could be very useful, included in a coherent comprehensive strategic plan,
3. each developed concept will be fully useless, if it remains excluded and unfunded.

Sectarianism was a practice of many religions, each one claiming to be the unique and only truth. Each religion called 100% people to “convert”, and to abandon the other ones.

But sectarianism in space advocacies also comes from the corporates competition practice. Each organization thinks to be in competition with every other organizations, and that only one should survive, killing or engulfing every other orgs.

However, even some of the main religions – i.e. Buddhism and Christianism – recently understood that they share some basic concepts, and should work to encourage people to peace and love, and not to jihads and religious wars.

As to cultural organizations, we should understand that organizations are not corporates, competing for the same “market”. We shouldn’t fight to attract the same space enthusiasts. Rather we shall turn outside the space movement, to attract sincere humanists to subscribe to the space movement.

If not merging many organizations into one only, we should find methods to join efforts on shared agreed campaigns, and to build a shared agreed strategy.

3.2 Western space agencies are missing a strategy

Space agencies don't have a strategy, nor strategic goals. The US goal of the space race was to demonstrate to the world that the American system of government was superior to the Russian one. The objective: put a man on the Moon before 1970 and return him safely to the Earth (a measurable one). Tactics: lunar orbit rendezvous, Saturn 5 program, and so on.

Now we have a goal, humanity has a goal: space settlement. But it is not recognized, yet. Therefore nobody dares to draw a strategy, to reach that goal. Or, at least, USA and EU don’t have a strategy. USA simply allows commercial space to develop. EU didn’t yet abandon the satellite paradigm, and is reluctant to admit that European rocket technology is now twice backward: fully spendable launchers, vs. fully reusable ones. China seems to have a strategy, and recently Russia subscribed to it.

Likely the new space race will be run by two main competitors, and many smaller competitors, each one focusing on some aspect.

Will such a messy race, characterized by half-strategies, succeed to open the high frontier and save civilization from an implosion in the closed world? Hard to guess.

However, we have an idea of a possibly successful strategy for space settlement.

4 A global progressive expansion strategy

Global world budget for defense is worth 2 trillions / year. Global space agencies budget in 2020 was little more than 70 billion. Of course it is useless, yet trivial, to comment the absurd disparity between the above two numbers: 2 trillions for death, and 70 billion for life.

However, nowadays many space things happen outside space agencies, in the so called new space market, though the biggest commercial space company, SpaceX, is getting financial resources to fund its own space research and development from NASA contracts.

Due to their delirious and suicidal military priority, governments are very concerned about containing space expenditure. According to such a ridiculous limitation, while the population in space is going to grow, the space budget should remain constant, or not to grow up too much. Well, there's nothing bad trying to lower the cost of space missions, provided that such aim will not hinder or meaningfully further delay civilization expansion into space. We will have once again, to recall a paraphrase of the famous Albert Einstein:

"Everything **should** be made as **simple as possible**, but no simpler."

We could say:

"Space systems, and missions, **should** be made **as cheap as possible**, but not cheaper."

Said Greason, in his 2017 speech, that the cost to put one human in space should decrease.

The key strategic question, given the military oriented governments in the whole world, is this one: how can we get the cost of any mission to significantly decrease?

After Elon gave his wonderful lessons of pragmatism, having the great basic requirement and goal, of making humanity a spacefaring civilization, it is now obvious that:

1) first of all we shall lower the cost to orbit, by optimizing the existing technologies, using what we have in a better and more efficient way: starship is the best sample of such a philosophy;
2) when the above priority will be decently satisfied, and the cost to bring a person to LEO will be <1 million, we shall focus on how to take down the cost of any mission from LEO to outside, and accommodating people in space; this goal requires more than developing one or two technologies, **it requires a strategy**.

Since the objective 1 seems to be not that far away, considering that Starship could be flying to orbit within the end of 2021, and be certified for human passengers transportation within 2022, it would be better to work on point 2, the strategy.

Drawing a good strategy in time, we will be ready to use fully reusable vehicles, as soon as they will be ready, in the best strategical way.

4.1 A progressive infrastructural expansion

Talking about human space infrastructures, what we have now is the ISS, and soon another LEO space station, the Chinese Tiāngōng space station. Maybe a Russian space station, during next years. Worth to note, all of these orbital facilities are just reproducing the ISS, and nobody plans to finally go ahead, establishing a rotating station, endowed with artificial gravity.

In the current non-strategy paradigm, the plan about ISS is to dismiss it, and to build a new Space Station in the Moon Orbit (the Gateway).

A mature strategy should move upward globally: when an outpost infrastructure has been established at a certain level – e.g. Earth Orbit –, agencies can set the goals to move to the next level. But keeping the built infrastructure level alive and operating. Leaving behind it all the suite of capabilities necessary to maintain human beings on that infrastructure, with a development and maintenance costs so low that is credible that other private customers will join the venture. A first step milestone would be reached: establishing a progressively growing infrastructure in orbit, were private investors will put their money at work.

4.2 Steps of a global expansion strategy: New space systems designed upon civilian requirements

The new systems shouldn't be designed upon government requirements. The old systems – including the "new" Boeing's Starliner – were designed to be research laboratories, operated by military astronauts. The new systems have to be designed upon private (civilians) users' requirements: reusable orbiters, reusable planetary landers, habitats in space, safe and comfortable space vehicles, with special attention to protecting

life and health in the hard space environment. Crew Dragon is on that way: it is more ergonomic, and its instruments are more user friendly. The internal environment is more comfortable. On more time, SpaceX leads.

4.3 Steps of a global expansion strategy: using in situ resources.

The true threshold, to take down the cost of any mission, is to start using in situ resources. That will be feasible and convenient, as soon as we will have fully reusable space vehicles.

Which in situ materials? Everything existing from LEO and beyond. The first in situ resource are space debris: they can be grabbed, reprocessed and transformed in “raw” materials, input for orbital additive manufacturing factories. According to several studies, among other products, fuel can be produced starting reprocessing captured space debris[11],[12].

Of course fueling stations in LEO, GEO, Lunar orbit and Lagrange Points, may be fed by other extraterrestrial resources: the Moon[13] and the Near Earth Asteroids, primarily.

The development of such a fundamental basic infrastructure will also require the development of some other items:

- industrial settlements, to mine and process the raw materials
- geo-lunar cargo and passengers transport systems
- habitats to accommodate laborers, business people, visitors

As well as during the American Railroads construction, producing fuel from the in situ resources will highly contribute to the building of space infrastructure, and lowering all missions cost.

4.4 A “Planet Hopping” strategy to space settlement, led by gas

The strategy model to be used is similar to the IIWW Pacific islands hopping. The “Planet hopping” strategy will establish human settlement from LEO, to GEO, to the Moon and Cislunar space region. Each established level, based on planetary or asteroidal surfaces, and supported by orbital facilities, will represent a milestone of the progessive expansion strategy.

Making gas on each celestial bodies will build the Solar Systems Railroads, and place human settlements everywhere.

Propellent can be used to reach other destinations, and brought back to already established infrastructural layers, having salutary effect on the cost of any missions, making the market become more and more large and predictable.

Of course the most critical stage is the bootstrap of the strategy, where first results will have to proof the profitability of the investments.

Having, in the first steps, re-fueling stations in Earth orbit, fed by space-made propellant, will reduce an order of three all missions and settlement plans, and make easier to use fully reusable vehicles everywhere. One of the Earth to orbit reusables contras is that they have to reserve more onboard space and weight to additional fuel, in order to allow the re-enter to the ground. This problem will simply disappear, when space made fuel will be available in LEO: each vehicle will simply refuel in orbit, before re-heading to ground. And the refueling will be made at a significantly lower cost, wrt re-fueling on Earth! People will have the first demonstration that space is easier and more convenient than Earth.

"Planets are the incubators of life, a womb for technologically advanced civilizations to mature. We must emerge from ours if we are to continue our evolution towards a spacefaring civilization. Trying to settle another planet would be like finding another womb to crawl into."[14]

This is what we could call the "settlement" paradigm:

1) **General Goal**: permanent and expanding population beyond the Earth
2) **Strategy**: for each layer, develop resources and use them to reach the next location; government purchases should add to commercial market to stimulate supply; identify technology gaps and fill them.
3) **Objectives**: LEO to L1 facilities so any kind of launch vehicle can supply propellant; Lunar base, human tended, for propellant production and export to L1/LEO; Phobos propellant production to support Mars missions (may practice on NEO); Mars base, human tended, for propellant production and to support further exploration and expansion.

In 2016, during the 2nd World Congress, we understood that many industrial activities can be done in orbit, by humans better and more profitably than by robots, when the cost to orbit will be lower than 1 million per ticket.

Nowadays, with Elon Musk's Starship, we could be not that far from that basic goal. And a settlement gas strategy will be feasible. That will truly open the space frontier to civilian space development.

5 A few problems to be resolved as soon as possible

The financial issues are the first ones to be faced and resolved, and the gas strategy will provide a logical path, to start the civilian space development before 2030.

But there are two more classes of problems, to be tackled: civilians life and health protection in space, and legal aspects. This is not the scope of this paper, therefore we'll just list them, since they're worth of an higher priority.

5.1 Civilians life and health protection in space

5.1.1 Protection from cosmic radiations

For exploration purpose, it could be enough to reach Mars and come back, even if astronauts will get a cancer and cannot have children anymore. For settlement purpose, we must be sure the settlers can have children after reaching Mars, or any location outside of Earth magnetosphere. And that is not trivial. We can solve the cosmic radiations problem, there are several solutions, we just have to understand which ones are the best one, for different mission and settlement requirements. The proper priority should be granted to this issue. Cosmic radiations are quite difficult to study on Earth. A facility outside Earth magnetosphere is key: we need to put a laboratory somewhere outside Earth magnetosphere, e.g. in L1, as soon as possible[15].

5.1.2 Protection from low gravity

Zero Gravity, or however gravity lower than Earth 1G is the second big issue, in a perspective of civilian space development. We already had enough experimentation of the effects of low gravity on human physiology: definitely, we wouldn't need further experimentation, on the skin of astronauts. Please check Scott Kelly dramatic witness[16] after one year on the ISS. Such a problem can be solved by building big rotating habitats in orbit (Earth, Moon, Lagrange Points, Mars, and beyond) according to the model described by Gerard O'Neill[17] in 970's. since we need planetary resources, we need to work on planetary surfaces, but nothing prevents us to reach our orbital O'Neill cities, after short working shifts. What we should start, as soon as possible, is to put in orbit some first experimental rotating habitats.

5.1.3 Green environments in space habitats

For exploration and scientific purposes, selected astronauts can live months, or even years, into small boxes made of metal or however only filled by instruments and experiments. When we think about normal civilians, living and working in space for long time periods, or permanently, we have to think about re-creating an as much as possible earth-like environment, giving enough space to vegetable and even animal life forms. That will be essential not only for production of food and oxygen, and water recycling, but to the mental health of the Spacers too. The proper priority shall be given to select the best plants and vegetable varieties, to assure the best living conditions, which could quickly become even better, wrt the conditions on the bottom of Earth gravitational well.[18]

5.1.4 Safe and comfortable space vehicles

For exploration and scientific purposes, selected astronauts, who passed through years of specific training, can travel on rockets bearing 4-5 G accelerations. More, all astronauts being military, they don't have normal civil rights. When we think about normal civilians, normally traveling in space for their business and jobs, travel conditions should be the same provided by a normal airline company. Acceleration should not exceed the one of an airliner at takeoff, re-enter in atmosphere should be safe and comfortable, ergonomics onboard should be sufficient to assure a pleasant and even amusing experience.

5.2 Legal aspects

The law system should do its best to follow and possibly precede the civilian space development, in order to assure at least the following requirements to be fulfilled:

1) To extend civil rights in space, and protect then
2) To assure human rights to be respected and enhanced, in space
3) To protect investments in space

4) To provide rules for fair competition and collaboration in space
5) To provide rules for the extension of usual earthly human civil activities in space
6) To allow use and exploitation of extraterrestrial resources
7) To allow private property of extraterrestrial ground and resources on celestial bodies
8) To provide a sustainable legal system, sufficient to allow civil insurance companies to work in space
9) To harmonize all of the above with the existent space legal system – the Outer Space Treaty – and eventually to change it according to the ongoing commercial space development

[acronyms] ----------

ACRONYMS

Acronym	Description
TIAA	This Is An Acronym
OMA	One More Acronym
AFAA	Association For Abandoned Acronyms

[references] ----------

REFERENCES

1 Robert M. Pirsig, “Lila, an inquiry into morals” 17, pag. 113, https://www.amazon.it/Lila-Inquiry-Robert-M-Pirsig/dp/0553299611

2 “The Turin Papyrus Online Platform (TPOP): An Introduction” https://rivista.museoegizio.it/article/the-turin-papyrus-online-platform-tpop-an-introduction/

3 Steven Gray “Fuelling mobility: coal and Britain’s naval power, c. 1870–1914”, University of Portsmouth https://core.ac.uk/download/pdf/83937265.pdf

4 Jeff Greason, co-founder and Chief Technologist of Electric Sky, chairman of the board of the Tau Zero Foundation, former CEO of XCORE Aerospace, https://en.wikipedia.org/wiki/Jeff_Greason

5 Jeff Greason, “ISDC 2017 Keynote Address A Settlement Strategy for NASA”, Youtube video https://youtu.be/KeSyBdqCAlc

6 The National WWII Museum New Orleans “The Pacific Strategy, 1941-1944” https://www.nationalww2museum.org/war/articles/pacific-strategy-1941-1944

7 “Railroads in the Late 19th Century” – Library of Congress https://www.loc.gov/classroom-materials/united-states-history-primary-source-timeline/rise-of-industrial-america-1876-1900/railroads-in-late-19th-century/

8 “Financing the Transcontinental Railroad”, Maury Klein, Professor Emeritus of History at the University of Rhode Island https://ap.gilderlehrman.org/essays/financing-transcontinental-railroad

9 “Transcontinental Railroad”, ConstructionCompany.com http://www.constructioncompany.com/historic-construction-projects/transcontinental-railroad/

10 “Transcontinental Railroad”, history.com Editors https://www.history.com/topics/inventions/transcontinental-railroad

11 Amrith Mariappan, et Al, “Theoretical studies on space debris recycling and energy conversion system in the International Space Station” https://onlinelibrary.wiley.com/doi/full/10.1002/eng2.12317

12 Mykola Dron , et Al, “Ways of reduction of technogenic pollution of the near-earth space”, https://www.researchgate.net/publication/296898891_Ways_of_reduction_of_technogenic_pollution_of_the_near-earth_space

13 Neel V. Patelarchive, “Here’s how we could mine the moon for rocket fuel”, https://www.technologyreview.com/2020/05/19/1001857/how-moon-lunar-mining-water-ice-rocket-fuel/

14 Erasmo Acosta, “We Are Doing Space Colonization Wrong. But will we listen?” https://medium.com/predict/3d0eabe2f2e0

15 “Lagrange mission”, ESA / Safety & Security, https://www.esa.int/Safety_Security/Lagrange_mission2

16 Scott Kelly, “Endurance”, https://www.amazon.com/Endurance-Year-Space-Lifetime-Discovery/dp/1524731595

17 Gerard K. O’Neill, “The High Frontier: Human Colonies in Space”, https://www.amazon.com/High-Frontier-Human-Colonies-Apogee/dp/189652267X

18 Adriano V. Autino, “The Fifth Season, the space ‘bingo’ surprises: very profitable and not obvious gifts of space” https://spacerenaissance.space/wp-content/uploads/2020/04/IAC05E1P03_The_Fifth_Season.pdf