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"GLOBAL EXPANSION VS. SPACE EXPLORATION, A FULL CHANGE OF PARADIGM"

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Abstract

Space exploration was started since the first satellite launch – Sputnik, October 4th 1957 – and developed for more than 60 years. A huge investment of public money was devoted to space agencies, however the high frontier was not yet opened to civilian development. Human space flight is still reserved to astronauts, bearing a hard training. Space programs are still based on the strategy and goals of 1) space exploration and 2) use of space to support Earth. The above two rationales are useful, and not to be abandoned. However humanity is in deep need of a third strategical setup: civilization expansion, and civilian space development.

The basic requirements of the stakeholders of such a change of paradigm are briefly reviewed, in order to motivate it upon sound and sustainable social needs.

Space tourism and citizens engagement are identified as an intermediate step, between space exploration and space settlement.

The superiority of a model of global progressive expansion, from Earth orbit, to geo-lunar space region, to Mars, Asteroids Belt and beyond is argued, vs. exploration round-trip missions.

A realistic road-map is also sketched, reviewing the evolution of mission requirements, related to human life, health and living conditions, from suborbital tourism, to orbital and cislunar tourism, long distance manned exploration missions, Earth orbit industrial settlements, Lunar and Cislunar industrial settlements, living in orbital space cities.

The paper also addresses some enabling technologies, and light training programmes, allowing untrained civilians to travel, work and live in space, such as: protection against cosmic radiations, artificial gravity, low cost, safe and comfortable space vehicle, smooth acceleration, safe re-entry into atmosphere, green environment in space habitats.

Finally, the paper analyzes the differences between exploration and expansion, in terms of feasibility, sustainability, opportunity and social needs.

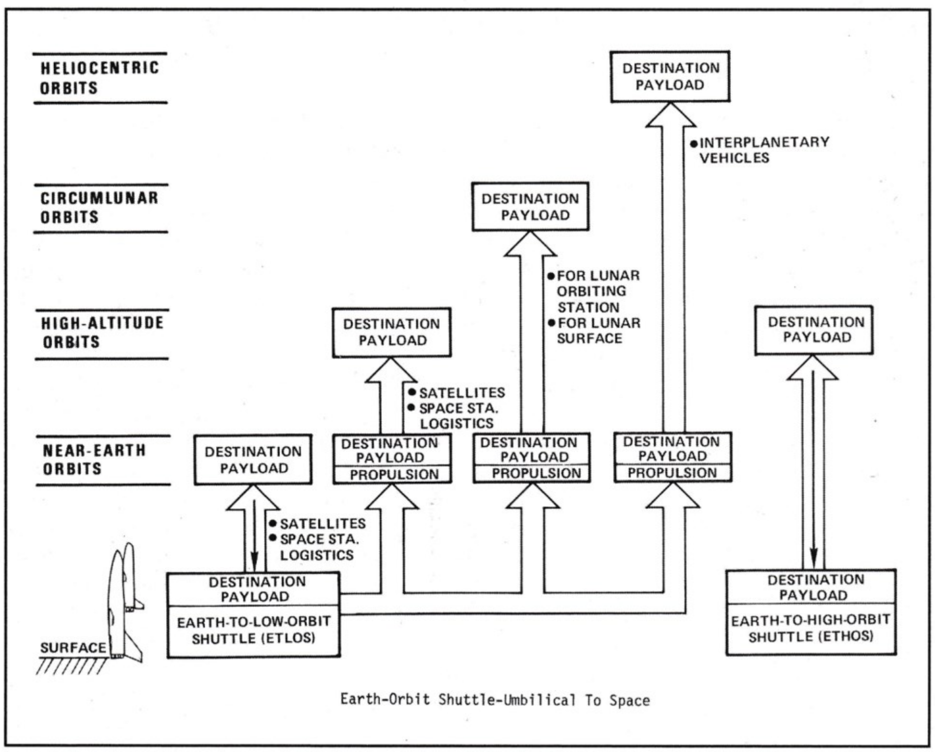
THE URGENT THIRD RATIONALE: CIVILIAN SPACE DEVELOPMENT

The huge delay of space settlement

Space exploration was started since the first satellite launch – Sputnik, October 4th 1957 – and developed for more than 60 years. A huge investment of public money was devoted to space agencies, however the high frontier was not yet opened to civilian development.. A huge investment of public money was devoted to space agencies, however the high frontier was not yet opened to civilian development. Human space flight is still reserved to astronauts, bearing a hard training. Space programs are still based on the strategy and goals of 1) space exploration and 2) use of space to support Earth. The above two rationales are useful, and not to be abandoned. However humanity is in deep need of a third strategical setup: civilization expansion into space, i.e. civilian space development[1]. The resources of our beloved mother planet – including environmental resources – became dramatically scarce, for 8 billion citizens: we don't have a "planet B", yet we desperately need the equivalent of several planets B, to be construed in the geo-lunar space region, on the Moon, on Mars, in the Asteroid Belt, and beyond.

The reasons of such a delay were deeply analysed[2], and it is largely understood that the main causes were not technological nor financial. Rather, the responsibilities are located mainly in the policies of the governments and the space agencies, more prone to favour the big traditional aerospace and military lobbies than the interest of humanity and civilization. The cost of transportation from Earth surface to orbit was artificially kept high for more than 50 years, and the reusable rockets technology kicked off, in 2015, only thanks to the initiative of a visionary entrepreneur, Elon Musk, and his company Space X. The process got the attention of media in 2004, when ScaledComposites[3] won the Ansari X Prize[4], flying at 100 km altitude with an investment of just 30 $M, demonstrating that low cost access to space was feasible. It was the beginning of the crisis of the traditional aerospace paradigm, the big space agencies became finally favourable to an open market, allowing startups to enter the game, reducing the cost to orbit. Such an epochal development finally made civilian space development feasible and affordable to privates.

Yet, the way to reduce the cost to orbit was clearly indicated already in 1969, when a fully reusable Two Stage To Orbit (to sub-orbit, actually), made almost 200 flights at 100 km altitude. It was the X-15[5], a NASA spaceplane, based on the same concept adopted by Burt Rutan's ScaledComposites with SpaceShipOne[6], later by Richard Branson's Virgin Galactic[7] with SpaceShipTwo[8]. The first design of the Space Shuttle (see Figure 1), by Krafft Ehricke during 1970's, was based on the same concept: a fully reusable Two Stages To Orbit[9]. The original space shuttle concept as a fully reusable orbiter backs to 1969, according to The Guardian[10]. But that solution was discarded, in favour of the partially reusable Space Shuttle, 5 unique pieces, instead of establishing a small industrial production: a choice that cost the destruction of two shuttles on five, and the sacrifice of two complete crews. The shuttle program total cost was estimated at $209 billion (in 2010 dollars), yielding a per flight cost of $1.6 billion[11].



As the Nixon Administration was deciding what would follow the Apollo program, Krafft Ehricke made a comprehensive case for a reusable shuttle vehicle, which he described as an "umbilical to space." As summarized in this diagram, lost-cost shuttle transportation would be the enabling capability to bring payloads to Earth orbit, which is then the gateway to circumlunar and interplanetary destinations. He also proposed that a shuttle vehicle to reach higher Earth orbits be developed. Credit: "Space Applications for Low-Cost Ferry Vehicles," lecture presented at the Space Institute of the University of Tennessee; August 18-22, 1969

Figure 1. Krafft Ehricke's first concept of the Space Shuttle

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Figure 2. First Space Shuttle prototype (The Guardiam)

The stakeholders of civilization expansion into outer space

From the Thesis-1[12] of the 3rd Space Renaissance World Congress (held from June 26th to July 15th 2021):

"Human civilization, at the threshold of 8 billion citizens, needs new resources, energy and space to retake its development. Such an evolutionary step is needed in order for civilization to survive as a high level and as an advanced cultural community, evolving towards all the key indicators, such as quality of life, science, technology, democracy, freedom, ethics, human rights, fair competition and collaboration. Reaching out to use the energy of our star in the space of the solar system, our civilization will be raised one degree in the scale traced by Nicolai Kardashev, and later by Bob Zubrin, Carl Sagan, Steven Wolfe, M. M. Cirkovi´c[13] and other philosophers.

Human species, at the threshold of 8 billions beings, needs to expand into a greater ecological niche, in order to assure the basic needs, referred to in Maslow's scale[14], to be satisfied, avoiding recession on the evolution scale back towards animal behaviors. […]

Civilizational history so far has clearly demonstrated that expansion to the whole surface of our planet was not enough, to allow the totality of earthly citizens to be included in a decent welfare, with sufficient opportunity of work and wealth for everybody. This is evident since we still have a huge percentage of Earthers trapped into starving geo-social situations. And this problem is mainly due to the scarcity of resources, as described in chapter 1 of this document.

Evolving to a level II civilization – by expanding into outer space – will also allow a progressive and fundamental step in our social evolution. More: such a social evolution will not only assure that the basic Maslow's needs will be satisfied, but it will also allow all individuals – with their huge diversity – to aim for their highest goals, self-realization.

The reality follows: on Earth there's not enough for everybody, but we need everybody, and more people, to succeed in our evolutionary next step. Expanding this statement: 8 billions of compeborating (competing and collaborating) intelligences are perhaps the minimum threshold necessary to step to the stars. And for sure we need to "grow up" much more, and reach maturity, by starting to really harvest the energy and resources of our solar system. We can grow further only expanding into outer space."

In the same document, the authors added a 4th criteria to assess the maturity of a civilization. After the Kardashev criteria (energy mastering)[15], Bob Zubrin's one (mastery of resources)[16] and Carl Sagan's mastery of information[17], Space Renaissance added full social inclusivity. Such a goal is feasible only by expanding into the Solar System, profiting the immense available materials, a virtually unlimited platform for our current size. Expanding Civilization onto space will allow to realize the first feasible utopia: each-one to reach their own highest Maslow objectives. The old utopia, which was actually taken from the Acts of the Apostles[18], said *"from everyone according to his abilities; to everyone according to his needs"*. As written in the book, "A greater word is possible"[19], such statement *"presupposes a criteria that judges needs, not aspirations or desires (…) Since the utterance does not take care to provide a description of the method that should be used to estimate needs, it is clear that it refers to easily identifiable needs, which everyone can see, what are the basic*

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needs of human beings: eating, dressing, protecting themselves from the weather, heat and cold." This utopia applies to the lowest level of the Maslow scale[20]: it is therefore necessary, but not sufficient, for an advanced full inclusive society. An up-to-date utopia, more suitable for our days, could say something like the following statement:

"by each one according to their capabilities, creativity and availability"
"to each one according to their desires and their capacity for imagination".

Discussing the dramatic experience of the last two years, due to the Coronavirus pandemics, Thesis-1 concludes that *"The pandemic must be defeated as quickly as possible: Civilization needs all of its members, who are not 'mouths to be fed' as Malthus claimed, but intelligences essential to the evolutionary leap that our species is facing. Every single human life matters, each individual holds the solution to one of the greatest problems: the multiple crises gripping civilization within the limits of the closed world. Many crises are encircling us, limiting our freedom of movement, and our very ability to react and respond to crises. Yet our numbers, which have become excessive within the limits of our planet, are the true wealth of our species, if we are willing to accept the evolutionary challenge posed by nature. Nicolai Kardashev, Krafft Ehricke, Julian Simon, Stephen Hawking, Carl Sagan, Robert Pirsig, Bob Zubrin and other neo-humanist philosophers have composed excellent rationales that made Malthus destructive theories fade away, on the book of history."*

Summarizing, the main stakeholders of the civilization expansion into space are therefore at least the following ones:

- the civilization as a whole, since only expanding into space human society can keep on developing as a cultural species, evolving as a civilization
- the young generations, present and to come, since the only way to have a future is expanding into space
- the economic and cultural growth, both indispensable to assure evolution of human rights, ethics, freedom and democracy
- the Earth environment, since only a progressive expansion and moving industrial development into space can relieve Earth's ecosystem
- the further space exploration, since only in a growing economy we can have financial resources to keep on feeding space exploration.

<u>A realistic roadmap for space settlement: planet hopping, led by gas production from extra-terrestrial resources</u>

In general terms, we understood that the problem we are facing is the following: space settlement will begin when it will be possible to move civilian people to space and accommodate them for long periods of time, eventually as resident space citizens. That is an issue that involve science, technology, finance, philosophy – and not only 'vision', as it is usually called – and policies. As Jeff Greason wisely observed, in his speech at ISDC 2017[21], the huge delay in space settlement is due to lack of a coherent strategy.

The paradox is that we are going quickly, now, to have a fully reusable space vehicle – the SpaceX's Starship – and likely we will reach such an epochal fundamental goal *before having a coherent strategy for space settlement*. Will it be possible to kick-off civilian space development in such way, just following the dream of Elon Musk and Jeff Bezos? Well, somebody says that it is even better, and that the high frontier can only be opened by the ingenuity and passion of visionary entrepreneurs, in a regime of fair competition. Maybe. Yet, to start building the space infrastructure is a very big project, the biggest one humanity ever undertook. As Alberto Cavallo and myself wrote in a recent paper[22], all of the successful big enterprises of human history had a strategy: the pyramids of ancient Egypt, the Nineteenth Century Mercantilism, the Transcontinental Railroads in North America, and the victory of USA of World War II.

The last mentioned case, WWII, saw the victory of USA because they conceived and adopted a good strategy, called "island hopping" strategy, that consisted in building the essential infrastructure to refuel the American vessels and feed the military contingents across the Pacific Ocean. Refuelling played a key role in at least other two mentioned cases: Mercantilism on the eastern root and the building of the Transcontinental Railroads in North America.

It is likely that gas production and supply will also play a key role in the civilization expansion into space, in the frame of a coherent progressive expansion strategy. Using in situ resources – namely Lunar and Asteroid raw materials – will allow to reduce the cost of any transport to anywhere in the Solar System to 1/3 of the cost when all the fuel shall be lifted to orbit from Earth. We can even dare to draft some essential steps of a realistic strategic roadmap. We could have the cost to orbit < $ 1,000/Kg, when a 100% reusable space vehicle for passengers and cargo, will be well established and in service. As soon as Moon Mining and processing plants, will be settled and producing fuel, the cost to orbit, to the Moon and beyond will fall under $ 100/Kg.

Refuelling stations will be developed and placed from LEO to GEO. Concurrently we will have orbital hotels in Earth orbit, on the Moon and at Earth-Moon Lagrange points. In the same time the essential enabling technologies will be perfectioned, to allow civilians to travel and stay for long time in space. It wouldn't be too optimistic, should the development keep the current brisk pace, led by Space X, to think that in 2040 we could have the seeds of the space industry well planted and growing luxuriantly. A feasible road-map to space settlement within 2030 was sketched in the Thesis-2 for the 3rd World Congress of Space Renaissance International[23] (see Table 1).

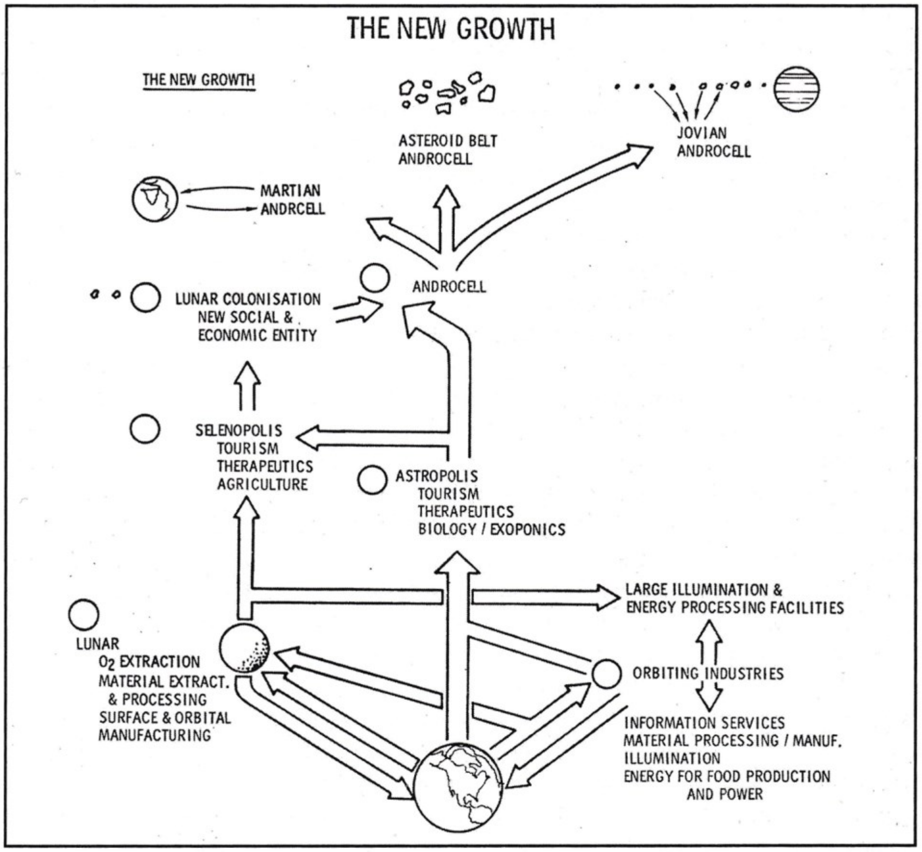

Figure 3. Krafft Ehricke concept of Civilian Growth in the Solar System[24]

STEP	ACHIEVEMENT
To define a strategy and some feasible goals. The need of a strategy was efficiently discussed by Jeff Greason in 2017[25]	
Developing low cost fully reusable orbital vehicles	Cost for one person to orbit < 1 million
Giving proper priority and developing some enabling technologies for untrained civilian space workers to travel, live and work in space, e.g.: vehicles endowed by smooth acceleration, safe re-enter into atmosphere, protection from space hard radiations, artificial gravity and green environment in habitats	More civilians allowed and secured to live and work in space
Development of suborbital tourism	Enlargement of space market and space industry
Development of proper insurance and legal responsibility, extension of civil rights in space	More civilians to travel and work in space
Civilian space development in Earth orbit: debris recovering, orbital tourism, satellites and spacecrafts assembling and maintenance	Raise of space economy, increase of investments
Developing capability of fuel production from Lunar and asteroid mined resources	Cost of any mission beyond Earth orbit lowered at 30% of previous cost
Establishing fueling stations in Earth orbit and Cislunar space	
Establishing information network in the Cislunar region	
Building Lunar industrial settlements for mineral extraction, such as helium 3, regolith processing, etc…	Development of extra-terrestrial production industrial segment
Building Lunar research settlements, such as astronomic telescopes on the dark side	
To start exploring and settling Mars, as a logistic pole towards Asteroid Belt and the external Solar System	

Table 1. A feasible road-map to space settlement, first steps within 2030

SPACE EXPANSION VS. SPACE EXPLORATION

While the new space vanguard industry is now oriented to the civilian space development, and a large part of the space advocacy community is supporting such effort, the main space agencies are still working in the frame of their space exploration strategy (NASA), telecommunication and Earth observing (ESA). Russian and Chinese agencies seem to be working on a space expansionist program. India is also moving fast on national space program. However, it is more likely that Russia and China will keep on operating in the frame of their governmental military setup. Should they result first in the new space race, it would be unlikely that the high frontier would be open to private enterprises and civilian initiatives. Hard to say – actually – what strategical address will be adopted by India.

Since there are some scientific issues to be solved, some classical research work should be done by space agencies and scientific research institutions. We are talking about the development of the enabling technologies to allow civilians to travel and live in space: these are the key items, to accomplish the shift of paradigm, from space-exploration only to space-expansion+exploration.

Of course we will always need exploration. Yet, exploration would be useless, without settling the already explored space regions. Moreover, if the economic and cultural revolution due to the civilian space development will not meaningfully take-off before 2030, the global economy will crash, and there will be no longer funds for space activities – including space exploration[26].

It is of paramount importance to fully understand the differences between the two paradigms, and to detect the obstacles preventing a full shift from space exploration to space settlement.

First of all, space expansion will not kill space exploration, while self-targeted space exploration can delay and even hinder space expansion, in the context of a space program void of proper strategy[27].

Several factors are determining the persistence of the space exploration paradigm over its age, and hinder the start of the space settlement paradigm. The main factor was the aim to protect the bureaucratic privileges of the space and government agencies:

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space exploration, as well as space science, can be "sold" to taxpayers forever (that's not true, as we will see), without any duty to give a return of investment. Space settlement, since it will necessarily involve private initiative and enterprises, will deal with investments, the related return of investment and commercial activities, as it happens on Earth. Legitimate concerns about environmental issues and the need to set-up a legal framework to avoid abuses and "far-west" behaviors can easily end in a delay in the bootstrap of civilian space development. That's why it is very much better to allow legal and environmental concerns to accompany the settlement, instead of preceding it. The space settlement should be seen as a needed ongoing social progressive process: any claim to plan and organize it 100% would likely have the same depressive effects on the real economy obtained by the historic attempts to plan the economy.

Jeff Greason said it clear, in several speeches at ISDC: everybody in the space community agrees that we need a change of paradigm, but nobody dares to draw the required need of designing a proper strategy, to set the goal, the milestones and the technological and financial means. In other words, there's a gap, between the current status and the desired space settlement context, and no strategic decisions were taken, to fill it.

As Jeff Greason proposed in a famous speech at NSS's ISDC 2017[28], 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 from such a cosmic renaissance. That's why the advocates of a further space exploration should become the best advocates of space settlement. No doubts that space exploration will always have its importance: what humanity desperately needs is to give proper importance to civilian space settlement, finally.

Let's see in details the differences between the two paradigms.

While space exploration, up to a certain extent, can exist without space expansion, space expansion requires more advanced exploration. When proper habitats and industrial settlements, the infrastructure of a space region – e.g. Cislunar – is consolidated enough, further advanced exploration will be required, to establish outposts on more distant frontiers. Mars and Mars's moons. Next levels will be Asteroid Belt, Jupiter Moons, and beyond. Proper webinars should be done, favouring the understanding of the relationship among space exploration and space settlement: space explorers should become the best supporters of space settlement!

Exploration is done by military trained astronauts. Space expansion is a civilian concept, developed by private enterprises. The main obstacle are the policies sustained by the military and "old-space" lobbies. Governments should work to illustrate the enormous benefits for all of the word economy segments, that will follow the civilian space development, and the advent of private enterprises on the high frontiers.

Exploration does not require industrialization or the construction of infrastructure, while expansion requires settlement, industrialization and infrastructure development. Proper studies and business plans should illustrate the enormous growth of the global economy, following space industrialization and infrastructure construction.

Exploration can be done by robots. Expansion requires a coherent development of human settlement, from Earth to nearby space, and progressively beyond. Robotic space exploration will not contribute to solve the environmental issues on Planet Earth. Human expansion and settlement will relieve Earth's environment, in perspective, from the burden of industrial development.

Exploration is done with public money. Expansion involves private investors and companies. In perspective, space will become a source of value, instead of a public expense. Profits coming from civilian space development will contribute tax money to public treasure.

Exploration is made of round-trip short missions, and doesn't consolidate infrastructures. Expansion is based upon permanent settlements, and require a progressive global infrastructure to be built, consolidated, inhabited.

Exploration does not imply growth. Expansion leads to a global progressive growth of civilization, on all vectors: economy, culture, ethics, freedom, democracy.

Exploration only gives technological payback to Earth. Expansion assures a continuous structural and infrastructural growth in space.

Exploration is based on human life expendability. Expansion requires a continuous evolution of technologies for life and health protection.

Exploration allows technology transfer from space to Earth. Expansion requires moving/evolving Earthly jobs to space.

THE KEY MILESTONES, CARDINAL SHIFTING POINT, FROM SPACE EXPLORATION TO SPACE SETTLEMENT

As deeply analysed in several papers[29], during the recent 3rd World Congress of Space Renaissance[30], a far higher priority should be granted to the enhancement of enabling technologies for civilian space development, i.e.: protection from cosmic radiations, artificial gravity, low cost safe and comfortable space vehicles, and green environments in space habitats.

It was deeply discussed why such technologies did not get, so far, the deserved priority.

The answer is not that obvious, though it may seem so, when the philosophical and political knot has been untangled: the technologies enabling civilian space travel were not boosted, so far, by the space agencies, since they are deemed useless, in the frame of the space exploration paradigm. And the space policy decision makers, so far, were stubbornly firm, in their will to keep space exploration 100% ruling, as much long as possible. That is not strange: all bureaucracies, in history, have been firmly clinging to their privileges. Talking about bureaucratic regimes, they generally could be removed only by violent revolutions. Until the scope and mission of the space agencies will be limited to science, Earth observation and exploration, their budget will be assured, without any duty to give back any return to taxpayers. A proof of such a strategical setup: in 60 years of activity, the main space agencies have not invested a cent in the development of technologies to support space tourism or civilian space travel in general terms. To the honor of space agencies, vs. other types of bureaucracies, they seem to be more keen to change, accepting the social changes – namely the development of the new space industrial segment – that are going on in the society. NASA opened its market to new dealers, such as Space X, Blue Origin and others, allowing the competition and the subsequent downsize of the prices. Such a development may offer a fertile ground for civilian space technologies to be recognized in their relevance, and to raise in priority.

These are the basic requirements for **civilian passenger and cargo transportation systems**:

- low cost
- full reusability
- comfortable travel conditions
- ergonomics
- low acceleration, both ascending and descending
- safe re-entry into the atmosphere
- horizontal take-off and landing
- protection from solar & cosmic radiation

And requirements for **Space Habitats:**

- protection from solar & cosmic radiation
- artificial gravity
- green environment onboard
- use of local resources
- recycling and sustainability

Nothing else can be feasible without the first two requirements: low cost and full reusability. All of the other requirements focus on protection of life and health in space. We can't stress enough that these requirements refer to civilian passengers, but there's no reason why astronauts' life and health shouldn't be protected as well!

The following quick discussion of the requirements aims to better define why they are needed and to give some basic hints about how to pursue them[31].

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.

The level of radiations inside the Van Allen Belt is modest, however considerably higher than the one we absorb on Earth surface, where we are protected by the atmosphere and by the Earth's magnetic field. The health effects of space radiation[32] involve both direct damage to DNA, indirect effects due to generation of reactive oxygen species, and changes to the biochemistry of cells and tissues, alteration of gene transcription and the tissue microenvironment, DNA mutations, stochastic events such as radiation carcinogenesis and deterministic degenerative tissue effects, higher risk for radiation cataract among the astronaut corps.

NASA postulated short- and long-term effects of central nervous system exposure to galactic cosmic radiation[33] are likely to pose significant neurological health risks to human long-term space travel. Apollo astronauts reported seeing light flashes: likely pathways include heavy ion interactions with retinal photoreceptors and Cherenkov radiation resulting from particle interactions within the vitreous humor. NASA-supported study reported that human spaceflight may harm the brains of astronauts and accelerate the onset of Alzheimer's disease. Research studies in small animals report changes to cognition and memory, neuro-inflammation, neuron morphology, and impaired neurogenesis in the hippocampus. Simulated space radiation tests in small animals suggest temporary or long-term cognitive detriments could occur during a long-term space mission.

There are several solutions to the cosmic radiations problem, we just have to understand which ones are the best one, for different mission and settlement requirements, and boost the research on the selected methods. 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, or on the Moon, as soon as possible[34].

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Protection from low gravity

Micro or Low 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[35] about his experience on the ISS. Scott Kelly, who spent one year on ISS (from March 2015 to March 2016), gave evidence of the huge effects of microgravity on human physiology, when lasting for a long time. Which include meaningful physical, cognitive, and genetic (DNA) changes. According to an article by Carl Zimmer on The New York Times[36], when Scott Kelly returned on Earth, his body showed signs of intense stress, and his immune system was in high gear. Despite that shock, Mr. Kelly's body mostly returned to preflight condition. People have asked him: 'Well, is going to space the fountain of youth?' I don't think so. If it is, you're going to have to stay up there forever.' That's exactly the point: space citizen could maybe adapt to space conditions -- microgravity maybe, cosmic radiations who knows… -- but for sure they will never come back to Earth, if not on a wheel-chair, and for short times. Holidays on Earth, for space workers and settlers? Not at all.

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[37] in 1970'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.

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.

Living in totally metallic and plastic environment could be fun and interesting, for a short time, as an experience, e.g. during a vacation, for tourism purpose. Some human types could even prefer a totally "artificial" environment. However, in general terms, humans grew up and evolved on a planet where vegetable life is 97% of the total life. Beyond the obvious consideration that vegetable life is essential to provide food and generate oxygen in space, the green is well rooted in our DNA and culture. It means that, forcing humans to live in green-less environments for long time could only result in heavy health issues, both physical and psychological, as the experience of living mainly in urban environment without green, would suggest[38 39].

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[40]. We can train citizens to work and live off the land, using analogues facilities on Earth in extreme sites (see for instance ILEWG EuroMoonMars Astronautics Training programme[41]).

Safe and comfortable space vehicles

For exploration and scientific purposes, selected astronauts, who passed through years of specific training, can travel on aircrafts and rockets bearing 4-5 G accelerations.

A summary of the effects of high g-force on human body is provided by this article[42] (excerpt): "In general, high velocity doesn't produce harmful injuries. But what is dangerous is the high acceleration or deceleration given at a certain time interval. Human body is composed of different organs each organ containing its own different given density. Under high acceleration brain, lungs, ribs (any bones), and women's breast (tissue fat) all affect the death of the human. Each different body part has a higher density than another which causes certain organs to undergo more g-force than other organs. Pilots, roller coaster rides, and car crashes are sufficient examples of g-force. Roller coasters undergo forces of maximum up to 3 to 4 g's for brief periods of time. Military pilots are trained to undergo accelerations of 9 g's to pull quick manoeuvres during flight for less than a second. If a force of 4 to 6 g's is held for more than a few seconds, the results could be devastating; such as blackouts to death."

As we learn by the existing literature, three parameters are important, to determine the danger of high acceleration on human body: the g-force, the time duration, the training.

Military pilots and astronauts can tolerate accelerations higher than untrained people. Astronauts are properly trained for that, and 4 or 5 G are well tolerated after a two years High-G training[43]. Such training techniques are designed to prevent a g-induced loss of consciousness (G-LOC), when the action of g-forces moves the blood away from the brain to the extent that consciousness is lost.

As they are not expected to be trained to fly on a normal airline, civilian passengers shouldn't need to

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be specifically trained to fly to orbit, or any further destinations in space.

More, all astronauts being military, they don't have normal civil rights (sic!). When we think about civilian passengers, normally traveling in space for their business and jobs, or for tourism purpose, travel conditions should be the same provided by a normal airline company. Acceleration should not exceed the one of an airliner at take-off, re-enter in atmosphere should be safe and comfortable, ergonomics onboard should be sufficient to assure a pleasant and even amusing experience.

Acronyms

acronym	description
DNA	DeoxyriboNucleic Acid
GEO	Geostationary Earth Orbit
G-LOC	G-induced Loss Of Consciousness
ILEWG	International Lunar Exploration Working Group
ISDC	International Space Development Conference
ISS	International Space Station
L1	Lagrange point 1 (Earth-Moon)
LEO	Low Earth Orbit
MMAARS	Mars-Moon Astronautics Academy & Research Science
NASA	National Aeronautic and Space Administration
NSS	National Space Society
SGAC	Space Generation Advisory Council
USA	United States of America
WWII	World War II

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