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"FROM SPACE EXPLORATION, TO SUBORBITAL SPACE TOURISM, TO LIVING AND WORKING IN SPACE: EVOLUTION OF THE MISSION REQUIREMENTS"

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Abstract

Civilization expansion into space is 50 years late. The advent of reusable rockets, by Space X since 2015, gave us hope, after a long wait for space tourism to become a reality. This paper briefly summarizes the causes of the delay. However, for the real start of the geo-lunar space industrialization, reusable rockets and low cost launch vehicles are just the first essential step.

A realistic business plan shall be drafted, addressing the most profitable industrial development strategies, such as, e.g., satellites assembly and maintenance in orbit, low gravity products, space debris and wreckages recovering and reusing in orbital workshops, by 3D printing and other technologies.

Envisioning industries in space, it is clear that space travellers and workers will not be only professional astronauts. In other terms, space settlement will begin when it will be possible to move civilian people to space and accommodate them for long periods, eventually as resident space citizens. Just as airline passengers don't need to be pilots, nor hostesses, nor stewards, space travellers shouldn't be astronauts.

It is clear that civilian space travellers have mission requirements different from military astronauts. Civilian passengers and settlers need softer traveling conditions and protection against the austerities of living in space, such as low gravity and cosmic radiations, they need green environments in the habitats, not to mention legal warranties, as any airline company knows well.

Astronaut Scott Kelly spent a year on the ISS, exposed to microgravity and radiation, which had detrimental effects on his health, as documented in his book, "Endurance". Microgravity can be solved by providing rotational gravity. Radiation can be solved by shielding. If we want the average person, without astronautic training, to travel in space, we also need vehicles as comfortable as normal airliners, with horizontal take-off and landing, low acceleration, and safe re-entry into the atmosphere. For the sake of our physical and mental health, we also need green environments in space habitats: vegetables and animals with us.

Passenger Transportation Systems and Space Habitats requirements are briefly captured and assessed, considering few evolving levels, from classical astronautic space exploration to space settlement, as to duration, distance from Earth, different vulnerability to radiations, low gravity, hard psychological and logistic conditions:

- Terrestrial analogue campaigns training for habitats and research (such as ILEWG EuroMoonMars and MMAARS)
- Sub-orbital tourism
- Sub-orbital transportation
- Orbital tourism
- Lunar tourism
- Space exploration: short missions, lunar missions, Mars missions long distance missions
- Working and living in space

SPACE TRAVELLERS WILL BE NON-CAREER ASTRONAUTS

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.

Just as airline passengers do not need to be pilots, nor hostesses, nor stewards, space travellers should not need to be astronauts.

Reusing the first stage of a Two Stages To Orbit vehicle, currently available from Space X[1] and soon available by Blue Origin[2], is just the first step. It is clear, from the point of view of human rights and interests, that civilians have mission requirements that are different from military astronauts. However, military people, (sad to say for a humanist) don't have civil rights, by definition, and their life is "expendable." Civilian passengers and settlers need softer travelling conditions and protection against the austerities of living in space, such as low gravity and cosmic radiation, and they need green environments in the habitats, and there are also legal constraints[3], as any airline company knows well.

The few tourists who have flown so far to the International Space Station paid an average $30 million ticket, and signed a release letter, in which they renounced any warrants about their life and health, relieving the involved space agencies from any damage or harm they could incur during their travel and stay onboard the station.

Of course the main challenge to be won is a meaningful downsizing of the cost of transportation from Earth surface to orbit. Thanks to the efforts of the pioneer companies Space X and Blue Origin, and now by many other followers, this challenge is finally being tackled.

Not so we can say about the other big challenge: protecting human life and health in space, or, in general term, developing the needed technologies in the frame of an exo-biology strategical frame. Such a development cannot be further delayed, considering the dramatic urgency, for our 8 billion citizen civilization, to start expanding into outer space[4].

THE DAMAGES TO HUMAN HEALTH CAUSED BY LONG UNPROTECTED STAYS IN SPACE

Effects of low gravity

The dramatic witness released by astronaut Scott Kelly[5], who spent one year on the ISS (from March 2015 to March 2016), gives 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. A comparative study was also conducted not only on Scott's conditions before and after his one year mission, but also with his twin brother Mark, an astronaut as well, who remained on Earth during the same period. As reported by Catherine Zuckerman in an article[6] on National Geographic of April 2019:

"One difference involves the protective caps at the ends of chromosomes, known as telomeres. These bits of genetic material are biomarkers of aging and potential health risk, says study coauthor Susan Bailey, a health researcher at Colorado State University. While aboard the ISS, Scott's telomeres became elongated, although it's hard to know at this stage what, if any, effects that might have. Researchers also found abnormalities such as inversions and translocations in some of Scott's chromosomes and some damage to his DNA, as well as changes in his gene expression. Beyond these genetic effects, Scott developed thickening in his retina and in his carotid artery. There were also shifts in Scott's gut microbiome that differed from those of his Earth-bound twin. Things didn't entirely go back to normal when Scott returned to Earth. More than 90 percent of Scott's genes returned to normal expression levels, but some small changes persisted. And while most of his elongated telomeres quickly returned to typical length upon return, some became even shorter than they were pre-flight. This shortening may be a concern that merits further study in other astronauts, Bailey says in an email, 'because short telomeres have been associated with reduced fertility' along with dementia, cardiovascular disease, and some cancers. Some chromosomal inversions also persisted, Bailey says, 'and so could contribute to genomic instability, which could increase risk of developing cancer.' In the months after Scott returned, researchers also noticed a persistent reduction in his cognitive skills. 'It wasn't getting worse, but it also was not getting any better,' says study coauthor Matthias Basner of the University of Pennsylvania's department of sleep and psychiatry."

Long permanence in space, getting cosmic and solar radiations many folds higher than what we get on Earth ground (were we are protected by the atmosphere and the Earth magnetic field), will bring for sure damages and changes in our genetic make-up.

According to an article by Carl Zimmer on The New York Times[7], 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 pre-flight 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.

From the autobiographic book Endurance[8], by Scott Kelly: *"I make it to my bedroom without incident and close the door behind me. Every part of my body hurts. All of my joints and all of my muscles are protesting the crushing pressure of gravity. I'm also nauseated, though I haven't thrown up. I strip off my clothes and get into bed, relishing the feeling of sheets, the light pressure of the blanket over me, the fluff of the pillow under my head. All of these are things I missed dearly. I can hear the happy murmur of my family behind the door, voices I haven't heard without the distortion of phones bouncing signals off satellites for a year. I drift off to sleep to the comforting sound of their talking and laughing. A crack of light wakes me: Is it morning? No, it's just Amiko coming to bed. I've only been asleep for a couple of hours. But I feel delirious. It's a struggle to come to consciousness enough to move, to tell her how awful I feel. I'm seriously nauseated now, feverish, and my pain has gotten worse. This isn't like how I felt after my last mission. This is much, much worse."*

More, from the same book: *"I struggle to get up. Find the edge of the bed. Feet down. Sit up. Stand up. At every stage I feel like I'm fighting through quicksand. When I'm finally vertical, the pain in my legs is awful, and on top of that pain I feel something even more alarming: all* *the blood in my body is rushing to my legs, like the sensation of the blood rushing to your head when you do a headstand, but in reverse. I can feel the tissue in my legs swelling. I shuffle my way to the bathroom, moving my weight from one foot to the other with deliberate effort. Left. Right. Left. Right. I make it to the bathroom, flip on the light, and look down at my legs. They are swollen and alien stumps, not legs at all."*

In a video-clip he released to the Gateway website[9], we can also see the conditions the Scott's legs were, during the first days after his return to the bottom of the gravitational well. Something nobody would like to experience, indeed.

Even more worrying, the researchers also found that Scott didn't do as well on his return on cognitive exams. "He got slower and less accurate on virtually all of the tests," said Dr. Mathias Basner, a cognitive scientist at the University of Pennsylvania. "And on an unconscious level, he may no longer have been pushing himself. I mean, he basically retired the moment he hit the ground, and so perhaps he just wasn't as motivated any longer," Dr. Basner said.

This is another very bad point, from an anthropologic point of view: staying long time in space – as an astronaut – has a strong demotivating effect, on human psychology: if you stay in space enough time, you never want to go back there. We do not want generations of depressed space pioneers, that will curse the day when they abandoned the Earth's ground.

It is of great urgency to start experimenting artificial gravity: as we learned by the dramatic experience made by Scott Kelly, this is fundamental for any strategy of expansion and settlement in space.

Effects of cosmic radiations

A danger that none training can avoid is the one coming from cosmic radiations. Astronauts so far absorbed radiations for a maximum of one year, on the ISS. 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[10] 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[11] 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.

Figure 1 shows a comparison of the received amounts of radiations in different locations[12]: Earth surface, the ISS, the Moon surface and Mars surface. Radiations absorbed on the ISS is 100 times the amount absorbed on Earth, and the dosage absorbed on the Moon is 200 times, while Mars is almost 300 times. Astronauts absorb a dangerous amount of radiations during their life.

The proof that the problem is serious is given by NASA, who established permissible exposure limits[13] (PEL), for short-term and career astronauts. The requirements include both cancer and non-cancer risks.

Effects of strong acceleration

A summary of the effects of high g-force on human body is provided by this article[14] (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 the 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[15]. 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. Since the 1970s High-G training has been the subject of research and literature, and training has contributed to extending pilots' G tolerance in both magnitude and duration. Training includes centrifuge, Anti-G Straining Manoeuvres (AGSM), and acceleration physiology.

As they are not expected to be trained to fly on a normal airline, civilian passengers should not need to be specifically trained to fly to orbit, or any further destinations in space.

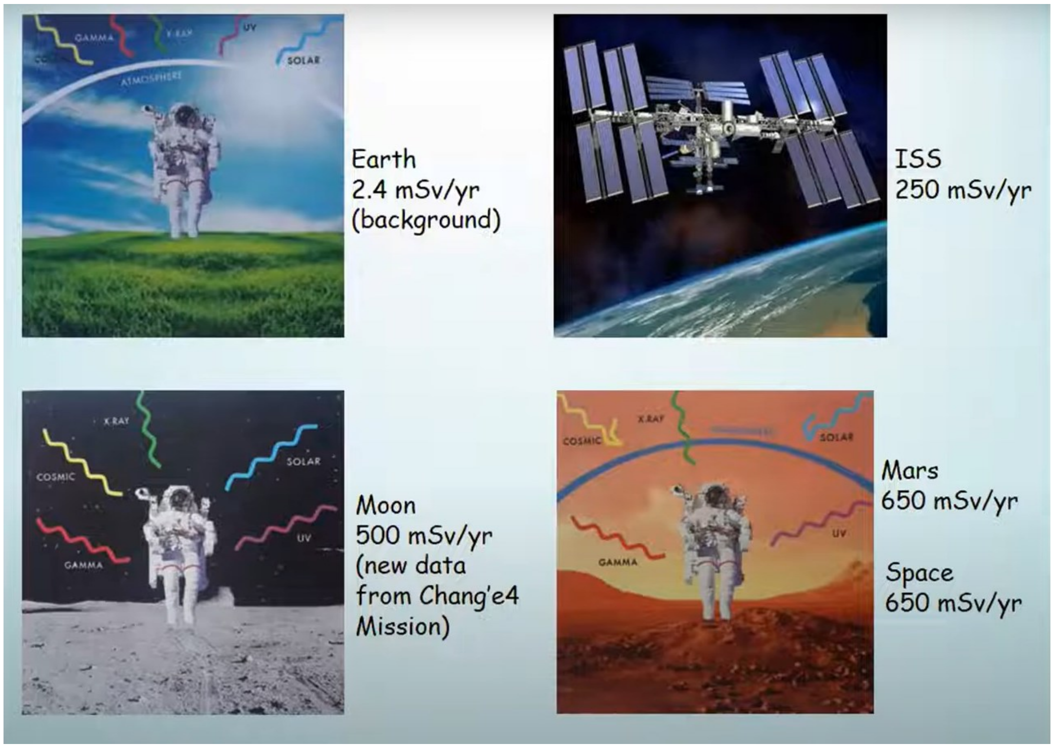

Figure 1. Cosmic radiations received on Earth and in space

Dangers of unsafe re-entry in the atmosphere

The danger of unsafe re-entry in the atmosphere was well illustrated by the disaster of Shuttle Columbia[16], that was disintegrated while re-entering in the atmosphere. The incident caused the death of all seven crew members.

Astronaut Paolo Nespoli -- 60 years old at the time of that mission -- reported the very hard and fatiguing conditions he had to bear re-entering on a Soyuz capsule from the "VITA" mission on ISS (2017).

Trained astronauts so far faced very unsafe and uncomfortable re-entry conditions: nothing prevent them to have better conditions in the future. Though they are military, not granted by civil rights, they are human beings. They are heroes, experimenting life in space for the benefit of humanity, however at a certain extent of the history, keeping on experimenting would be inhuman, since astronauts are our kids, and nothing prevents them to be more protected, now that we could develop means to protect them. Civilian passengers, of course, shall be protected by law, not only for ethical reasons.

Effects of green-less space habitats

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 vegetal life is 97% of the total life. Beyond the obvious consideration that vegetal 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 in living mainly in urban environment without green, would suggest[17 18].

EuroMoonMars[19] is an ILEWG[20] programme following up ICEUM declarations as a collaboration between ILEWG, space agencies, academia, universities and research institutions and industries. The ILEWG EuroMoonMars programme includes research activities for data analysis, instruments tests and development, field tests in MoonMars analogue, pilot projects, training and hands-on workshops, and outreach activities. EuroMoonMars includes a programme of grants for Young Professional Researchers. EuroMoonMars field campaigns have been organised in specific locations of technical, scientific and exploration interest. Field tests have been conducted since 2008 in ESTEC, EAC, at Utah MDRS station[21], Eifel volcanic region, Rio Tinto, Iceland, La Reunion, LunAres and AATC bases in Poland, HI-SEAS base in Hawaii, AATC Poland. These were organised by ILEWG in partnership with ESTEC, VU

Amsterdam, Leiden, NASA Ames, JSC & KSC, GWU George Washington, ISU Intl Space University, Supaero, Ecole de l'Air, IMA International MoonBase Alliance[22], IPSA Toulouse-Paris, AATC Analogue Astronaut Training Center[23], EMMATA Euro MoonMars Astronautics Training Academy[24], and recently with SRI[25].

Observing the experience and learning of space analog stations, Habitat Marte[26], it is possible to see some reasons for plants aboard:

1. Evaluates air quality;
2. Brings nature to space habitat = psychological well-being = less-stress + more health and well-being;
3. Possibility of vegetables production bringing practicality and easiness to prepare fresh meal. Pick and eat concept;
4. Helpful to meditation.

One of the challenges related to present plants aboard in real space station, as International Space Station-ISS, and also analog habitats, are the care about them.

In Space analog station Habitat Marte, based in Brazil, a set of protocols to keep the plants live and other routines under development and improvement was developed:

1. Cultivating and management seeds in seeder;
2. Transferring to aquaponics systems;
3. Follow up and maintenance;
4. Harvesting. The importance related to operate plants in analog stations is identify learnings about how to cultivate plants in space and predicts possible threats and necessary solutions.

If we are considering large areas to cultivate food with more reliability to supply vegetables to prepare meals to an entire crew, will be requested more investment in automation and Artificial Intelligence applied to Image Learning to identify possible actions to keep the plants green and healthy.

It is therefore urgent to boost experimentation of artificial green ecosystems in closed environments, in view of the incoming implementation of first Moon Villages and first outposts on Mars.

THE CHALLENGES WE SHALL OVERCOME, TO KICK-OFF CIVILIAN SPACE DEVELOPMENT

The concept of expansion vs. exploration

Expansion into space may turn out to be difficult. But, do we really have other choices? No, we don't. Any possible alternative includes the possibility of a horrible holocaust, very much worse than facing the problems of developing good living conditions in space. Therefore, our real priority is to develop other models of space settlement that allow for optimal human habitation. Artificial gravity is key, and so is protection against cosmic radiation. But these are not the only challenges we should tackle. If we want the average person, without astronautic training, to be able to travel to and from orbit, we also need vehicles as comfortable as normal airliners, with horizontal take-off and landing, low acceleration, and safe reentry into the atmosphere.

Last, but not least, for the sake of our physical and mental health, we also need a green environment in space habitats: flowers, trees, grass, flowing waters and, yes, animals with us.

Summarizing, what we need is a substantial advance in a series of enabling technologies for civilian space development.

For example:

Passenger Transportation Systems:

- low cost, fully reusable
- comfortable
- low acceleration, in both directions
- safe reentry into the atmosphere
- horizontal take-off and landing
- protection from solar & cosmic radiation

Space Habitats:

- protection from solar & cosmic radiation
- artificial gravity
- green environment onboard
- recycling and sustainability

A progressive research strategy, following the health requirements growth

All of the above was conceived as the result of the humanist philosophic setup[27] of the Space Renaissance International association. When developing our concepts, we always start from humans: their rights, their health, their life, and their hopes for a better future[28]. We work to allow people's lives to become better, not worse! There is no doubt that traveling and living in space like astronauts would be quite a poor life. An astronautic experience could be exciting, of course, if it is for a short duration. That's the point where space tourism comes in.

Space tourism is an intermediate stage, between astronautic space exploration and resident space citizenship. Space tourists will stay short periods in space, perhaps a week, or at most a month. Therefore their physiology will not be dramatically endangered by low gravity, though cosmic radiation could be an issue even for short periods. However, when flying with vehicles conceived for astronauts, tourists will need to be trained, in order to tolerate 4–5 G acceleration, vertical launch vibrations, and the hard onboard conditions. Elder people couldn't go, just to mention one important limitation, considering that retired people are the most keen to travel for tourism.

Figure 2 shows the progressive mission requirements for a transition from space exploration to space settlement. Also see the discussion of this concept in a 2020 article for US and International Mensa Global Risk SIG[29].

Such a progressive change in the mission requirements – yet the term "mission" as well will have to be abandoned, since we don't use it when we travel, for instance, by airplane -- suggests a progressive strategy, to model the scientific and technology research to be developed, to accompany the transition. It will be not only necessary, but mandatory, also from the legal point of view: when Virgin Galactic and Blue Origin will start to transport civilians into space, they will be legally bound to assure the proper rights to their passengers. Protection of life and health are primary criteria.

requirements / flight levels		low cost	low acceleration	safe re-enter in atmosphere	comfortable flight	cosmic radiation protection	artificial gravity	green emvironment
space exploration	short missions	LR	NR	MR	LR	LR	NN	NR
	Moon	LR	NR	MR	LR	LR	NN	LR
	Mars	LR	NR	LR	MR	HR	MR	HR
	long missions	LR	NR	LR	MR	HR	MR	MR
space tourism	sub-orbital tourism	HR	HR	NN	HR	LR	NN	NN
	sub-orbital transport	HR	HR	NN	HR	LR	NN	NN
	orbital tourism	HR	HR	HR	HR	HR	MR	MR
	lunar tourism	HR	HR	HR	HR	HR	NN	MR
space settlement	working in space	XR	XR	XR	XR	XR	XR	XR
	living in space	XR	XR	XR	XR	XR	XR	XR

LEGENDA: XR mandatory
HR highly required
MR medium required
LR low required
NR not required
NN not needed

Figure 2. Space Transport Vehicles and Space Habitats Requirements Evolution

A consideration on the cost of space flight is due. Space exploration was made by public money, so far, thus it did not need to be low cost. Or, better, in an ideal world it should had been low cost, in the interest of taxpayers. However, as the agencies' market was reserved to the big traditional aerospace lobbies, the costs were artificially kept high: spendable rockets were integrated part of such paradigm, perfectly working both as a very lucrative cash-cow, and a high barrier to prevent new competitors to enter the market. The reducing cost became a meaningful parameter only after ScaledComposites[30] won the X-Prize in 2004[31], flying at suborbital altitude with a 30 $M budget, and demonstrating that cheap access to space was feasible[32].

Yet, the scope of this paper is not to add more scientific data and motivations to the requirements of the research from now on. Our purpose is more addressed to improve the policy (i.e. priority) of the research, recommending a higher and better attention to human needs and requirements. In short, we are suggesting a humanist philosophical approach to the scientific and technology development: humanity needs to expand and settle into space as soon as possible, humanity needs to do it in the safest and most healthy mode, avoiding as much as possible to loss lives and to ruin the health of many people. Having too many dead heroes deprives the world of potentially useful intelligence. This consideration is particularly true, thinking that often the most intelligent humans are also the most generous ones, making their life available for exploration and science.

The development of the civilian space settlement, as it is actually happening, offers a kind of progression, as far as requirements are concerned. We can consider three main levels of space flight, characterized by a growing importance of safety requirements:

1. **Space exploration**, where the explorers are military trained astronauts, the mission duration so far did not exceed 1 year, the maximum distance from Earth was the Moon distance.
2. **Space tourism**, where the tourists are civilians, the duration will be shorter than exploration missions – typically hours in suborbital, days or weeks in orbit and on the Moon --, the maximum distance will be the Moon distance.
3. **Space settlement**, where the space citizen will be civilians, the staying duration will be accountable in months, years, or permanent, the maximum distance from Earth will extend to Mars and beyond.

What will help us defining the mission requirements of each step? A number of conditions, e.g.:

- Infrastructures inside the Van Allen Belt will require lower severe protection against cosmic radiations[33].
- Suborbital passengers transportation vehicles should complain with low acceleration, safe re-enter and a mild protection against cosmic radiations.
- Orbital passengers transportation vehicles should complain with low acceleration, safe re-enter and a better protection against cosmic radiations.
- Lunar passengers transportation vehicles and infrastructures should complain with a higher protection against cosmic radiations.
- Any infrastructure, from LEO to Moon orbit and Lagrange Points should be endowed by artificial gravity[34]. *"Any space station design that does not include rotation, is almost a waste of time"*, said John Blincow[35], the founder of the Gateway Foundation[36].
- And so on.

Of course, incoming Mars exploration missions will oblige to take some civilian requirements with more attention and priority[37]. Namely, spacecrafts cannot avoid having proper protection against radiations and some kind of artificial gravity, by rotation. If implemented, it will be the first experimentation with artificial gravity in space. If nothing else, a Mars mission is worth to be supported.

THE EXPANSE AS SPHERICAL PROGRESSIVE GROWING CONCEPT

Summarizing, expanding civilization into space is a thing quite different from exploration. Expansion should logically come after a good period of exploration: we had 60 years of space exploration, so far. We are sending automated probes to the orbits of Jupiter, Uranus and Neptune, and even out of the solar system. Of course there is still very much to be explored in the inner solar system, on Mars, on the Moon, on Asteroids. We should not stop exploring space. Yet, we definitely and desperately need to start expanding into outer space[38].

Expansion is a progressive advance in the cosmic realm, starting on the ground, colonizing Earth orbit, from LEO to GEO, the Moon, the Near Earth Asteroids, building infrastructures in the whole geo-lunar system. Such a process should be designed as a steps procedure: each step need proper scientific and technological advances[39].

Figure 3 represents a possible model of global expansion of our world.

The expansion paradigm requires a quite new methodology to be conceived and adopted, including a long term roadmap, defining for each step the required technologies, the scientific milestones to be reached, the prototypes, the experiments, the tenders. A great collaboration is necessary, by all the Governments, agencies, research institutes of Planet Earth, in order to create the proper program management of the greatest human enterprise of all times in history.

Yet, we would like to reassure the supporters of exploration: exploration will always be necessary, expansion will never extinct exploration. Opposite, expansion will require more advanced exploration.

Unfortunately, exploration can exist for long time without expansion. But we have to raise a warning here: should the civilian space development not kick-off before 2030, the global economy will fall in an endemic crisis, and likely political leaders – more and more oriented by financial concerns – will decide that we don't have enough money to continue space exploration. Therefore we would suggest exploration supporters to stop opposing space settlement: space settlement is in their interest too, since only in a realm of big economic growth, space exploration will be sustainable.

Exploration is a military concept, while expansion is a civilian one, though it does not prevent military in space. Exploration does not require industrialization nor infrastructure construction, while expansion requires industrialization and infrastructure construction. Furthermore, as the civilian space development will grow, more and more human presence will be required, and this is the true key condition: only moving growing numbers of people to become space citizen our civilization can really grow, both in size and culture. In fact, while exploration can be made by robots, endowed by artificial intelligence, expansion requires a coherent enlargement of human settlement, from Earth to near space, and progressively beyond.

Last, but not least, exploration is made by public money, and tends to keep the launch costs high. Expansion requires private enterprises, and stimulates human ingenuity to invent suitable technologies and methodologies at progressively lower cost, to step to the stars.

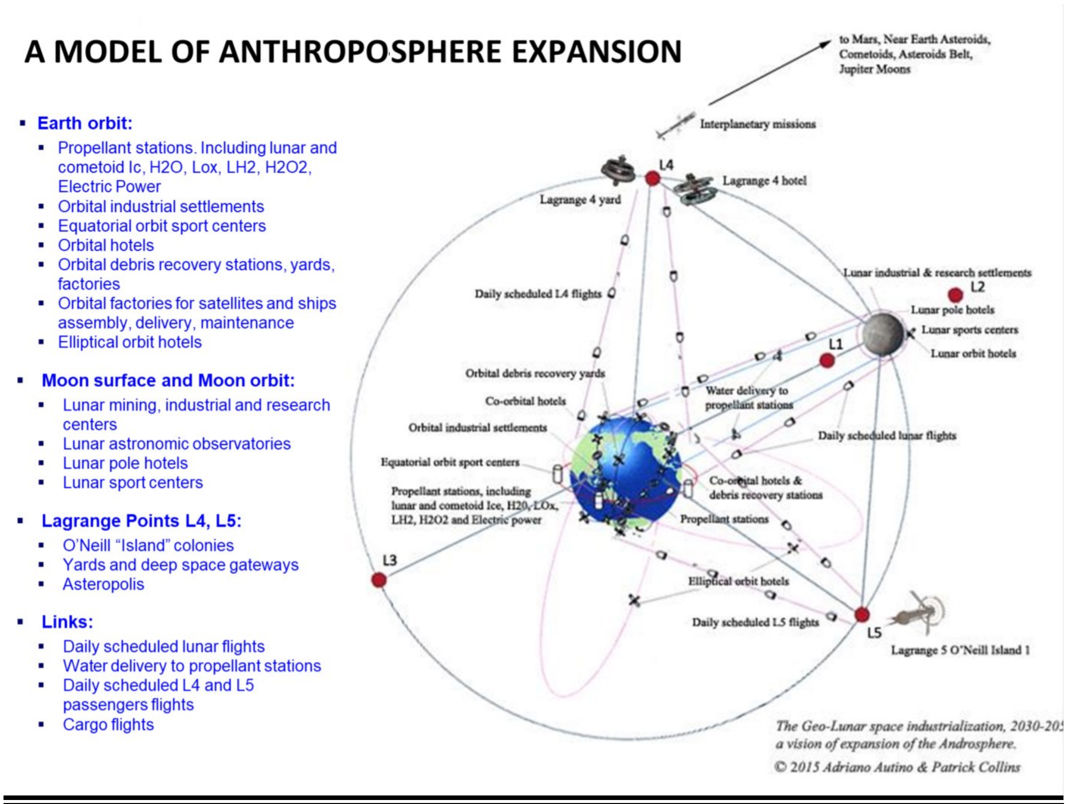

Figure 3. A model of Anthroposphere Expansion

<u>Acronyms</u>

acronym	description
AATC	Analogue Astronaut Training Center,
AGSM	Anti-G Straining Manoeuvres
DNA	DeoxyriboNucleic Acid
EAC	European Astronaut Centre
EMMATA	Euro-Moon-Mars Astronautics Training Academy
ESTEC	European Space Research and Technology Centre
GEO	Geostationary Earth Orbit
G-LOC	G-induced Loss Of Consciousness
GWU	George Washington University
HI-SEAS	Hawai'i Space Exploration Analog and Simulation
ICEUM	International Conference on Exploration and Utilization of the Moon
ILEWG	International Lunar Exploration Working Group
IMA	International MoonBase Alliance,
IPSA	Institut Polytechnique des Sciences Avancées
ISS	International Space Station
ISU	Intl Space University,

JSC	Johnson Space Center
KSC	Kennedy Space Center
LEO	Low Earth Orbit
MDRS	Mars Desert Research Station
MMAARS	Mars-Moon Astronautics Academy & Research Science
NASA	National Aeronautic and Space Administration
SGAC	Space Generation Advisory Council
SRI	Space Renaissance International
SUPAERO	Institute Superior de l'Aeronautique et de l'Espace
USA	United States of America
VU	Vrije Universiteit (Amsterdam, Leiden)

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