69th International Astronautical Congress (IAC), Bremen, Germany, 1-5 October 2018.

IAC-18,D3,1,10,x46284

Technology-driven challenges in the governance of future space colonies

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Abstract

Recent plans for human missions to the Moon and Mars have brought the discussion of space colonization into the spotlight of the space community. Many topics remain to be clarified regarding space colonization. These range from legal, ethical and planetary protection concerns to how the colonies will be governed. Answers to these questions will vary broadly even between the two most probable off-Earth settlements in the near future (the Moon and Mars) mainly due to differences in environment and location. Different solutions will certainly bring different governance challenges according to their dependence on Earth. This paper discusses the different possibilities for the governance of future space settlements brought about by selecting a different colonial technological complex; the interdependent technologies running the colony. Future space colonies will be able to manufacture some of their tools with in-situ resources and additive manufacturing from the beginning, but some vital resources and components might only be available from Earth. This imbalance will influence the extent of the colony's independence as it grows. The whole chosen technological complex will influence the colony's development and its capability to thrive. We presume that greater reliance on its own ingenuity will bring the colony more freedom and independence, even if such development is not in the interest of the authority on Earth. Based on our knowledge of history, we can assume that reliance on technology for survival will temper the likelihood of governance shifts in critical policies related to life support systems in the early stages of space colonization. Technological innovation will likewise probably remain under centralized governance for decades. However, the possibility of political shifts within growing colonies cannot be dismissed because the current design of future survival technologies will certainly have unintended political implications. We aim to understand and analyze the various impacts of current and future technological complexes of the off-Earth colonies on their governance. We present different operational periods in the development of an off-Earth colony, based on the societal functions allowed by the required technologies. We also draw on historical parallels by studying the economic, social, and political shifts that have led colonies to seek independence. We focus on the enabling periods in which new technology becomes available to the colony and allows new political structures to arise and provide a potential evolution for the governance of the colony, from initial outpost to self-sustained settlement.

Keywords: (maximum 6 keywords)

1. Introduction

We are planning to send humans to live on other planets. Yet, we have not discussed in detail how these people will govern their colonies regardless of the literature addressing this problem for decades and some more focused recent thoughtful contributions [8,13].

Five to ten astronauts selected according to their expertise and sent by their national or any capable space agency are a mission crew consisting of a group of people. Sending 100 astronauts in one SpaceX's BFR or several hundred in several BFRs is a society.

All current analog missions such as MDR are studying crews tasked to deliver particular mission objectives but do not focus on the problem that bigger groups of people sent to live on other planets will form societies and those have significantly different social dynamics than crews.

We have built various political institutions on Earth but still the governance of complex issues inherently involving science including climate change seems to be a gargantuan task. However, blurring of specific knowledge on a populated mission on another planet directly threatening its own survival is inevitable if the decision making will not be delivered by the experts dedicated to the task but by people empowered through elections. The other option is a direct rule over the colony by the mission leader or by the space agency from Earth possessing required expertise and thus possessing proper epistemic authority necessary for survival, however, this option would be soon or later perceived as a protectorate through authoritarian power regardless the need of exercised expertise.

This is why a bigger mission is not about the crew but society. Either one does not ensure that the proper decision will be made. People make bad decisions or can become insane in harsh environments no matter whether they are experts or elected.

Centralized governance of a mission make sense in small crews, but it is definitely not an option in a mission consisting of hundreds or even thousands of members. Opinion leaders, rebels, grieved individuals, addiction-prone citizens will be inevitably part of any permanent mission to live on other planets and not for bad. Imagine a city on Mars consisting of one thousand precisely selected people without any negative personal characteristic. Such a utopia might turn to even more dystopic future than we think. Thus, precise selection of people is not an answer, especially if the first thousands of colonists will prevalently pay for their adventure.

In a practical perspective, a thousand-size mission will have hundreds of engineers. However, some engineers might be willing to see progress in their careers, learn something more, thus the rotation of them will happen. Then, some engineers will be more or less specialized. The latter will have a wider overall perspective on the engineering solutions and system dependencies and those will have closer relations to mission leaders on Earth as they will deliver a better picture of the mission status. This is only one example of how an engineer will gain political power.

Politically empowered engineers or scientists may fade away with the growing colony. However, at the same time specific knowledge may in contrary develop specific technological solutions or open new methods to extract materials or produce critical substances such as oxygen in a novel way concentrating critical power into hands of limited people. Governing colony by those who in particular time possess the knowledge needed for its survival and flourishing would not only move the authority very often but would lead to the power disputes or even deliberate sabotages between competing power groups.

However, is it the desirable end that an engineer leads a permanent mission? Who should have political authority and from what the political authority should be deduced? Is it expertise, elections or loyalty?

Besides the problem of authority, the common debate how the space governance should proceed is divided into four branches we follow in our paper:

I) Governance by science is a common and well working approach in missions of small groups or crews where different expert roles are applied to various crew members.
II) Libertarians argue that because governments are not willing to invest in massive space missions, companies might and if they invest enough money to make revenue from space mining the space capitalism may prove being viable. Libertarians building their businesses are convinced that the will to invest should lead space exploration because it does not need to overcome plentiful regulations.
III) In contrast to the free market effect, national exceptionalists see their nations leading humanity to the space final frontier usually in state capitalist policy model.
IV) Communitarians argue that the libertarian approach or national exceptionalism driven free-market capitalism would lead to corporations driven and owned dystopic tyranny. Approaches driven by exceptionalism, whether national or corporate, creates an environment where international or inter-corporate war is inevitable. Moreover, the libertarian model would lead into corporate wars over resources due to the lack of publicly funded law enforcement. Thus communitarians are proposing a cosmopolitan perspective of human future in space.

To be clear, all treaties constructing the core of current space law have been drafted in cosmopolitan ideas in mind, until now, until the beginning of the space mining age.

The question who should have the power over life-supporting systems in a city of thousands of people on Mars, whether a mission commander, a government, an engineer or artificial intelligence, is not easy to answer. Everybody can become mad or act against common interest. Our aim is to show that we can merge those governance models representing various tensions and inclinations of various entities, provide them with a substance that drives each motivation but direct the energy towards a common objective: stable security stimulating human flourishing [5] in space.

2. Three approaches to space governance

2.1. Governance by science

As the title hints, the first governance model focuses on scientific expertise. It is unthinkable to reach the space frontier without scientific rigor and on science-based engineering capacity. Space exploration is inherently bounded to specific expertise without which no-one can leave the colony and survive. Moreover, the life dependency on science and technology is not a one-way dependency. It is naturally necessary to design functioning life support systems to survive where deliberative discussions do not make sense, but rather a peer-review approach and linear knowledge scaling is needed. Systems must work, and better reliability is a quantifiable category. This is the principle scientists and engineers generally tend to put above the inevitable political ideas – to our deep conviction – are inherently incorporated in system designs. Politics and technology are mutually constituted.

Polanyi in his well-cited piece Republic of Science [17] argued that scientists are perfectly organized because otherwise they would not be able to reach new discoveries and build a massive cloud of knowledge. This advantage gives them the authority to govern complex issues because the authority is dynamic as the success of scientific discovery moves from one scientist to another. Polanyi perceives scientists as those who lead us toward intellectual self-improvement, unveil hidden reality, to explore new frontiers for the sake of intellectual satisfaction. His argumentation is very common for technological determinists of the late 50s in the 20th century who saw technology and science as the tool for society enlightenments, following Vannevar Bush report to the president accentuating national funding to science and technology as the driver to keep post-war superiority of USA [6].

This perception is also visible in the general engineering discourse within the science community as the current human spaceflight faced only short or crew-commanded missions. The idea of governance by scientific communities is well developed e.g. in Kim Stanley Robinson's novel trilogy Mars [19–21] that follows Polanyi ideas. However, as we are introducing the argument that bigger missions consists of society and not of crew, a mere governance by scientific experts is not desirable because it will be prone to develop technocratic despotic political systems.

Beside this commonly known problem, technology itself cannot be developed without politics. The well-followed argument made by Winner [28] says that each technology design carries a political message. Winner made his argument e.g. on US highway built to Long Island, which was first designed with low bridges to save money, however, low bridges caused the inability for buses to use the highway, thus preventing people not owning cars to reach Long Island. In fact, even science depends on its context and practices, which can differ according to power relations, personal bias and overall environment [22].

A comparable argument was made by Charles Cockell that prison guards will be directly empowered by the technological characteristic of space prisons, e.g. if they are given with oxygen regulation valves to prevent prisoners to escape or a space lock designed in each cell as a psychological pressure on the prisoners [9].

These examples show that regardless of practicality delivered by skillful engineers, technology will be used to deliver political ideas. The problem arises in environments where people directly depend on technology such as in space or on open seas where the scenario of strict control regime is likely if not inevitable.

In this perspective, technological designs are made in accordance of particular cultural values and reproduce them. Chinese, US and EU missions can have compatible airlocks but procedures in case of emergency or how to use particular systems might differ. However, the design apparently cannot follow mere practical objectives because it risks empowering tyrants. It should rather have backdoors to prevent tyrannical behavior of whoever in power becoming insane. Despite the efforts of pilotless planes to be introduced in the next decade, planes still do not have backdoors to be controlled from the ground to rule out possible cyber hijack. Hence, interplanetary spaceships and especially colonies on another planet will probably not have such backdoors as well. Moreover, the contextual knowledge of somebody living in a colony and communication delay will trump the argument of remote control. There are clear downsides of scientific governance.

2.2. Libertarian driven space capitalism

A lot of people in space community believe that only free-market capitalism in the libertarian fashion is able to open the space for human flourishing. Based on the general argument of the libertarian movement coined by people such as John Perry Barlow emerging around the growing internet who wrote the manifesto "A Declaration of the Independence of Cyberspace " [2], we can observe comparable thoughts in minds of current leaders of space exploration. Space Frontier Foundation openly bases its activities on a belief into free-market capitalism as the only viable way towards space colonization. Founder of SpaceX Elon Musk visibly falls into this category despite his deep personal moral principle that all of his efforts are dedicated to safe humanity and despite the fact that he has been heavily reliant and dependent on subsidies and government contracts for its business existence. For both cyber and space libertarians, technology is a critical enabler of personal liberties.

The core of the current discussion related to space mining includes a question "what is the benefit to mankind" as stipulated in the Outer Space Treaty. For libertarians, e.g. through the words of general counsel of Deep Space Industries Sagi Kfir, the benefit is just the fact that humanity can buy their resources (his words on UN COPUOS meeting in 2018). For cosmopolitans, the benefit would be the equal redistribution of wealth, maybe even through global taxation as fees for space mining were openly discussed on the UN COPUOS 2018.

The whole discussion of what constitutes the benefit of mankind can swing to the discussion of how the colonies or any other space operations should be governed to make them thrive but let all humans equally participate on the space mining profits. Above all, Sagi Kfir tacitly mentioned that Deep Space Industries finally wants to mine asteroids and if the UN took action to make people in Africa less poor, he would support it.

Thus, the libertarian vision of free-market space capitalism is a proper driver for investors to move

forward but ensuring the benefit for all humankind will have to complement this design through some redistributive mechanism. It would be better to make this dilemma clear and discuss proper solutions beyond the traditional framework of taxes now, than to face the curbing of space tax heavens created by libertarians for their own businesses later.

Besides this debate over the balance between libertarian business and global equality, a strong driver in scientific discoveries or even space exploration has been the power philanthropes. Telescopes have been historically funded by philanthropes and are significantly supported until today [27], however, projects like Breakthrough Initiatives show that it is private equity that is not scared funding insanely risky projects with possible tremendous scientific discoveries if successful. Moreover, Robert Zubrin argues that the harsh and deadly environment maybe with single-way tickets for colonists would foment an incredible acumen of innovation and technological progress. For Zubrin, the adventure is well idealistic in developing a new society because being out there in a remote area, in a cultural distance and without cops representing obsolete and not functioning institutions being too close would open new possibilities to the local society to flourish [29].

The libertarian regime ultimately does empower businesses interested in profit. The pure focus on profit can be negative but also positive. Their perception of science is solely focused on making revenue and politicized science would harm their chance for success. This profit-oriented pragmatic approach has to be balanced however.

2.3. National exceptionalism

Whether national exceptionalism on Earth driven by reaching the final frontiers [4] or newly emerged national exceptionalism on Mars as we know it from the series The Expanse, both scenarios are visibly prone to conflict as the "others" are less exceptional than those who do exceptional things. This is a well-studied topic since the WWII but as we can observe on current global political affairs a problem that tends to recursively come back.

National exceptionalism can and did open the final frontier. The Apollo program proved the world that the will to do exceptional things is unstoppable and made in the name of humanity according to the Neil Armstrong's quote. Moreover, the Apollo program stipulated the legitimacy of the liberal democracy and free-market capitalism and to some extent contributed to the fall of the Iron Curtain in Europe. However, national exceptionalism is prone to impose a regime emanating from one national experience or empower their national institutions that are well developed in a particular state arguing that institutions with global impact are less developed, thus less justifiable, which was the recent argument by John Bolton criticizing International Criminal Court. Nevertheless, putting selective national bodies above global in space exploration would cause ignoring their authority by people who think that the jurisdiction does not apply to them which may eventually lead to war in space. Especially in cases, in which one criticizes global body being incapable to properly investigate cases of human rights abuses and at the same time being scared of its existence [7].

Exceptionalism ascribed to an exceptional group of explorers consisting of super educated people building technological and industrial complexes in space can contribute to their identity formation, which can be counterproductive for the sake of global – or solar system – security by the division of identity politics.

Robert Zubrin can be as well included in this category as he argues that the "progressive humanistic culture" is fading because we have closed the final frontier and decided not to go. Thus, those willing to go should be given the opportunity. According to Zubrin, those who go and explore the first another planet finding water and proving capability to stay would be celebrated for centuries.

2.4. Cosmopolitanism

Cosmopolitanism is a broad theoretical approach that has been influencing human thinking for thousands of years. According to the cosmopolitan thought, all human beings belong to one community that shares its own normative foundation – moral principles. This is why all space-related treaties have been based on the cosmopolitan thought as it would be hard even for national exceptionalist to make the point that something out there belongs to them according to their national identity and exclude others from it.

Cosmopolitan advocates argue for strong redistributive obligations, against national identities causing inter-national tensions and ineffectiveness in global governance as those identities are socially constructed, based on self-interest and thus they are not objectively attributable, for common heritage, shared future and global responsibility.

Beardsworth approached cosmopolitan study by giving it a spectrum [3]. He divides cosmopolitanism according to what the core cosmopolitan thought intends to address: cultural cosmopolitanism studying flattening of cultural differences and identities, moral cosmopolitanism studies the basis of universal moral principles, normative cosmopolitanism how these principles transformed into rules people unknowingly follow, institutional cosmopolitanism how these norms form institutions, legal cosmopolitanism how these institutions draft treaties and political cosmopolitanism how treaties keep tyrants out and put the global equality in while forming new political structures.

Most importantly, political cosmopolitanism examines possible political systems that are utmost

democratic, granting every citizen an equal voice over their own fate, which is impossible on the basis of nation-states with different populations and political or economic strength.

Based on the core basis of cosmopolitanism that humans are equal, political cosmopolitans have argued that their first and foremost objective is to

I) promote a cosmopolitan disposition – a global perspective and tie it to a theory and practice,
II) lower the nationalist temper by curtailing the nationalistic hypocrisy of nation-states,
III) promote and show that democracy on a global level is the only justifiable democratic political system – the true rule of the people [3].

The question would be here, how remote colonies in space massively funded by public or private entities on Earth and being extremely dependent on Earth supplies, or unable to become fully self-sufficient, can remain free while being part of a bigger political structure that does not cling to a tyrannical rule or which does not let the colonist to decide over everything as possible accidental vote of delusional political leader would cause collapse of the colony?

3. Problems and goals of future human colonies

One would criticize that the term "colonization" itself should not be used and that "settlements" is a more proper term, however, we do follow Outer Space Treaty here as we use the term "colonization" in a cosmopolitan meaning because as we both believe there is no other than cosmopolitan governance in space possible. Living on other planets is about colonization by humankind, settlements are part of it. Colonization of space will stimulate human flourishing, settlements will lead to nations-like political structures that are prone to conflict.

As we already stated, we make difference between space mission delivering objectives in project-like timeframe through appointed crew members and permanent colonization.

The colonies themselves will have various natural goals:

I) security based on life support systems reliability,
II) security based on rule of law,
III) colony flourishing,
IV) political stability
V) general sustainability.

Moreover, thinking about space colonization opens various new problems:

I) source of political power and authority especially over significantly remote places fully dependent on Earth,
II) relations between colonies (political sub-ordination, private property relations, mutual rights over critical resources),
III) role of experts and their epistemic authority given their specific role on the colonization,
IV) new forms of legitimacy as a building block of future political structures.

We do not have an idealistic vision of a smooth cosmopolitan space colonization. Each colony will be established for different purposes and driven by different motivations. Some colonies may be established as a part of ambitious national space program focusing on scientific objectives, others will be visibly established by wealthy individuals acting according to different motives (humankind survival, massive messy industrialization, mining of rare materials disrupting Earth markets etc.). Some colonies might be set up to as a permanent planetary defense of Earth. Some, as we proposed recently, may be multipurpose permanent bases set up as planetary defense of Earth with philanthrope-backed interstellar travel laser acceleration system [23]. In this perspective, the cosmopolitan approach to colonization emanating from the Outer Space Treaty is more than desirable because the disruptive effects back on Earth or practicing authoritarian rule over space colonies seem to be possible scenarios.

Another problem we identify is a mere impossibility of a balanced position between colonies or between colonies and Earth in the neoliberal meaning. Idea that colonies will be thriving based on free market economy is visibly impossible and looks like utopia. Colonies will be designed from the scratch to do particular objectives that make sense in relation to the characteristics of the celestial body (methan on Titan, water on comets, metals in asteroid belt etc.) Therefore, colonies will not be significantly dependent only on Earth but interdependent between each other. Notion that each colony should be independently profitable according to the market price of their commodity is non-sense as other colonies might be fully dependent on e.g. delivered oxygen. Later they may master extracting some rare materials useful across the Solar System or back on Earth but will not be able to produce oxygen. Such a colony cannot be left to buy oxygen on the market as any market disruption would cause direct death to the colonists. Libertarian vision of solar system governance would be visibly dangerous while the libertarian approach at the beginning would help to set up various colonies.

Moreover, while the stable demand of the material may help the colony to thrive, high demand will visibly provoke independence motions because of wealth it can produce, and low demand will lead to the colony collapse. In other words, the floating of demand which is inevitable on open markets will lead to revolution and political instability. An idea that any colony on any

celestial object in the Solar System can ever become self-sufficient is utopian and does not have a logical sense as colonies will be established and thrive according to special outcomes it can bring to humanity.

Why would any colony build a factory to produce something that can be easily and reliably supplied from Earth? For the sake of independence? We argue that this will not happen as any authority overseeing the colony will not be willing to hand over the power but also because colonies will have other demanding tasks to do.

Therefore, any analogy to the Boston Tea Party will not happen as the idea of self-sufficient colony is unlikely to fulfil due to the specific physical characteristics of other celestial bodies, interconnected nature of space threats (neither planet Earth can independently thrive without reliance on cosmic activities) and extreme mutual dependency on life-support systems, technology and knowledge. Colonies in other Solar Systems will be a different question due to the distance if we do not master the wormhole transport but that is a case for another analysis.

We think that cosmopolitan governance is inevitable because both scenarios (full independence and full dependence or independent democracies and dependent protectorates) cannot lead to political stability. Even colonial protectorates will occasionally cost Earth some money or the colony will produce money to the authority on Earth. Neither status leads to a desirable end as the economic collapse would not be acceptable to the Earth authority and explosion of wealth will trigger movement to independence.

Various colonies established for different purposes throughout the Solar System cannot become independent and then try to avoid escalating conflict by signing treaties. The sensitivity of being fully dependent on Earth supplies or utopia that colony on Titan can be fully independent and make money by selling methane and thus be fully self-sufficient because it will have money to buy necessary supplies such as oxygen shows that historical analogies with e.g. British colonies would not work. Leaving colony on another planet being dependent on its own capability to buy oxygen on a fluctuating market is visibly immoral.

Cosmopolitan perspective effectively erases both perceptions because in cosmopolitan Solar System governance there is no self-sufficiency, independence or dependency but only policy how to make humanity flourish.

The broader perspective, in this case not a planetary but solar system perspective, will be necessary – that the colonies have been established to make humankind flourish. Cosmopolitan theory can be a good basis for thinking over possible political structures governing the Solar System.

4. Governance principles of space settlements

The topic of organizing space colonies is hard to narrow down to one grand narrative. We can divide the different types by their purpose and goals, whether they will only serve as a mining outpost, scientific camp or a massive settlement making humans a true multi-planetary species. Firstly, this part discusses different political implications of these characteristics before moving to the debate of their examples on the Moon and Mars.

The governance status of new colonies will largely depend on the amount of their dependency on their mother entity. The possession and operation of resources essential for maintaining life will rise to the forefront of factors shaping the functioning model of the colony. This can mean either technologies or material resources. With the abundance of natural resources in our solar system from water to sunlight, the deciding variable will be rather the possession of technologies capable of harvesting necessary materials ensuring human flourishing. But as stated above, any colony is unlikely to grow completely independent or to develop all necessary technologies to support itself. Even the host planet, planet Earth, will not become independent of other celestial settlements, whether it is for a supply of different natural resources or functions such as planetary defense, communication or travel.

Any rational plan for the development of an off-Earth colony will aim at increasing the overall contribution of the colony. This can have different forms and should not be perceived as a simple calculation between export and import. Trade deficits are not a negative phenomenon, they are a logical side effect of the division of labor. A Moon colony built for planetary defense will aim to use local resources such as water, helium or regolith for shielding, fuel or power. But its added value will be the defense of Earth, not a tradable good to be sent back to Earth in exchange for nutrition, machinery, tools or any sophisticated technology. A base on Ceres serving as a refueling point for interstellar exploration would not be maintained with a goal of immediate economic contribution.

Market forces, economic models and rate-of-return calculations will not provide the main arguments, even though the ultimate wealth, knowledge and benefit to humankind will be unmeasurably paramount. Similarly, Portuguese, Venetian, Genoese, English kings all rejected Columbus' voyage as economically not prospective. Even colonies dedicated to mining would continue to be dependent on technology and other resources from other places. What will undoubtedly change through time with new technology, however, is the level and format of mutual dependency that will have implications on the governance model. This change will can be a grave source of instability, should it not be governed properly.

Any off-Earth human colony whose population cannot be counted in single digits, but rather tens of hundreds will require a different design than a pre-set and mission-oriented division of labor, roles and time management of small experimental missions. The minimal viable population calculations for an off-Earth settlement fluctuate around 5,000 [12,18]. Sociological aspects rise in importance for larger groups of people and carry more organizational and governance requirements. In an unforgiving environment of other celestial bodies, any societal model will be evaluated against its effectivity in ensuring survival and basic life-supporting conditions. Therefore, it must be effective in delivering such solutions.

Effectivity is largely depended on authority that can deliver. Authority can be described as legitimated power based on shared understanding what legitimation is [10]. At a space settlement, this legitimacy would first likely come from the acceptance of the authority or governance model by its effectivity in ensuring survival and human flourishing.

In the early stages of colonization, this will largely be dependent on Earth-based entities providing critical technology, finance, human capital and resources for the settlements. Those invested in building up the colony with Earth resources will clearly exert authority over the settlements as indispensable guarantors of life. But as growing knowledge allows for greater use of resources available *in situ* or at nearby celestial objects, the dependency on Earth will lower. As the stakeholders change so will the political relationships.

In the development stage, the question of who can ensure the survivability of a colony is clear. However, as the colony progresses to another stage and becomes a contributing settlement, the question of political rights and decision-making becomes more complex. Deciding such question on territoriality would be irrelevant as geography becomes obsolete in an interconnected space economy. The system of political rights should rather be based on pure functionality and the basic democratic principles, with the former meaning societal stability by delivering and latter guaranteeing that those affected by a decision should have the possibility to influence it. This copies the lines of the input and output legitimacy and the democratic dilemma [11,16].

The legitimacy of a system or authority is based on its effectiveness to deliver for all its members to be accepted by them and thus remain stable. This means some degree of democratic participation must be included to warrant accountability of those taking decisions to avoid neglect and exclusivity. The democratic dilemma uncovered by Robert Dahl [11] describes the tension between effective, centralized decision-making and inclusive citizens' participation. In a similar manner, this dichotomy transforms into the division of two types of authority:

one coming from its legitimacy, or political authority,

one coming from expertise, or epistemic authority. Finding the right balance between the two is already complicated in the contemporary world with a growing disdain for experts and scientific arguments in democratic societies. We should not view them as mutually exclusive.

Complex questions amount regarding the decision-making. Should an independent expert opinion be taken as imperative over the right of self-determination by a colony inhabitant affected by the decision? What principle should decide on the political autonomy of colonizers?

More democracy does not always mean better governance. Governments include many bureaucratic bodies that must maintain its independence and impartiality in the democratic process. These are the expert bodies, governmental research offices or the judiciary, that protects values and serves as a check on the will of the majority, influential power groups. But as Oliviero Angeli points out, the mere fact that someone wants to make the best decision for themselves does not mean they have the necessary knowledge or ability to decide that way [1].

Yet, this can also be a slippery slope that can lead to elitism and most importantly the elimination of accountability and inclusivity. It is not a good principle to leave the decision-making on specific issues only to those who possess a certain degree of expertise while leaving others without a voice in the decision that will impact them. And as technological capabilities and the need for different life-sustaining resources change, so would those who possess the most knowledge about the current challenge of the moment. That would not provide a stable political environment due to the lowered possibility for self-determination. In a situation of changing dependency between different authorities, this could rather lead to a rebellion against a perceived outside authority lacking the legitimacy by delivery or inclusivity.

Addressing this possible split would not only come from the democratic principle, but also of the deliberative principle that avoids simple aggregation of votes to find a majority. While many would argue that shared identity or the so-called *Demos* represent the precondition for democratic decision-making that requires the suppression of the losers' preferences for the benefit of others, Michael Zürn [30] argues it can be achieved rather by a mere commitment to such shared values and principles. If this commitment is made to impartiality, human flourishing and the power of scientific objectivity, it can ease the tensions between scientific authority and democratic participation. However, our current space efforts are nowhere close to this thinking.

It is not technological constraints that prevent humanity to become multi-planetary, it is the constraints of our collective behavior.

5. Moon and Mars Colonies empowered by cosmopolitan principles

5.1. Multipurpose Moon Base

While concepts to set up a base on the Moon have been developed for decades, none have materialized. The plethora of engineering, technological, financial, strategic and legal constraints present a set of obstacles that have put off these efforts. However, the common denominator of them is exclusive, national or market thinking that prevents a global collaborative effort since none single government or entity possesses or is likely to possess the capacities to act alone.

The concepts for a Moon base vary, moving from Earth-assembled to Moon-assembled to Moon-sourced structures, from inflatable, to cylindrical to underground units, from processing regolith or using 3D printing. The settlement will have to deal overcome constructions challenges in a vacuum, shielding from radiation, micrometeorites and extreme temperature fluctuations, maintaining internal air pressurization 6.9 x 104 to 10.3 x 104 Pa (10.0 to 14.9 psi) and sustaining power generation to name a few.

Recently, new commercial or multi-stakeholder initiatives spurred out from the Moon Village Association, the Lunar-COTS or the Evolvable Lunar Architecture marking the shift from strictly public-funded to private-funded format. As new technology unlocks new opportunities in space, additional commercial projects are likely to evolve. But budget limitations, lack of long-term vision, complexity and narrow governmental national outlook that prevents any meaningful and effective global cooperation on such a global effort remain the main obstacles. Their coordination and synchronization beyond the national optic and in line with the all-humankind principle of the international space law regime offer answers to some of these challenges. It is not financial or technological constraints that prevent humanity to become multi-planetary species, it is our limited collective behavior that is caged in national or commercial perceptions.

A joint global effort to establish a Moon base has its economic, practical, legal and political arguments. A permanent presence on the Moon is the first step in establishing our future functioning in space. The exciting sector of asteroid mining serves as a critical stepping stone for utilizing space resources to enable new space activities by lowering the current complete dependency on costly supplies from Earth. And while many new probes and concepts are developed for attaining the riches of attractive platinum-rich achondrite meteorites with a high concentration of rare metals, the main name of the game is water, or more exactly its electrolysis into hydrogen and oxygen.

Besides extracting water on the Moon itself, an industrial scale facility for water's electrolysis, its storage and refueling would likely be firstly developed on our only natural satellite before moving further away from Earth. It would serve as the very first stepping stone for the establishment of the cislunar economy, refueling of spacecraft including those orbiting Earth or set for further space travel. For deep space travel, a Moon base equipped with a square kilometer laser facility of 100GW can send exploration probes at the 20% speed of light as envisaged by the Breakthrough StarShot, a private initiative of billionaire Yuri Milner. A similar structure is also the politically and technologically unique solution for the defense of Earth from asteroids and comets, while the same laser ablation technique is key for the hyperspectral imagining of asteroids composition. All these efforts are heavily interlinked technologically but would unlikely generate the necessary financial or political support for their development by alone.

As mentioned above, the main constraints are rather political, legal and governmental. A coordinated global effort addresses these issues effectively as well. Considering the international legal framework that is unclear about the possible mining and use and especially monetization of space resources, the investment model for setting up a refueling station by private entities is uncertain.

While a lot of legal discussion focuses on the explicit prohibition of appropriation of celestial bodies, ownership rights are not necessarily a precondition for its use, or beneficiation. However, the distribution and further use of the final material remain subject to the principle that warrants benefits to all humankind from space resources. Water mined for the purpose of shielding fuel facilities from radiation, or Helium-3 extracted in space for nuclear fusion reactors powering lasers for planetary defense constitute a much clearer benefit for all humanity than any single governmental or commercial activities.

Connecting these missions not only technologically and financially but also legally and politically can foment a new format of global governance based on cosmopolitan and democratic principles that will create the necessary conditions for further space exploration.

5.2. Mars colony

While the economic feasibility for Moon is much achievable, a Mars colony faces many bigger challenges as well as opportunities. Given its orbit, proximity, size and resources, Mars presents the biggest prospects to become the main off-Earth human settlement with relative self-sufficiency, serving as an insurance policy for humanity. The potential to be the prime destination of space migration has several components to it.

It is rich in metals but also in carbon, nitrogen, hydrogen and oxygen. It boasts sun exposure almost identical to Earth and an atmosphere (although very thin) to protect against some light harmful to plants, holding better outlooks for some basic botany. Unlike the Moon, its regolith is much more humid and frozen water is abundant on its poles in vast amount – altogether increasing the prospects of a possible terraforming through releasing of artificial halocarbon gases with supply power of 5,000 MW in a millennium according to Robert Zubrin [14].

While the Moon would combine different roles from resource mining, scientific outpost, departure point for travel from Earth or planetary defense, Mars' orbit would give it a unique place to exploit the asteroid belt, develop its own economy and become a true colony.

Such a vision is appealing. But even with great scientific progress and utilization of local minerals or resources from the asteroid belt, interplanetary supply chains through Mars-Earth cyclers are to be an inherent part of its functioning. It is unlikely that Mars would develop such an internal consumption that would foster a big enough demand to sustain the mass mining of the main asteroid belt.

Further, the process of terraforming would require mass efforts and investment of all entities functioning in the Solar System. Mars will require an artificial magnetic field or a magnetic shield on L1 to sustain a newly created atmosphere, moreover, considering its 1000-years-plus timeline, any economic rationale or market planning are unfit for it.

In a short-term view, a succinct summary of all concepts and plans for Mars settlement and mining missions point to commercial unfeasibility of creating water in the Red Planet. Changes in regolith water content, extraction efficiency and unknown distances between sites aside, the study puts the price of a liter water at 40-60 thousand dollars [24]. However, if humans decide to develop a chain of robots to grasp water-rich comets and redirect them against Mars in order to create planetary-scale oceans [15] the price of water will decrease significantly. This idea is not about quick achievability but about supporting an argument that any idea in a new method of extracting resources in Solar System will bring radical changes back on Earth or in the Solar System colonies. A stable open market economy in the Solar System will not be possible.

Amounting to these issues is the weak magnetic field, prevalence of dust including toxic materials like gypsum, chromium, perchlorates, silicic acid, more than double radiation background of Mars orbit compared to Earth's [26].

Settling Mars presents a different endeavor for the society than building a multipurpose Moon base. Increasing its population to the mentioned 5,000 inhabitants will be conditioned by off-Earth reproduction carrying ethical and scientific questions but also an opportunity to create a value system adequate to the environment. As suggested by some authors, morality and ethics will be much more flexible while cooperation and cohesiveness of the group are likely to be stressed above individual rights [25]. The inability of an individual to survive alone is a simple explanation.

Living alone is not an option. Thriving in space as lone colony is not an option either. Technology and science are likely to impact our morality and behavior in a more invasive way in hostile environments of off-Earth colonies. On Earth, technological progress already exerts pressure on society to adjust but some values and human essence should be perceived as incorruptible.

The choice between free self-determination of individuals and collective prosperity should not be viewed as mutually exclusive but rather as mutually enforcing. Rebellion on Mars will not and should not be prevented despite the strict regime ensuring survival, however, new kind of rebellions might emerge because rebellion by sabotage would be suicide. However, suicidal tendencies need to be identified in advance probably leaving some of our privacies available on Earth.

On the other hand, ensuring that people can influence their lives even in complex and challenging environments is equally important for societal stability as nurturing an imperative collective perception – not collective only from the territorial or planetary view but from the view of the interconnected Solar System.

6. Governance Model

The interconnected nature and complexity of either colonization, planetary defense, space resources extraction or deep space explorations deserve a holistic approach and coordination. The contemporary state-centric format of global governance does not offer us much of guidance, neither does its violent, bloody and exploitative history of colonization and imperialism. The democratic deficit originates from the disconnect between space and political authority.

The nearly 500-years-old global governance model of nation-states delimits political authority by geography, yet not only space issues but imminent global challenges do not respect borderlines. In the world of borders, those that affected by certain decisions lose the ability to influence its forming. Further, the incongruence between decision-makers (the people) and decision-takers (world leaders) reduces the accountability of those forming policy. With each nation-state possessing a voting voice, the voting strength of each citizen in billion-person India is dramatically lower than of those living in San Marino with 33,000 people. Finding an international consensus is thus plagued by over and under-representation that does not reflect functionality or those most affected by

the decisions, but the historical division of power and territoriality.

It is becoming increasingly more apparent that the contemporary international space governance, including legal, regulatory, commercial, or national security frameworks, is not applicable to the new space age characterized by growing role of private actors, new space powers and technological possibilities. However, just like the colonization of the New World in North America enabled the development of new and better modes of governance, the space domain can also enable new ideas about organizing and governing human activity in accordance with reality and function, not history.

Current space law depends on its transposition into national legal systems and nation-states assuming responsibility for actors based in their jurisdiction, authorizing and coordinating mining activities logically would fall into their area – a view stipulated by even the progressive Hague Working Group on mining. However, moving such a process on the national level is likely to complicate cooperation and coordination efforts.

Individual states will further lack the necessary capacities and knowledge to assess the technical aspects of such complex and long-term missions. A global mechanism of evaluating, coordinating and authorizing space missions would be required. Extending beyond space resources, any system of planetary defense also requires a global governance mechanism that will pool resources and guarantee global control that will protect inclusively the entire planet Earth. Deep space exploration, whether it is by observation or travel, can lead us to a critical decision about the future of humanity. Issues such as contacting possible extra-terrestrial forms of life, interstellar travel or space migration will also require a global governance and coordinate structures.

In some areas, the technological imperative is so strong that it dictates effective cooperation, such as the case of the International Technological Union. Should the states not reach a consensus on rules and assigning of radio frequencies, no one is communicating. ITU's growing powers in assigning orbits to new satellites would logically be complemented by decision-making over launch licenses as well as space debris removal. Should everyone not cooperate, no one would be communicating through satellites. Should all stakeholders not cooperate in joint global efforts for the defense of the planet or make humanity a multiplanetary species, no one would be living. Coming back to the basic democratic principle, all those affected by a decision should have the opportunity to influence it. In space, this often includes all of humanity.

7. Planetary Council

Building upon the three most likely scenarios, the discussion of governing principles and problems related to off-Earth settlements, we propose a new governance structure. The Planetary Council would combine the technological and scientific rigor necessary for the functioning of highly advanced multiplanetary humanity with the contemporary division of power and authority in the world and cosmopolitan and democratic norms. Its three components, epistemic authority, technical commission and cosmopolitan assembly would act in concert to carry out the joint, collaborative, inclusive and effective governance of humanity in the Solar System. They are also based on the three different scenarios and their positive contributions while suppressing the negative factors.

Two concepts, horizontal and vertical dispersion of sovereignty and sectorial constitutionalization, are incorporated into the structure. To avoid the concentration of sovereignty into sole units, the nation-states, the Council will disperse power into two directions. The vertical dispersion of sovereignty would be achieved by incorporating supranational units – regional or international organizations – and subnational units – cities, provinces or local administrations – in accordance with the democratic principle. The horizontal division will include spread to other stakeholders including private firms, philanthropists, research centers, academies of science, international organizations and other non-governmental entities as well as states themselves by their capacities to address different aspects and challenges. Further, sectoral constitutionalization would be another key component that would divide the decision-making process by issues-specific areas. This would channel power struggles into disputes over competencies between different bodies. The division into deeply-technical areas can also limit the national outlooks. It gives more power to the pure scientific argument.

To reflect the invasion of technological and scientific imperatives on human survival and flourishing, the epistemic authority would act as the prime source of scientific debate and evaluation as the guiding principle for finding the best and objective knowledge. Made up of academies of sciences, universities and other scientific centers, its power would be constituted by what is in the name – its epistemic authority. While working on the basis of scientific peer-reviewed argumentation with fluid authority over shared knowledge, we understand that even science is vulnerable to politicization as described in the governance by science scenario.

The recommendations, directives or regulations of the epistemic authority would be passed onto the technical commission, a body providing the technical capabilities made up of nation-states, private companies, philanthropists and businesses possessing the necessary

hardware or technological capital. The innovative drive of profit-oriented business will serve as a check on politicization by nation-states or dangers of methodological nationalism since anything else than objective scientific and technological progress would harm their revenue. The keen on contribution to humankind benefit by billionaire philanthropists can team up with businesses but also nation-states to implement recommendations of the epistemic authority. The drive for national excellence by nation-states in a form of national pride in a specific issue-area (an idea similar to Centres of Excellence within NATO) or large technical complexes can be used to complement the motivations of other parts of the technical commission.

Finally, a democratic oversight is required to include the cosmopolitan perspective, global accountability and legitimacy of the entire system. The cosmopolitan assembly that would incorporate democratic and deliberative principles would include all affected by the issue-specific area. For example, in planetary defense, it would be mainly cities as the threat of city killers, or smaller and untracked asteroids, concerns mainly them considering the high rate of urbanization. It would also serve as a check on abuse of power. The details for deciding on the makeup of the assembly in specific-issue areas is still up for debate, but the democratic principle of inclusion of all affected would lay at its core.

8. Conclusion

The new space frontier is presenting us with immense challenges but as well as an opportunity for how humans organize and govern themselves. The pathologies, democratic deficits and dysfunctionality of the current global governance model can serve as a motivation rather than a guideline. In the hostile environment of outer space, science and technology will play a more crucial and decisive role in human society. Incorporating it into decision-making of the multiplanetary species we aspire to become will present many unique challenges. Similarly, the new environment will require different moral and ethical assumptions and overall adjustments in human collective behavior. However drastic the changes might be we should sacrifice short-term stability for long-term sustainability. This pertains to the democratic dilemma between effectivity and democratic participation, the balance between scientific expert opinions and self-determination of those subject to the decisions but as well to choosing between individual rights and collective good. Abandoning one value or scenario for the other might prove short-sighted while finding the right balance between all as proposed in this article will prove difficult, frustrating and challenging.

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