Natural Sustainability Ethics for Resolving Current Outer Space Challenges

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Abstract

Currently, NASA and several outer space industry multi-billionaire entrepreneurs (e.g. Elon Musk (Space X), Jeff Bezos (Blue Origin), Richard Branson (Virgin Galactic)), are actively engaged in outer-space research that reports innovative advances such as, outer space: mining, tourism, medicine labs, terraforming Mars and the Moon, and altering celestial bodies and terrestrial humans to enhance extra-terrestrial survivability. All these advances unearth serious ethical concerns of human identity and cosmic sustainability that we address here. Further, the current understanding of sustainability development (SD) is highly anthropocentric (i.e., the earth is meant solely for man's use), and limited in scope as a terrestrial, temporal, economic and pro-human project. We expand SD to include trans-terrestrial, trans-temporal, trans-economic, and trans-human developments. We view this complex problem by distinguishing anthropocentric (nature is for man) versus non-anthropocentric (man is for nature) modern views of natural sustainability; Each view can be made to include either natural outcomes / processes of nature, or industrial uses and outcomes of nature to provide a four-fold framework of Natural Sustainability within which we explore ethical implications of outer space advances (OSA). We discuss managerial implications and limitations and suggest directions for future research.

Key Words: Outer space industry, terraforming celestial bodies, Natural Sustainability, Cosmic Sustainability, transhumanism

Introduction

Visionary millionaire entrepreneurs in collaboration with governments (e.g., NASA) have been active in the space sector for a long time; they drove the development of astronomical observatories since the early 1900s (MacDonald, 2017). But the actual act of sending humans into outer space or the cosmos was primarily a US government-led initiative until the end of advent of the 20th Century. Now, since the dawn of this century, global billionaire entrepreneurs have taken the lead with their own capital and corporate initiatives: Elon Musk (Space X), Jeff Bezos (Blue Origin), and Richard Branson (Virgin Galactic), to name a few. The emergence of these entrepreneurs signals a crucial turn in the institutional leadership in the development of outer space research, expeditions, travel and tourism – a shift away from governmental agencies (that are constrained by UK and NASA directives and tax payers' funds and concerns) towards private foundations willing to deploy their private monies more imaginatively on more daring projects that demand high-risk and audacity (Solomon, 2017).

The importance of investigating the sustainability-related implications of this new era of space travel is emphasized by the fact that the National Aeronautics and Space Administration (NASA) and several private companies have both the intention and capacity to send tourists into space in the near future (see BBC, 2018; Foust, 2019; Johnson, 2018; Malik, 2019; NASA 2019). Additionally, launch rates are increasing to unprecedented levels. From 2000 to 2010 the annual number of successful launches ranged from 50 to 81, whereas there were 163 launches planned for 2020 (Timeline of Spaceflight, 2019). The surge in launch rates underscores the need to investigate the environmental, social, and economic consequences of humankind's increasing ability to reach outer space.

Elon Musk, Nick Bostrom, Stephen Hawking, and many other influential thinkers view expansion into space necessary for our survival. Some initiatives are driven by concern about the survival of the human species if life on Earth will eventually become unsustainable (Slobodian, 2015). Such hopes and concerns have emerged advocacy groups such as 'The Mars Society' and the 'Homo Sapiens Foundation,' which seek to advance human settlement outer space.

Most outer-space advances raise sustainability and ethical problems not only domestically at the micro level of national social, economic and environmental issues, but more critically at the macro levels of terrestrial, extra-terrestrial and cosmic sustainability levels. The main deliberations on these issues took place in the UN Committee on Peaceful Uses of Outer Space (UN COPUOS), which generated a set of recommendatory guidelines for the long-term sustainability of outer space activities in 2016 (UN COPUOS, 2018a). However, the reference point for sustainability discussions was still terrestrial economic growth and prosperity, that did not necessarily factor in the more than a billion on this earth that are living in extreme forms of poverty (which is a key factor in jeopardizing planetary sustainability) (Sachs, 2005).

Recent plans to exploit the mineral resources found on celestial bodies – on the Moon and asteroids - for further economic growth, have only intensified these discussions. Further, one foresees additional ethical concerns of these outer-space forays. We seem to forget that nature has its own life, system-identity and destiny that stretch far beyond human use and aspirations. We call this "Natural Sustainability" and propose a framework to understand and respect natural sustainability in its other related dimensions. Natural sustainability as sustainability of Mother Nature in her entirety (more about this concept in Part III) is interconnected and interdependent with cosmic outer-space realities and raises ethical and sustainability concerns that we address in this paper. The framework of Natural Sustainability transcends Millennial Developmental Goals (MDGs), an era that ended in 2015, and even the 17 Sustainable Developmental Goals (SDGs) of this century that were framed in 2015 by UN-related international institutions.

In ethically analysing these outer-space advances (OSA), we confine our discussion to macro-natural Sustainability issues in four parts;

i. Recent NASA and Privately Sponsored Outer-space Advances and Issues
ii. Transhumanist Aspirations in Conjunction with OSA
iii. The Brundtland Concept of SD and Related Ethical Concerns of OSA
iv. Natural Sustainability to Further OSA Developmental Goals

Recent NASA and privately sponsored outer-space advances and issues

NASA is currently engaged in the development of a new generation of space robots (Gao & Chien, 2017), that will be tasked with preparing life-sites on celestial bodies, such as Mars, for human arrival and survival, and to explore sites which are too hazardous or inhospitable for humans to approach (Radford et al., 2015). NASA seeks to ultimately develop the humanoid (Radford et al., 2015; Tanaka et al., 2017) or autonomous robots (Sterritt & Hinchley, 2005) that will independently engage in space exploration. Whilst the agency has clearly seen the advantages of robotic spaceflight, NASA continues to envisage cosmic exploration in terms of human, robotic, or joint endeavours (Launius, 2006; Launius & McCurdy, 2007, 2008).

Elon Musk, a billionaire innovative entrepreneur seemingly pioneered the OSA venture; his principal concern is with the development of the means of space transport, and his immediate goal is to bring humans to Mars. For this purpose, in 2016, Musk "announced the creation of an Interplanetary Transport System designed for planetary colonisation using reusable launch and spacecraft vehicles. The Mars colony concept would begin with ten people and eventually grow to support a population of a million people in a self-sustaining community" (Peters, 2017, p. 88). To achieve this aim, SpaceX has developed a space vehicle called 'Starship' and a rocket, presently called the Super Heavy, with a thrust big enough to transport 100 persons as also supplies to Mars (Weitering, 2019). The first human flights to Mars were planned for the early 2020, though such predictions have often proven overly optimistic in this industry.

Jeffrey (Jeff) Bezos, the founder of Amazon, the world's largest retailer, has also entertained a life-long passion for outer space (Weinzierl & Acocella, 2016). He founded Blue Origin in the year 2000 as a private aerospace company, with the aim to "design and produce rockets and engines for sub-orbital spaceflights" (Gudmundsson, 2018, n.p.). But currently, Bezos entertains a much grander vision for his company, stating, "Ultimately, the plan is for Blue Origin to become a profitable, self-sustaining enterprise with a long-term goal to cut the cost of space flight so that millions of people can live and work off Earth" (Gudmundsson, 2018, n.p.). He discussed "having millions of people and then billions of people and then finally a trillion people in space" (quoted in Clifford, 2018, n.p.), and proclaimed that "[t]he solar system can support a trillion humans" (Harris, 2019, p. 26). Bezos is driven by the desire to avoid the inevitable rationing of resources that will become necessary if an expanding population remains confined only to this Earth; instead, he seeks to overcome this 'stasis' by going into space where "for all practical purposes we have unlimited resources" (Bezos, 2019, n.p.).

Bezos sees the first step to attain his vision as building "a low cost, highly operable, reusable launch vehicle" (Harris, 2019, p. 26). To achieve that goal, Blue Origin developed a spacecraft, the New Shepard, which is 'a suborbital space-tourist vehicle;' the next step is the development of a massive rocket, called the New Glenn, which "could enable cheap lunar missions and kick-start Bezos's grand vision of human beings living all over the solar system" (Harris, 2019, p. 26). Bezos added approximately USD 24 billion to his personal fortune during the COVID-19 outbreak (BBC, 2020); thus, further increasing his ability to fund space projects.

Virgin Galactic's Richard Branson has similarly emphasized human spaceflight, saying, "We hope to create thousands of astronauts [i.e. space tourists] over the next few years and make alive their dream of seeing the majestic beauty of our planet from above, the stars in all their glory and the amazing sensations of weightlessness and space flight" (quoted in Davenport, 2018, p. 80).

Transhumanist aspirations in conjunction with OSA

Transhumanism is a recent philosophical and scientific movement that believes our current human life and human dignity are too fragile and unevolved; future radical scientific and AI (Artificial Intelligence) technologies could so enhance human capabilities as to expedite evolution of humans into a new, post-human species (Bostrom, 2005; Kurzweil & Grossman, 2006; Moravec, 1999). The ''NBIC" (nanotechnology, biotechnology, information technology and cognitive science) initiatives proposed by transhumanists intend to spur human evolution into a 'posthuman' species that will be capable of engaging in outer space travel and human settlement in other celestial bodies (Herrick, 2017).

In contrast to NASA and space entrepreneurs, transhumanists are less concerned with the means of future transport of people to other celestial bodies. Rather, they focus on the modification of humans. This aspirational 'human enhancement' by scientific/technological means could be conducive to travel and settlement in the cosmos and increase the viability of living on presently inhospitable celestial bodies (Launius & McCurdy, 2008). Thus, Stoel (2019) recently declared, "In order to survive in space …it is time to contemplate and discuss volitional evolution, to genetically engineer humans to live in space" (n.p.). If such advances come to fruition, the goal of settling space could be realised, albeit not by humans as we know them.

NASA's reticence to directly and publicly engage with the tenets of transhumanism can be seen as related to the characteristics described above – it is a government space agency reliant on public funding and presidential directives. Any missions advocated by the agency must be palatable to both the public and the politicians, and the aims of transhumanism do not meet those criteria (Cohen & Spector, 2020).

NASA, alongside most of the prominent space entrepreneurs, are currently increasingly aware that the human form may not constitute the ideal space traveller. Post-humans, should they come to fruition, would potentially be far better suited to the inhospitable environs found in space. In addition to exploring the ethicality of altering the human form, the ethics of substantively changing other celestial bodies (even if they are devoid of life) must be considered.

The Brundtland concept of Sustainability Development and related ethical concerns of OSA

The Brundtland Report (1987) definition of sustainable development (SD) required meeting the needs of the present without compromising the ability of future generations to meet their own needs. This formulation of SD described three domains of sustainability: social, economic, and environmental. Accordingly, Sustainability is development that meets the social, economic, and environmental needs of the present without compromising the ability of meeting similar needs of future generations. Recent research adds a fourth ethical element, purpose. The Brundtland definition of SD, however, seems anthropocentric in that it makes provisions only for humans of future generations and that it believes that all nature is solely for man's use. Further, present-day views of SD typically assume that humans will remain confined to Earth's biosphere, an assumption that appears increasing problematic given the intended and unintended consequences of visionary thinking and rapid advancements in the outer-space domain.

Further, the new era of outer space expeditions complicates every component of Brundtland SD conceptualization. The Brundtland Report, also known as Our Common Future, assumes, a) short inter-generational human futures, b) mostly confined to this earth, where c) despite current space, resource, and overpopulation constraints, we should not compromise what we owe to future generations. All three assumptions are increasingly untenable in the context of outer-space advances (Cohen & Spector, 2020).

Table 1 lists and addresses some of the major ethical issues stirred by outer space advances (OSA) and advocacies. *Table 1* invokes four major ethical theories of teleology, deontology, distributive justice, and corrective justice to analyze to what extent any major OSA can be morally and ethically justifiable and legitimized.

Teleology defines morality in terms of costs and benefits, a kind of Cost-Benefit Analysis (CBA) of ends versus means (telos = end in Greek, and hence the term teleological - thinking that considers ends and means), while deontology deals with rights and duties (deon = duty in Greek, and hence the word deontological). Distributive justice analyzes the equitable spread of costs / benefits, rights and duties; corrective justice seeks to create correct procedures (hence, also called procedural justice) to rectify processes that violate all three previous theories of justice.

According to teleology, a useful moral rule is that if the social, economic, and environmental benefits from a specific OSA decidedly exceed corresponding costs compared to those of any other comparable OSA, and if this true for the greatest number of human beings affected by the OSA, then it is (teleologically) moral. Entries in *Table 1*, in all three columns under this ethical theory, are major teleological concerns based on this rule. The rule also assumes that costs and benefits can be evaluated by money, a socially constructed economic unit of exchange, and that it is the best base for cost-benefit analysis we have thus far. In this sense, money, besides being a tool of social measurement, is also a mechanism of "social equalization" (Fourcade 2011, p. 1733), in that it is available to all to earn and accumulate.

According to deontology, a useful moral rule is that an OSA is (deontologically) moral if it upholds social, economic and environmental rights of human beings affected by the OSA decidedly more than it violates corresponding duties to the same people relative to the same OSA, and if this equation is

true in relation to the greatest number of people affected by that OSA. Accordingly, entries in all three columns under this ethical theory are major deontological concerns based on this rule.

Similarly, according to distributive justice, a useful moral rule when applied to OSA is that an OSA is (by distributive justice standards) moral if, regardless of its costs and benefits, rights upheld and duties violated, the spread of its social, economic and environmental costs and benefits, rights and duties, is decidedly more equitable than corresponding distributions of any other comparable OSA, and if this is verified true for the greatest number of humans affected by the OSA. Entries in *Table 1*, in all three columns under this ethical theory, are major distributive justice concerns based on this rule.

Finally, according to corrective justice, a useful moral rule when applied to OSA is that an OSA is (by corrective justice standards) moral if its procedures for evenly distributing social, economic and environmental costs and benefits, rights and duties of that OSA are decidedly better than corresponding procedures of any other comparable OSA, and if this holds true for the greatest number of humans affected by the same OSA.. Entries in *Table 1*, in all three columns under this ethical theory, are major procedural justice concerns based on this rule.

Table I: Ethical Issues regarding Sustainability Development (SD) given Outer-space Advances (OSA)

SD Ethical Issues	National Sustainability Foundations		
	Social	**Economic**	**Environmental**
Teleological Ethics (Cost vs. Benefits to Humankind and earth)	**Billions of private dollars spent for OSA:** ▪ **Could be used for eradicating terrestrial poverty & inequalities;** ▪ **May still create planetary problems of ecology and cosmic unsustainability;** ▪ **May impose disproportionate harm on innocent millions as by-standers.** ▪ **May maximize profits to the elite few thus increasing Gini coefficient of income inequality and exacerbating poverty;** ▪ **May negatively impact Rawlsian Fair Equality Opportunity (FEO) creating enclaves that qualify for Mars, leaving the LDCS, their poor and the powerless behind on a depleted earth;** ▪ **Thus may be globally polarizing and divisive.**	**Teleologically, OSA's costs may far exceed corresponding benefits to most as indicated by:** ▪ **Increasing domestic GDP without social progress that lifts all;** ▪ **Worsening inflation and Gini income inequality;** ▪ **Creating Mars entry barriers for developing countries;** ▪ **Creating cosmic monopolies & monopsonies;** ▪ **Colonizing outer space for private benefit at the expense of planetary ecology;** ▪ **Importing cosmic pandemic disease to earth** ▪ **Inciting international cosmic space wars;** ▪ **Aggravating extra-terrestrial imperialism and USA outer-space hegemony;** ▪ **Thus increasing cosmic unsustainability;**	**To legitimize well-planned OSA, they:** ▪ **Should minimize carbon emissions on earth or maximize carbon neutrality;** ▪ **Prevent harm to terrestrial arctic zones, forest belts, wildlife preserves, bird sanctuaries, and ocean life via noise pollution;** ▪ **Not increase industrial pollution of air, water, land, soil, energy and food chains on earth;** ▪ **Should Minimize non-biodegradable cosmic-e-waste;** ▪ **Should not over-deplete terrestrial resources and human habitability to fuel frequent OSA-related rocket launches;** ▪ **Welcome international supervision on major OSA forays to avoid unforeseeable global catastrophic outcomes (such as arctic meltdowns, tsunami, earthquakes, global forest fires…);** ▪ **OSA could disable cyber-hacking and invasion of terrestrial privacy;**
Deontological Ethics (Rights and Duties of humankind)	**Ethics of altering the human form to suit outer space survivability needs to be studied;** **OSA may spur transhumanist violations of Human dignity;** **OSA-stirred transhumanism could violate terrestrial human rights for:** ▪ **One Human family and solidarity;** ▪ **One human nature and dignity;**	**With no government control or regulation, OSA may violate distributive justice by:** ▪ **Pre-selecting candidates for Mars.** ▪ **By over-powering private wealth – (i.e., money is might, might is right);**	**Human multi-planet settlement:** ▪ **May jeopardize planetary ecology and cosmic sustainability;** ▪ **May export terrestrial diseases there that could kill possible humans and non-humans in outer space!**

	▪ Planetary ecology; ▪ Global sustainability; ▪ Cosmic sustainability. Posthumanism may jeopardize humanism and human rights restoration;	▪ Wanton abuse of outer space thus endangering cosmic sustainability; ▪ Disregarding responsibility for human fatalities associated with colonizing outer space; ▪ Colonizing solar galaxy that may violate cosmic rights and our duties to the cosmos.	▪ May negatively affect terrestrial human happiness and eco-sensitivity and green mindfulness; ▪ May demand too many outer-space rocket launches that could deplete earth's already depleted energy resources;
Ethics of Distributive Justice (Fairness and Entitlement)	Fairness: OSA should also sustain Fair Equality of opportunity (FEO): ▪ For human asset development for all; ▪ For education, healthcare and hygiene for all the marginalized. ▪ For eradicating poverty and thus restoring human dignity;	OSA concerns could also include: ▪ Gainful employment for all as human entitlement; ▪ Artificial intelligence (AI) as mechanization- or automation of labor creates over- or under-employment; ▪ OSA can level ownership and wealth accumulation opportunities for all in Mars.	OSA should also support: ▪ Planetary ecology & climate control: ▪ Outer-space mining for eradicating terrestrial poverty; ▪ Outer-space human migration to resolve terrestrial migration problems; ▪ Cosmic sustainability; ▪ Control on global warming;
Ethics of Corrective Justice (Right procedures for just distributions or entitlements)	OSA can help: ▪ Reduction of Gap between the rich and the poor; ▪ Global peace, harmony and solidarity; ▪ May increase opportunities for global learning and continued education; ▪ Control of bigotry and terrorism; ▪ Control on global migrations; ▪ Control on international or national remote vote-rigging systems that despoil democratic election results	OSA can enable: ▪ Reduction of undeserved opportunity advantages of some (based on nationality,, creed, gender, race, or geography); ▪ Fairness in treating asylum seeking international emigrants; ▪ Fair procedures for treating internal domestic migrants; ▪ Instituting international institutions for adjudicating law, order, justice, and globalization issues.	OSA Should ensure: ▪ Reduction of cosmic satellite-debris ▪ SD as correcting over-extractive and exploitative practices; ▪ Establishing global sustainability and outer-space jurisdictions; ▪ Control of Overuse of earth's energy resources for outer-space commercial tourism; ▪ Reduce or recycle outer-space e-waste and cyber traffic;

[Source: Author]

OSA aspirations for an unimpeded conquest of the universe or, to begin with, to colonize Mars or make multi-planet human settlement possible, are seeking several paths:

1. Through several launches of Starship (Elon Musk) or New Glenn (Jeff Bezos), they are seeking to populate Mars within this decade;
2. If human survival is not possible on Mars, then as Elon Musk states, we must alter Mars (or "nuke" it) to make human arrival and survival possible – this is terra-forming strategy (terra = earth in Latin); terraforming Mars, is to transform Mars to make it sustain and thrive extra-terrestrial human settlement);
3. Failing (2), alter humans to empower them to survive in Mars) – this is the transhumanist movement that seeks via Artificial Intelligence (AI) to genetically alter terrestrial humans for enabling Martian life;
4. Since (2) and (3) are beyond NASA's current political and regulatory scope, this is current thinking at NASA; NASA's scope might change rapidly given OSA of private adventurers. NASA plans to send robots into spacecraft bound to Mars to prepare for human landing.

All four strategies indicate ends that are good and laudable. But ends (e.g. strategy (1)) chosen do not or should not justify means (e.g., strategies (2) and (3)) – this is a teleological mandate. Further, even if means chosen can justify ends, they cannot violate the fundamental rights of humans involved - these are deontological considerations. If there are other alternatives (e.g. strategy (4)), that can achieve the same end even on a different frame of time and scale, it should be explored before wantonly implementing strategies (2) and (3). Further, whether one uses one's own monies or private wealth for any of these OSA adventures does not change the moral principles and mandates involved. Wealth should not affect morality of right and wrong, or vice versa. One cannot buy or alter morality.

What we need at this juncture, therefore, is an open discussion and dialog regarding the moral implications of OSA for Mother Nature and humanity in general and for the millions marginalized, in particular, that will presumably be left behind in a dilapidated fragile planet, and arrive at a strong ethical code for all future OSA forays.

Natural sustainability to support OSA developmental goals

Nature means the terrestrial and extra-terrestrial spaces and entities. It includes everything around us - the entire environment of planets, stars, sun and galaxies - the whole of creation. We believe that all nature, albeit in different degrees, is made in the image and likeness of its Creator and hence, has its own destiny beyond serving humankind (de Chardin, 1955). Humans are a species among many other species on this earth. Hence, there is no intrinsic reason to claim human superiority over non-human nature. Despite our rationality and intellectual pursuits, our current claim to superiority and use-rights over non-human nature are presumptuously self-referencing. In fact, to a large extent the way European voyagers discovered and occupied the Americas in the 15th and 16th centuries almost suppressing aboriginal native tribes and their natural possessions, was an excellent example of human nature fighting against native human nature.

Cosmological anthropology that deals with the theories of origin, duration, composition, and destiny of the cosmic universe tells us that the universe is very vast (some light years in diameter), very ancient (some billions of years in existence), and still expanding (into trillions of galaxies) (Stoeger, 2009), that we cannot presume all nature is only for human use and progress, especially living as we are in a tiny speck of this mighty universe we call planet earth, where we arrived just a few thousand years ago compared to billions of years of cosmic evolution and existence (Harari, 2011). Hence, all of us need a change of attitude that will respect nature with reverence and seek mutually developmental partnership with it, rather than conquer to dominate it with for our good-willed industrialization goals.

Philosophical critics (e.g., Ackerman & Heinzerling, 2004; Sagoff, 2004; Satz, 2004) and environmental scientists call upon the public to recognize the right of nonhuman species (a vast part of nature) - our moral duty to future generations, and the valuable goal of enhancing bio-diversity, or the beauty of untouched landscapes (Fourcade, 2011; Tilman, 2000). Nature is also a very important stakeholder embedded within the entire environment of the firm (Laine, 2010). “The most striking feature of Earth is the existence of life, and the most striking feature of life is its diversity. This biological diversity, or biodiversity, has long been a source of wonderment and scientific curiosity, but is increasingly a source of concern. Human domination of Earth’s ecosystems is markedly reducing the diversity of species within many habitats worldwide, and is accelerating extinction.” (Tilman, 2000, p. 208). The possibility of negatively impacting biodiversity wherever it thrives in the cosmos cannot be taken lightly by OAS advocates.

Over-used nature needs time for regeneration and rejuvenation. Covid-19 has silently unfolded the damage caused. Nature is too gentle to retaliate, but still tells us something very important. It has a life of its own with its intrinsic cycles, seasons, rhythms, identity, and destiny that we must begin to recognize, learn, and respect. We should allow, and even enable nature to recover its sustainability, regeneration and maintenance. This is our duty and responsibility. Natural Sustainability is a moral demand on humanity before and after we seek any OSA.

Natural sustainability as challenge to OSA

In order to ethically analyze OSA from a sustainability point of view, we define and characterize what we call Natural Sustainability in four levels as follows: we first distinguish the traditional anthropocentric view of nature (i.e., nature solely for humans) from its radical reverse - a modern non-anthropocentric view (i.e., humans to serve nature). Each view can be applied to nature as natural

phenomena (produce) or to nature's support of industrial outcomes (products). The resulting fourfold matrix of Natural Sustainability is described in ***Table 2.***

Table 2: Characterizing Natural Sustainability

Nature's Sustainability as:	Approach to Nature	
	Anthropocentric (Nature serves mankind)	**Non-Anthropocentric (Mankind to serve nature)**
Natural Outcomes	**Quadrant I: Nature's Phenomenological Sustainability**: **All phenomena of natural outcomes** also for man's use such as all flora and fauna (e.g., fruits, flowers, trees, barks, herbs, birds, fish, wildlife) **All ecosystemic phenomena** that generate natural outcomes that we may absorb and learn such as, natural cycles, seasons, rhythms, resolutions, motions or times, rain, sun, light, heat, darkness, cold, snow, forestation,, evolution of animals, spawning fish, all bio-ecosystems). **All biodiversity phenomena).** "The recent rediscovery of the importance of biodiversity highlights an under-appreciated truth; although society is dependent on natural and managed ecosystems for goods and services that are essential for human survival, we know all too little about how ecosystems work" (Tilman 2000, p. 209). This is not so obvious in terrestrial nature, given our myopic view. But, nature has immense biodiversity spread all over the earth far beyond our use and understanding (Tilman 2000, p. 208).	**Quadrant III: Nature's Noumenological Sustainability:** Nature has its intrinsic value, goals, and destiny beyond its natural outcomes and industrial use that we must understand, respect and nurture (e.g., its life, habitat, age, growth, progeny, environment, biodiversity and bio-species – all are independent of man) Respect nature's rights and privileges for natural existence and evolution, natural survival of the fittest, natural weeding (forest fires, drought, blight, disease, and tsunami) – all are independent of man, but we can seek developmental partnership with. We should cooperate with nature such that while using and extracting nature's industrial resources, we should give time, and space for nature to regenerate and even rejuvenate. In this sense, we must serve nature. Hence, our positive ecozoic duties and ecological obligations to nature is to seek developmental partnership with nature for SD and thus eradicate poverty and restore human dignity, green planetary ecology, and safeguard cosmic sustainability; OSA as a movement can pioneer this undertaking effectively.
Industrial Outcomes	**Quadrant II: Nature's Teleological (Utilitarian or temporal ends) Sustainability**: **Natural resources for industrial use:** (oil, gas, coal, water, minerals, precious metals,…) Nature is freely extracted for economic development and Infrastructure (roads, bridges, ports and transport) thus enhancing human productivity for supplementing natural outcomes); But our extraction of nature was not always to empower man's meaning and dignity in work; or, we do not deploy nature to enhance human dignity and planetary ecology as our primary goal and objective.	**Quadrant IV: Nature's Eschatological (ultimate ends) Sustainability**: The future of nature: its ultimate finality and destiny of nature independent of man that we must respect, nurture and enable as part of the same nature, we must liberate nature to freely realize its own destiny with the rest of the cosmos; How can extra-terrestrial industrialization, specifically OSA, enhance earth's role and share in cosmic SD and Cosmic natural evolution (unharmed by terraforming and outer space human colonization)? Invent or re-Design industrialization for non-anthropocentric evolution and destiny; (e.g. global cooling that stops arctic meltdowns; reducing carbon emissions for

	If all nature is for the use of all mankind; then poverty is unnatural; it violates nature's bounty and human dignity; hence, eradicate poverty (before, or with OSA);	greening; ecozoic partnership for rejuvenating nature; infrastructure for enhancing nature's biodiversity).

[Source: Author]

Natural Sustainability (NS), as the term indicates, is the way nature sustains itself through its phenomenological outputs (flora and fauna) and its phenomenological processes or ecosystems (e.g., seasons and cycles, rhythms and resolutions) that churn the natural outcome we call this *phenomenological* NS, because this is how nature "appears" to us (appearance = phenomenon in Greek) in its natural visible outputs and processes. We like to believe these outcomes are primarily for man's use, hence, anthropocentric. In the second quadrant we use the not so visible but useful resources (coal, gas, oil, mines, minerals) for manufacturing industrial outcomes; there are other resources yet to emerge via OSAs such as (Mars, Martian resources, terraforming other celestial bodies to discover their hidden treasures of energy and food/air chains). We call this nature as *teleological* (i.e., telos = temporal ends in Greek; ends useful or utilitarian to us humans). In Quadrant III we go even deeper to understand the "being" of nature and hence we name it *noumenological* (noumenon = being or reality in Greek)) manifested in its own intrinsic purpose, goals, and destiny independent of man (hence non anthropocentric). Finally, in Quadrant IV we speculate on the ultimate destiny, hence called *eschatalogical* (eschata = ultimate or eternal ends in Greek) of nature which is also independent of man's use (i.e., non-anthropocentric). *Table 2* provides more details on each of the four layers of NS. *Table 2* is not a sketch of the evolution of nature or of man (for a good account see Harari, 2018). It is an outline of evolution of the use of nature by man which has ethical implications relevant for assessing OAS. We submit, *Table 2* offers a new and expanded framework for a more objective ethical analysis and justification of present and future OSA.

1. **Nature's Phenomenological Sustainability:** This primordial nature of natural sustainability is based on its phenomena of natural outcomes that mankind can enjoy and share with other humans, birds and animals. Natural outcomes include nature's bounty represented by its flora and fauna (e.g., birds, animals, fruits, trees, fish, and the like). This was many centuries before our industrial society, when nature enjoyed its best level of sustainability, greenness, and original natural status that our human ancestors cherished, worshipped, and preserved. Nature was available to all for clear-cutting, as much as needed; there was no scope for greed or poverty then, nor any divide between the rich and the poor; no ecological problems; nature supported human dignity to flourish in its own way in a nature-based natural civilization of the Homo Faber. Then, when Homo Sapiens emerged with gaming and hunting, fire and cooking skills, claims of ownership, tilling and fencing; agronomy was born which eventually led to feudalism. Humans tried to improve upon nature to supplement natural outcomes by agronomic produce and products. Cultures were born, spread, and migrated, in search of better pastures. In the process, interbreeding generated richer human cultures and races (Harari, 2011). Natural Sustainability flourished; mankind was very close to nature, often part of it. Humans flourished, and so did religion and nature worship. The spirits of departed ancestors were also considered a part of nature.

2. **Nature's Teleological (Utilitarian) Sustainability**: Soon those humans who skilled, hunted, and fared better than others, began to exert power and influence over other humans. Some successful humans began to mark, own, brand and fence land and forests claiming as their own, while those humans that trailed behind in this ownership race, willingly worked for the owners for wages in kind. Soon feudalism was born with master and slaves. Income inequality emerged together with poverty. Beyond mere natural outcomes (Quadrant I) humans began to discover and extract useful natural resources (e.g., coal, oil, gas, metals, minerals and ores) (Quadrant II) to transform them into industrial products for infrastructure and development (e.g., cement, roads, bridges, sea ports, cities, towns,) and soon industrialization appeared with urban versus rural cultures. Finally, when humans discovered

the wheel, steam and the steam engine, energy production, transportation and mobility became prominent. We began overusing all resources and soon teleological NS was strained; planetary ecology got endangered.

3. **Nature's Noumenological (i.e., Reality or Being) Sustainability:** This is founded on the ontic value of nature that goes beyond its natural outcomes and industrial use. It recognizes that nature has intrinsic value with its own goal and objectives that we have unwittingly failed to acknowledge, respect, and empower. That is, nature has an identity, purpose, and destiny beyond its natural outcomes and use for industrialization. At a deeper level, we also perceive a reciprocity between nature and humankind, between the earth and the galaxies, and an interdependence between their identities and destinies (de Chardin, 1955). "The recent rediscovery of the importance of biodiversity highlights an under-appreciated truth; although society is dependent on natural and managed ecosystems for goods and services that are essential for human survival, we know all too little about how ecosystems work" (Tilman, 2000, p. 209). This is not so obvious in terrestrial nature nor given our myopic view. But, nature has immense biodiversity spread all over the earth far beyond our use and understanding that we must recognize and include in our OSA planning adventures.

4. **Nature's Eschatological Sustainability:** This level of Natural Sustainability is the destiny of the previous three sustainability levels (Quadrants I-III)**.** That is, the eschatological sustainability of nature follows from its ontic sustainability and expresses its finality and ultimate destiny beyond the universe. This indicates that nature's eco-intelligence far exceeds human intelligence (this is subtly evident from the Covid-19 pandemic that we could barely stop, control, or cure). Minimally, in order to recover Natural Sustainability of all four quadrants of *Table 2*, we need a refined industrialization plan with the following features: a) less extractive and exploitative industrial production; b) we further adopt a mutually developmental partnership with nature and thus c) we begin to return what belongs to nature (of course minus what we have irretrievably extracted from it) but with d) a decided approach of reinvigorating nature with innovative technologies for streamlining this reinvigoration); e) we do this with the conviction that nature has its own being and processes that we must recognize and respect. This is the call and meaning of Deontological or Noumenological Natural Sustainability we try to capture in Quadrant III, which when internalized and implemented duly, can further resolve the four nature sustainability goals (NSGs): poverty eradication, restoration of human dignity, planetary ecology, and cosmic sustainability, before we proceed with further OSAs.

Discussion, managerial implications and limitations

OSA is a great movement to have happened in our time given that the earth is already over-used and almost exhausted of the resources to support life. given ever growing industrialization demands and more importantly, that we helplessly accept that the majority of earth's resources are in the hands of very few. OSA is morally justified if it promises us greener pastures in the outer space, more equitable access for all to these pastures, and thus, better hopes for brighter futures. Moreover, OSA needs moral legitimization by being acceptable to global eco-scholars and ethicists. Table 1 is a preliminary step in this regard – the ethical concerns raised are based on four major ethical theories of teleology, deontology, distributive justice and corrective justice, fairly universally accepted among ethicists. Other ethical theories that apply are those of human dignity, human virtues, moral responsibility, and trust, to name a few. They apply identically as the four ethical theories we have invoked in *Table 1*. Future OSA-related ethical research could apply these ethical theories to bring out other nuanced ethical aspects of OSA.

The ethical concerns raised are not mutually exclusive and collectively exhaustive (MECE). *Table 1* is positioned as a comprehensive call to proactive responsibilities from all involved with OSA adventures. They are just suggestive and contingent upon current OSA; future OSAs may generate

further issues that must then be specifically addressed. Most of the entries of *Table 1* are self-explanatory. We do not expect that current OSA efforts should be constrained with all the ethical mandates of *Table 1*. However, they indicate the large canvas of ethical imperatives that OSA could include. They become concerns given the ethical theory under question. Most ethical concerns listed in *Table 1* are interdependent in their understanding and resolution. Moreover, no ethical concerns from any ethical theory are mutually exclusive – they are interconnected and interdependent. All ethical theories deal with human values and aspirations.

Table 2 is a macro ethical analysis of OSA from a fourfold layer of Natural Sustainability (NS) viewpoint. Most of the current OSA are necessitated by overstrained natural sustainability at the phenomenological (Quadrant I) and teleological (Quadrant II) levels. We submit that the best source of morally legitimizing OSA lies at the noumenological (Quadrant III) and eschatological (Quadrant IV) levels of NS. In Quadrants III and IV, nature includes terrestrial and extra-terrestrial spaces viewed from a non-anthropocentric perspective. OSA is strategically positioned to restore nature, and with some magnanimity of purpose, could easily enable the regeneration and rejuvenation processes of NS at the noumenological and eschatological levels (Quadrants III and IV) as stated.

Mankind should, non-anthropocentrically, serve nature in this process. Current OSA, without compromising their original goals and visions, could comfortably redirect efforts towards this end for the future generations that may not live long enough to be included in multi-planet settlements. Eschatalogical NS outlined in Quadrant IV has to be sustained via redesigned industrialization strategies. It seeks a gradual transition from the current over-extractive and over-exploitative intrusions into natural resources to future developmental partnerships with nature that must be innovatively conceived, planned, and executed. We contend that OSA are best positioned for developmental partnerships with nature. Thus, all four Natural Sustainability goals (eradication of poverty, restoration of human dignity, restoration of planetary ecology and cosmic sustainability) could be simultaneously realized via OSA. Future research should sharpen these possibilities.

Sustainability development is not achieved in isolation from nature but in interdependence with it. We are interconnected with nature in its entirety. Even our knowledge of ourselves is dependent upon nature. For instance, “Human health and prosperity depend on the health and prosperity of the entire biosphere” (Barbiero, 2017, p. 186). The awareness of the biological foundations of knowledge, or of what connects us with other living beings, helps us to be more tolerant and respectful of all life forms, because when one recognizes his own affinity with the rest of the world, he inevitably treats it more similarly to how he treats himself, that is, in a more ethical way (Danon, 2019). This implies that sustainability should not simply be seen as an outer layer of respectability in terms of recycling and waste reduction. In fact, sustainability implies an ecozoic vision equipped with the awareness that our gestures and choices have profound implications on the system (Danon, 2019), for now and future generations to come.

Concluding remarks

The billionaire entrepreneurs supporting OSA could be commended for their generous private investments for undertaking high-risk pathways to populate outer space, thus hoping to resolve terrestrial problems of increasing pollution, increasing population, and decreasing human habitable spaces. In doing so, however, OSA must gain legitimacy in the international arena as also moral acceptability among ecological and ethical scholars. *Table 1* unearths major ethical concerns that OSA should be aware of, while *Table 2* offers Natural Sustainability-based morally defensible legitimizing scope for OSA.

References

Ackerman, F., & Heinzerling, L. (2004). *Priceless: Human Health, the Environment and the Limits of the Market*. New Press.

Barbiero G. (2017). *Ecologia Affettiva*. Milano: Mondadori.

BBC (2018). Elon Musk unveils first tourist for SpaceX 'Moon loop.' Retrieved May 20, 2019. https://www.bbc.com/news/science-environment-45550755

BBC (2020, April 15). Coronavirus: Amazon boss Jeff Bezos adds $24bn to fortune. Retrieved April 4, 2020.

Bezos, J. (2019). Going to space to benefit earth. Retrieved May 14, 2019. https://www.youtube.com/watch? v=GQ98hGUe6FM

Bostrom, N. (2005). A history of transhumanist thought. *Journal of evolution and technology*, *14*(1), 1-25.

Brundtland, G., Khalid, M., Agnelli, S., Al-Athel, S., Chidzero, B., Fadika, L. & Singh, M. (1987). *Our Common Future* (\'Brundtland report\').

Clifford, C. (2018, May 1). Jeff Bezos dreams of a world with a trillion people living in space. CNBC. https://www.cnbc.com/2018/05/01/jeff-bezos-dreams-of-a-world-with-a-trillion-people-living-in-space.html [accessed March 13, 2019].

Cohen, E., & Spector, S. (2020). Comparative visions of cosmic expansion: implications for sustainability. *Journal of Sustainable Tourism*, 1-16. https://doi//10.1080/09669582.2020.1777142

Danon, M. (2019). "From Ego to Eco": The contribution of Ecopsychology to the current environmental crisis management. *Visions for Sustainability*, in press. http://dx. doi.org/ 10.13135 /2384-8677/3261

Davenport, C. (2018). *The space barons: Elon Musk, Jeff Bezos, and the quest to colonize the cosmos*. Hachette Book Group.

de Chardin, T. (1955). The Phenomenon of Man, trans. *Bernard Wall*.

Fourcade, M. (2011). Cents and sensibility: economic valuation and the nature of "nature". *American journal of sociology*, *116*(6), 1721-77.

Foust, J. (2019). Blue Origin unveils lunar lander. SpaceNews. Retrieved April 25, 2019. https://spacenews.com/blue-origin-unveils-lunar-lander/

Gao, Y., & Chien, S. (2017). Review on space robotics, Towards top-level science through space exploration. *Science Robotics*, *2*(7), eaan5074. https://doi.org/10.1126/scirobotics.aan5074

Gudmundsson, S. V. (2018). Blue Origin, Riding the wave of disruption in the space industry. Toulouse Business School Case. Retrieved May 20, 2019. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3179135

Harari, Y.N. (2011). Sapiens – A Brief History of Humankind. Vintage Books, London

Harari, Y. N. (2018). *Homo Deus, a brief history of tomorrow*. Random House.

Harris, M. (2019). The heavy lift, Blue Origin's next rocket engine could power our return to the Moon. *IEEE Spectrum*, *56*(7), 26–30. https://doi.org/10.1109/MSPEC.2019.8747308

Herrick, J. A. (2017). *Visions of technological transcendence, Human enhancement and rhetoric of the future*. Parlour Press.

Johnson, E. M. (2018, December 14). Virgin Galactic completes crewed space test, more flights soon. Reuters. Retrieved March 18, 2019. https://www.reuters.com/article/us-virgingalactic-rockets/virgin-galactic-completes-crewed-space-test-more-flights-soon-idUSKBN1OC1HA

Kurzweil, R., & Grossman, T. (2006). *Fantastic voyages: Live long enough to live forever*. New York, NY: Redale Books.

Laine, M. (2010). The nature of nature as a stakeholder. *Journal of Business Ethics*, *96*(1), 73.

Launius, R. D. (2006). Compelling rationales for spaceflight? History and the search for relevance. *Critical Issues in the History of Spaceflight*, 37–70.

Launius, R. D., & McCurdy, H. E. (2007). Robots and humans in space flight: Technology, evolution, and interplanetary travel. *Technology in Society*, *29*(3), 271–282. https://doi.org/10.1016/j.techsoc.2007.04.007

Launius, R. D., & McCurdy, H. E. (2008). *Robots in space, technology, evolution, and interplanetary travel*. JHU Press.

MacDonald, A. (2017). *The long space age: The economic origins of space exploration from Colonial America to the Cold War*. Yale University Press.

Malik, T. (2019). Russia Says It Will Launch 2 Tourists into Orbit for Space Adventures in 2021. Space.com. Retrieved September 25, 2019. https://www.space.com/russia-launching-space-tourists-2021.html

Moravec, H. (1999). *Robots: Mere machines to transcendent mind*. New York, NY: Oxford University Press.

NASA. (2019, June 7). NASA opens international space station to new commercial opportunities, private astronauts. Retrieved June 9, 2019. https://www.nasa.gov/press-release/nasa-opens-international-space-station-to-new-commercial-opportunities-privatem

Peters, M. A. (2017). Beyond Earth globalization, Sociology of outer space? *Review of Contemporary Philosophy*, *16*, 83–91.

Radford, N.A., Strawser, P., Hambuchen, K., Mehling, J.S., Verdeyen, W.K., Donnan, A.S., Holley, J., Sanchez, J., Nguyen, V., Bridgwater, L., Berka, R., Ambrose, R., Myles Markee, M., Fraser‐Chanpong, N.J., McQuin, C., Yamokoski, J.D., Hart, S., Guo, R., Parsons, A., Wightman, B., Dinh, P., Ames, B., Blakely, C., Edmondson, C., Sommers, B., Rea, R., Tobler, C., Bibby, H., Howard, B., Niu, L., Lee, A., Conover, M., Truong, L., Reed, R., Chesney, D., Platt, R., Jr, Johnson, G., Fok, C.‐L., Paine, N., Sentis, L., Cousineau, E., Sinnet, R., Lack, J., Powell, M., Morris, B., Ames, A. and Akinyode, J. (2015), Valkyrie: NASA's First Bipedal Humanoid Robot. J. Field Robotics, 32: 397-419. https://doi.org/10.1002/rob.21560

Sachs J. (2005) *The end of Poverty: how we can make it happen in our Lifetime.* Penguin Group, England.

Sagoff, M. (2004). *Price, principle, and the environment*. Cambridge University Press.

Satz, D. (2004). Noxious markets: why should some things not be for sale. *Globalization, Culture, and the Limits of the Market: Essays in Economics and Philosophy,* Oxford University Press: New Delhi.

Slobodian, R. E. (2015). Selling space colonization and immortality: A psychosocial, anthropological critique of the rush to colonize Mars. *Acta Astronautica*, *113*, 89-104.

Solomon, L. D. (2017). *The privatization of space exploration: Business, technology, law and policy*. Routledge.

Sterritt, R., & Hinchey, M. (2005, April). Engineering ultimate self-protection in autonomic agents for space exploration missions. In *12th IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'05)* (pp. 506–511). IEEE.

Stoel, A. (2019). Should we genetically engineer humans to live in space? In *The transhumanist handbook* (pp. 619–621). Springer, Cham.

Stoeger, W. (2009). Cosmology. Interdisciplinary Encyclopedia of Religion and Science INTERS.org. http://inters.org/cosmology

Tanaka, G., Nakane, R., Yamane, T., Takeda, S., Nakano, D., Nakagawa, S., & Hirose, A. (2017, November). Waveform classification by memristive reservoir computing. In *International Conference on Neural Information Processing* (pp. 457-465). Springer, Cham.

Tilman, D. (2000). Causes, consequences and ethics of biodiversity. *Nature*, *405*(6783), 208-211.

Timeline of Spaceflight. (2019). Wikimedia Commons. Retrieved October 9, 2019. https://en.wikipedia.org/wiki/Timeline_of_spaceflight

UN COPUOS (2018a). The Hague Space Resources Governance Working Group: Information provided by the Netherlands, UN Doc. A/AC.105/ C.2/2018/CRP.18.

Weitering, H. (2019). How SpaceX's Starship will help establish a Mars base. *Space.com*. Retrieved May 26, 2019. https://www.space.com/spacex-starship-mars-transportation-plans.html

Weinzierl, M., Acocella, A. (2016). Blue Origin, NASA and NEW Space (A). Harvard Business School Case. Retrieved May 26, 2019. https://www.hbs.edu/faculty/Pages/item.aspx?num=50708.