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ORIGINAL PAPER

Near, Far, Wherever We Are: Space Exploration Urgently Needs an Ethics-Informed Planning Revolution

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Abstract

Projects concerning space are hugely valuable to our species. Two notable physical districts are (a) the various orbits local to earth and (b) areas that are more remotely located in the interplanetary and interstellar regions. However, the legacy of decades of human space observation, exploitation, and exploration has not always been positive. Environments have been impacted and key groups have been inconvenienced and even their safety threatened due to the ventures of some actors. If such activity continues, the damage caused to our societies, our local space, and even our outer space might become irretrievable. This paper calls for actors to work with their fellow earthlings to identify and address the negative consequences of space endeavours *prior* to their eventuation. By employing notions of long-view sustainability, we may visualise how our projects affect not only the environment, but also us, and the legacy that we leave for our future generations.

Keywords Space · Ethics · Astroethics · Sustainability · Exploration Ethics · Astrobioethics

1 Introduction

Considerations of astroethical issues are frequently framed within the context of science-fiction or as something to be considered in the deep future. As a species, space feels so big and our projects so comparatively small that it is tempting to believe that any impact that our activities have is negligible. Yet, submitting to this notion is dangerous; these impacts are accumulating more rapidly than we might like to believe.

There are many examples of negative legacies that can result when humanity interacts with space. These effects can be environmental, such as the massive carbon dioxide emissions generated at each rocket launch [1], or the debris left in orbit from discarded equipment. These effects can also be societal, one comment being that each time that taxpayer's monies are spent gazing *up there,* there remain many issues faced by the humans who pay for them *down here* [2]. Many of the environmental issues have not gone unnoticed and there have been some attempts to address them in the planning and execution of space-related ventures. Well-noted examples include publicly funded efforts such as NASA's Space Shuttle programme which featured the first reusable spacecrafts, and those that are privately funded such as Blue Origin's and SpaceX's achievements in reusable rocketry. Yet some endeavours seem to exemplify the frivolousness with which we treat the pure expanse in which we are suspended; for example: when the first Tesla vehicle was sent to float past Mars [3]. It may appear that many of the potential issues related to the artifacts of human space activities might arise 'later' (if at all), but 'later' can feel so physically and chronologically far away that it is tempting to believe that maybe those problems could be delt with by other people in the fullness of time. However, this paper will show that some of the dramatic predictions made by science fiction *are* rapidly eventuating, and in ways that are affecting not only our own scientific endeavours but also the environment with which we are entrusted, in the here and now.

In this article, I will note two distinct physical districts to frame the astroethical issues which have arisen from various privately and publicly funded space-related pursuits in recent history. I will use these examples to argue that, whilst individual activities might have manageable consequences, the immense volume of human activity in this arena requires us to prospectively examine and effectively address the practical and ethical cumulative impact of future space activities in the long-term, prior to their commencement. Without doing so, we risk creating and storing up enormous problems which

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will need rapid solutions sooner than some might have anticipated.

2 Near

The first spacial district is that of the various earth orbits. This physical area is scattered with examples of human activities, particularly so in the low earth orbit (LEO) altitudes between 160 and 1000 km [4], at altitudes of tens or hundreds of thousands of kilometres, and even at distances millions of kilometres further out from the surface of the Earth.

Artificial satellites are vital assets to modern life, but, despite their benefits, can also have a tremendous negative effect on the scientific work undertaken on *terra firma*. SpaceX's Starlink, One Web, and Amazon's Project Kuiper are three notable examples of satellite internet services that are currently planned or under construction in LEO. Satellite internet services greatly overcome the issue of internet connectivity in remote areas, but, to perform this task, hundreds of devices needed to be deployed and collectively linked into 'megaconstellations'; sadly, the effect of these deployments has been far from neutral [5].

Starlink has had complaints about their satellites from the scientific community since they were first launched in 2019. Astronomers operating from ground-based observatories discovered that SpaceX had not taken sufficient precautions to dim their satellites [6]. Even at night, the procession of satellites reflecting sunlight could be seen with the naked eye, the consequential light pollution affecting sensitive astronomic telescopic work [6]. SpaceX's use of anti-reflective paint [6] on their table-sized satellites [7] helped reduce its brightness by half, but this is not enough and more is needed [6] as images continue to be streaked [8]. Disappointingly for astronomers, potentially tens of thousands of these objects will be positioned in LEO in the coming years; without action, observers may expect to find these objects ghosting and streaking their images indefinitely [9].

This situation was not unforeseeable; before the megaconstellation launches, naked-eye observers could spot the reflections of older satellites orbiting the globe (more on these later in this section). The additional presence of megaconstellation satellites in their planned multitudes would foreseeably affect the natural sciences that observe the skies. SpaceX and Amazon are now voluntarily participating with the astronomical community on how to mitigate their effects [10], and this should be absolutely encouraged, yet it still leaves the question: why were these potential effects not noted and these conversations not been initiated earlier?

As well as interfering with ground-based observatory work, satellites can also present risks to each other. As the reader shall see, this next example is apparently directly from the Hollywood playbook of the film Gravity. In November 2021, Russia announced that their weapons test to destroy one of its non-operational satellites had been executed with "razor-sharp precision" [11]. The shot's accuracy successfully broke up their Cosmos 1408 [12] but in the process also created a debris field; the trajectory of which intersected with the path of the manned international space station (ISS) every 90 min. The crews were immediately woken and instructed to shelter in their Soyuz and Crew Dragon spacecrafts [13] until a risk assessment had been made by NASA's ballistics specialists [14]. NASA Administrator Bill Nelson's press release was nothing short of scathing:

> *"I'm outraged by this irresponsible and destabilizing action. With its long and storied history in human spaceflight, it is unthinkable that Russia would endanger not only the American and international partner astronauts on the ISS but also their own cosmonauts. Their actions are reckless and dangerous, threatening [the ISS] as well the Chinese space station and the taikonauts on board."* [14]

As the ISS is at an elevation of 400 km [15], the residents of the station may potentially have further interactions with this debris cloud until it deorbits. Indeed, the fallout from this incident will be prolonged as much of the remaining orbiting detritus crosses orbits ranging from 400 to 1000 km and will take a decade or longer to burn up in Earth's atmosphere [16]. LEO space is occupied not only with humans but also with communications satellite systems such as SPOT [17] and Hubble Space Telescope [18]. Whilst we can expect them to fail one day in the future, it is favourable for these highly useful and expensive instruments to continue to function for as long as possible with as little risk as possible of being hit by rogue debris, thus causing them to break up and become debris themselves.

It is not just the insertion of megaconstellations or the detritus from exploded obsolete satellites that is a threat to current space projects. On first glance, the night sky looks vast and empty, but we live under an array of thousands of fast-moving objects, many of which have been there for decades. One does not need to be an advanced scientist or technician to appreciate them; resources such as Heavens Above [19] give real-time information about natural and man-made objects so that we can spot them with the naked eye as they fly over our heads, and LEO Labs's Earth Orbit Visualization [20] shows the incredible global swarm of human relics. Whilst the mega constellations have been the target of much recent bad press, the presence of non-deorbited rocket debris has been just as guilty of hampering scientific works; recently, a discarded Russian rocket photobombed one observation leading to the erroneous claim of a gamma burst from galaxy GN-z11 [21].

Considering this context, planning for the decommissioning of man-made orbiting objects at the end of their working life is necessary. Wyler [22] has had OneWeb's satellites designed to not crash into each other at the point of failure, thus reducing the risk of them breaking into smaller pieces, which then crash into other objects, which then break up and destroy other objects ad infinitum thereby making space travel impossible; a phenomenon known as Kessler Syndrome [23, 24]. With each new launch, comes more matter deposited into Earth's orbits, materials such as satellites and non-reusable booster rockets, and each new item brings a higher risk of Kessler Syndrome initiating. As yet, there is no craft capable of travelling to retrieve these objects when the time comes to decommission them and no comprehensive coordinated anticollision programme for those objects still in operation. Without such a project, the net result could envisionably be that the LEO space will become ever more crowded with the installation of new generation satellites, and all being yet another potential source of unintentional shrapnel.

The consequences of Kessler Syndrome are far from insubstantial. Doboš and Pražák [23] note that a severe debris-resulting incident may limit humanity's ability to access outer space. But Adilov et al. [25] predict that, before orbital spaces eventually become physically unusable, increases in debris will result in an increase in spacecraft failures rendering orbital spaces economically unprofitable for siting new satellites. It is in no small way ironic that humanity's attempts to open up space for exploration and exploitation might cumulatively result in the inaccessibility of space and thus the downfall of our own aims.

Whilst not much can currently be done for the discarded and uncontrolled items which float around the globe from historical human endeavours, there is scope to consider what can be done for those objects which are still in operation and those yet to be launched. The question of the effective regulation of the use of space has been floated before, not least so that the 'rules of the road' may be established in these busy spaces where multiple parties wish to competitively operate whilst travelling around each other [22]. Yet this can only work if actors have an understanding and forewarning of other actor's actions. Satellites, such as those deployed by SpaceX, have thrusters allowing them to be boosted to higher altitudes [26] to avoid collisions [27]; but when a satellite's manoeuvring strategy is unknown then other nearby actors are forced to implement their own collision-avoidance measures [27]. This happened recently where one Starlink satellite's orbit continuously changed, and another dropped into an orbit that risked a collision with China's space station, Tiangong; both of these incidents necessitated Tiangong to manoeuvre in response [27]. This resulted in China communicating to SpaceX via the United Nations, calling on them to act responsibly due to near misses [27].

When it comes to their decommissioning, some foresight has been demonstrated; OneWeb satellites [22] and the Hubble Space Telescope [28] are, respectively, fitted with grappling fixtures and a docking system allowing potential future vehicles to capture them. However, this only offers the potentiality of capture rather than the comprehensively planned removal of these objects. LEO is relatively close to the earth, so the distance to travel for retrieval is relatively short, yet the voluminous number of OneWebb satellites appears to indicate a redundancy rather than a retrieval model. Since the Space Shuttle program has now ended, the decommissioning of Hubble is contingent on NASA's Space Launch System being brought into operation [28], the first flight of which was 16th November 2022 [29]. If retrieval is not possible, then it is projected that, sometime in the 2030s, Hubble will be electively de-orbited and burnt up in Earth's atmosphere [30]. However, not all satellites that de-orbit burn up and some large pieces can reach the ground intact [31] risking damage on impact. This may be especially problematic if a de-orbit is uncontrolled and the resultant debris reaches locations of human habitation, potentially yielding an outcome of unintentional yet significant harm to both persons and property.

The challenges of planning and executing the controlled decommissioning of space objects are linked not only to LEO operations, but also those located further afield, for example to extraplanetary activities such as the James Webb Space Telescope (JWST). The JWST has been fitted with an interface point allowing future service vehicles to grapple it for either retrieval or repair [32]. Yet, once again, the provision of interface points on space artifacts appears moot; in the case of JWST, its positioning nearly a million miles away from the earth at the second Lagrange Point (L2) [33] is inaccessible to human or robotic crews for the foreseeable future. JWST was never intended to be serviced due to the increase in cost and mission complexity not offsetting the potential benefits that servicing the device could bring [32]. The benefit of JWST's location in L2 is that it uses less fuel to stay there [34] due to L2's orbital 'sweet spot' which allows spacecraft to remain in a reliable orbit [35]; this is beneficial in prolonging the life of the mission but makes for a challenging retrieval exercise.

Whilst there is much human-placed matter floating around in space, some recovery projects are planned; notably ESA's ClearSpace-1, which aims to remove its first object from LEO in 2025 [36]. Yet surely, to be meaningful, a serious plan for retrieval of human artifacts in space, complete with full funding for mission development and execution, ought to be in place *prior* to any satellite's deployment? But even if this were to be made mandatory for every launch, the popularity of extra-terrestrial enterprises may mean that each retrieved object will be replaced as fast (if not faster) than it is removed.

Despite these initial plans to reduce and remove debris, some offer the view that space is not a resource that ought to be kept pristine. Jeff Bezos has declared that all heavy industry should be moved to space [37] between the Earth and Moon, thus allowing Earth to be rezoned for light industry and habitation [38]. Such a move has been compared to 'sacrifice zones' where human development has permitted the spoiling of locations so that others may benefit from the chosen industry [37].

To avoid any actor from creating an intentional off-earth sacrifice zone, the mitigation of undesirable potential effects of each item that is installed in LEO (for example, containment of contamination) needs to be carefully considered prior to its delivery to orbit. That analysis needs to be mandatory and weigh the views of not only those who would gain from that activity now, but also those who will be subject to any benefits or losses of these activities in the future; for example, through loss of opportunities due to the effects of a congested LEO, or simply the loss of the unspoilt night sky.

Earth's orbits are exploited for human uses, and the consequences of that exploitation are now becoming apparent to us. Yet, the further away from the earth we travel, the more difficult it is to visualise the impact of the consequences of human activities in space, especially so when we may personally never see them.

3 Far

The second spacial district that this paper considers is that ranging from interplanetary to interstellar.

All planets in our solar system have been visited by our spacecraft counterparts within living human memory. Some of these visitors have deployed robotic expeditionary landing parties. Of these, a few, such as that of Spirit and Opportunity's visit to Mars [39], have lasted up to several years, whereas others, such as Venera 7's landing on Venus, have yielded data transmissions for only a matter of minutes [40]. Those devices which have expired off-earth have remained there.

Our artifacts do occasionally return from space. The Hayabusa2 project successfully briefly returned to drop off samples from the asteroid Ryugu before heading off again to the smaller asteroid 1998 KY26 [41]. Additionally, there are some proposed plans for samples to be retrieved from Mars [42]. Yet, other artifacts do not return to us, and their working lives end in a variety of ways.

Some projects have come to a very deliberate close; for example: Cassini's mission retired with it crashing into Saturn to ensure that its body did not inadvertently contaminate the potentially habitable or prebiotic bodies of Enceladus and Titan [43]. The same fate befell Galileo's mission to Jupiter [44] and also lies ahead for Juno's decommissioning [45]. Such demises reflect the COSPAR Policy on Planetary Protection [46]; this policy guides actors to avoid biological agents from the Earth being landed in locations where life could evolve, thus avoiding compromising future investigations. These actions favour the protection of (as yet undetected) extra-terrestrial life, yet what of other non-biological artifacts of our extra-terrestrial visits which are left behind when they have completed their purpose? Mars's Perseverance rover exemplifies this with its jettisoned parachute and backshell from its 2021 touchdown [47]—the question to be asked here is if humanity wants to leave such debris behind as a legacy for future visitors to contend with? And if not, how may any retrieval take place?

Currently, there is no plan to collect many of our robotic away teams. Some of these have remained where they have ceased to function (e.g. Mars robots) and some have been sent flying to boldly go into interstellar space (e.g. Viking 1 and 2) transmitting until their transmissions can no longer reach us, or until they fail (e.g., their power runs out); whichever happens soonest. The conceptualisation of these tremendous distances in such an unimaginably large area makes the consequences of sending objects away into a seemingly endless void acceptable to many.[1]

With each step further from Earth brings the feeling of immense space which seemingly permits humanity a fair leeway to leave our mark, however, and wherever we wish. We can justify this by arguing that when comparatively small artifacts are left behind from missions, their presence is balanced by the knowledge gained that enriches humanity and informs our future activities. One wonders if our descendants will view this similarly, or question if there were foreseeable undesirable consequences of our pursuits that we could have reasonably recognised and countered prior to our actions.

Much the same as the ongoing problem with refuse on Earth, disposal is not just a matter of throwing something 'away'; there is no 'away' just the place that it lands [49]. If we send our robots to visit somewhere once, it is not inconceivable that we will return; if not within our own generation, then in those which follow. Much the same as we have found with artifacts in LEO, eventually someone (maybe early Mars colonists) will be faced with our abandoned scientific remnants and will have to decide what to do with them. This could be a source of embarrassment to us as humanity's historical agents if the consequences of our abandoning our objects have caused, say, damaging pollution to the area in which the artifact is subsequently found. For this reason, it is reasonable for fair consideration to be given to our artifacts before they are deployed to ensure that their effects do not interfere with our future activities, honour the innately valuable environment in which they have visited, and ensure that that which we wish to appreciate in the future is not spoilt.

[1] "Space is big. You just won't believe how vastly, hugely, mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist's, but that's just peanuts to space" [48].

4 Wherever We Are: How Ought Our Exploration Go On?

As a species, we need to decide how we wish our actors to behave when engaging in space-related activities. Chon-Torres [50] explains the appropriateness of calling on the philosophical branch of ethics when calling for the establishment of a code of ethics for astrobiological concerns. It is logical that humans currently be noted as guardians in the universe [51] as we are, at present, the only known capable moral actors[2]; but we need to guard not only the extra-terrestrial lifeforms that we could potentially encounter, but also ought to also consider more widely the effects that we have on the environments in which we conduct ourselves.

A planning revolution that is ethically informed would enable humanity to assess for the potential implications of our practices and processes. This would ensure that our future actions enable our species' flourishing whilst avoiding harm to the environments in which we wish to explore or inhabit and the societies in which we live. To do this, our earth-dwelling community needs to make decisions regarding how we wish to treat the various environments in which we explore space, and how we will enforce behaviour that reflects the values that we determine to uphold.

Traditional ethical theories are commonly utilised in ethical discussion; for example: Graves [53] employed utilitarian and deontological approaches to determine that the risks of using nuclear-powered space probes are sufficiently small thus morally defensible to permit their use. However, such approaches usually consider the effects of people's actions on other people, living things, or environments where humanity is sufficiently proximal to—thus able to connect with and appreciate—both the problematic action and its effect. Astroethics' territory may concern matters far away from Earth, meaning that ethical theories used in this field additionally need to consider causes and effects of actions that can be dramatically separated in both physical distance and time.

Humans might realise immediate benefits from the knowledge and discoveries that a mission may deliver, but there is the potential for undesirable outcomes from that mission, for example: pollution originating from a damaged unmanned spacecraft on an uninhabited planet. Additionally, where an observer's location is very remote relative to the results of their actions, they might believe that any negative effects in that far-away place are abstract to the point of irrelevancy. Where one person's activities impact another person or a valued environment on or near Earth, harms can be readily appreciated and considered (the aforementioned activities in LEO exemplify this); additionally, potential as-yet-to-be-discovered lifeforms off-Earth are argued as having intrinsic value [54] and are therefore protected [43–46]. But when we make our mark on environments that are devoid of life and out of our immediate sight (e.g. the leaving of debris [47] and remains [39, 40] of robotic interplanetary missions), it is harder to meaningfully value that impact as negative or recognise those actions as harmful, especially when there is apparently no extra-terrestrial life to protect, an abundant environment to explore and exploit (why worry about a few square meters of an entire planet?), and when our actions do not directly affect us or anyone we know. Comparatively, on Earth, a no-longer functioning robot would be noted as electronic waste and (ideally) decommissioned safely and responsibly via, for example, removal and recycling. Society would have cause to object were it left indefinitely where it ceased to function as it would be unsightly and may prove hazardous as it deteriorates over time.

We also might not be aware of the negative impacts of our space-exploring artifacts for many reasons; they could be so far away that we cannot observe them, our instruments might no longer be operational or able to report their condition to us, or—given enough time—we might have simply forgotten that they are out there and are no-longer monitoring their status. Not knowing that there has been a problematic impact caused by our space-faring artifacts prevents the negative effects of its deployment being acknowledged, and if issues are not acknowledged they cannot be meaningfully addressed. This would inhibit considerations of restitution for harms done to that environment or for future planning to prevent similar undesirable risks eventuating in other locations.

Just because we cannot always see the impact of our actions does not mean that those impacts have not taken place and that they do not matter. In fact, even from tremendous distances, the outcomes of our actions do matter, particularly if we wish to explore that location further in the future.

The fact that humans have been so curious as to send their robotic representatives to remote places demonstrates that that location has some kind of special value to our species—without uniqueness and the promise of a high reward (e.g., scientific discovery or resources) for the visit, the cost of going would be unjustifiably high. Because of the relative remoteness of almost everywhere off-Earth, humanity will never fully know the value of a location until it is explored. Because it cannot be fully known what is there before arrival, one cannot discount the immense value of what might be found. The value could be high due to its irreplaceability; for example, unexpected lifeform discovery. This means that all space exploration is worthy of the assumption that the desired destination possesses immense

[2] "The great thing about being the only species that makes a distinction between right and wrong is that we can make up the rules for ourselves as we go along" ([52], p.49).

This freedom is troublesome though as no-other species' civilisations are available to hold us responsible for our actions; currently only we can hold ourselves to account.

value, even when that value has not yet been formally determined.

The reality is that the value of any location might not ever be fully recognised. Despite the immense length of our entire species' existence on Earth, we are still surprised daily by new discoveries of natural wonders both on and off our planet; each of which are unique and deserve protection. Thus, this argument supports the case *against* the aforementioned industrial sacrifice zones in space exploration. Every space that we are able to reach has intrinsic—if not immediately recognised—value, so must not be irreparably damaged. We must respect that with every literal or figurative rock turned over there could be a discovery to be made, and, if devoid of discovery (e.g., a planet that has no determinable immediate value), then we must respect that others in the future may wish to appreciate and use that space for other purposes without having to first decontaminate it from past exploits.

Yet, humanity will continue to explore the stars and, even with the best of intentions, we will leave our mark each time that we do so. To help address this astroethical problem, I offer the following notes for consideration.

As this paper has described, the negative impacts of science and innovation are not insignificant. Responsible Research and Innovation (RRI) practices address this by asking us to involve society in science and innovation so that outcomes are aligned with societal values [55]. RRI practices help by aiming for outcomes to be ethically acceptable, sustainable, and socially desirable [55] and can be adopted from the outset of a project; engaging with and including diverse voices in practice, deliberation, and decision-making [55]. This would aid actors to anticipate, address, and mitigate for potential undesirable consequences which may arise due to their activities.

However, it is not as though space practices have historically been lacking in regulation and guidance. There are international agreements that have considered the impact of human activity in space; the foundation of which is the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (otherwise known as the Outer Space Treaty) [56]. This dictates that "States shall be liable for damage caused by their space objects" and "States shall avoid harmful contamination of space and celestial bodies." However, it seems that countries apply such instruments differently. For example, the USA's Federal Aviation Administration's Office of Space Transportation requires actors to apply for launch and re-entry licences. Issuance of these licences is conditional upon compliance with the National Environmental Policy Act to ensure that launch plans do not harm or pollute natural or historic areas [57]. Similarly, the UK's approach to space regulation requires environmental assessment and stipulates insurance and indemnity limits with which to cover an actor's liabilities [58]. Yet, the Outer Space Treaty is apparently not a deterrent to all actor's behaviour that can lead to harmful contamination—e.g. when nations shoot their satellites.

None of the issues described in this paper have been created by a single event with a single actor. Observatories, rockets, and satellites have been permitted one at a time and we are now witnessing the cumulative effect of decades of these decisions. To enable issues to be proactively identified and addressed prior to activity commencement, key interested parties need to be meaningfully afforded the opportunity to have their values heard and considered, thus allowing them to participate in steering the development, exploitation, and/or the preservation of space and space-related environments. Without this measure, the actions of a small number of both private and publicly funded actors will stand to greatly influence how the remainder of the global majority are affected by space-related activities in the future.

This paper absolutely does not advocate for the discontinuation of space activities. Yet actors often operate in domains possible only to those with the power and resources to do so. Conducting these operations is a privilege, and, as such, actors need to respect that privilege by ensuring responsible and sustainable use of these environments as well as cultivating a shared interest in ensuring they remain open, usable, and unspoilt by meaningfully employing toolkits such as RRI and complying with agreed international treaties.

Opportunities need to be made where global societies may jointly consider the benefits, burdens, costs, and fairness of public and private organisations' space-bound activities. Evaluations need to be made of the potential harm that could take place from pursuing a proposed activity and mitigations must be considered prior to deployment. I do not propose that such considerations should be as restrictive as to unnecessarily remove autonomy of space activities from actors, but activities should be collaboratively planned in a manner that is aligned with and representative of global societal values and is considerate of and (insofar as is possible) in agreement with those other actors which are already performing in the same proposed space, and also that of those who may come to occupy the same space in the future.

Space-related activities can be persuasively argued as positive for society. If the artifacts of human activities offered no benefit, it would be easy to simply condemn them and demand their discontinuation; indeed, the scientific and practical benefits that they offer humanity are immense. Humanity might decide that an item is a piece of history worth preserving: the Apollo Missions' landing sites on the moon, the first rovers on Mars, the Voyagers, maybe even Elon Musk's first interplanetary Tesla. But the presence—or saturation—of these items in areas that we want to use or preserve may result in the value of their novelty wearing off with the realisation that such artifacts will need resource expenditure to be either responsibly maintained as museum exhibits or removed as waste.

It would be wise for all actors and interested parties to consider how space-related activities in our immediate present may foreseeably affect ourselves, our neighbours, and the environments that we appropriate (both on and off Earth), but there is also value in looking significantly further forward than the here and now. Long-view sustainable environmental ethics approaches could be adopted. One such example is that of the Haudenosaunee (Iroquois) people; they believe that "individual humans and human communities must be responsible for taking actions that positively affect seven generations hence. Thus they must also avoid actions that might negatively affect future generations, as far ahead as "the seventh generation" [59, p.41]. This approach could be employed to encourage actors to consider the future effects of their space activities and to look beyond their current position in time. Seven generations may feel unfathomably long to many actors, how can progress ever be made if we are always thinking of the impact deep into the future? How can any plans be reasonably modelled when the state of technology that far ahead cannot be predicted? Yet, this prolonged period might not be unreasonable when considering space activity; much good, or much damage can happen within seven generations. A long-view approach to sustainable planning has yielded incredible environmental and societal benefits which we have reaped within our lifetimes; an excellent example is that of naval planning. After the Napoleonic Wars, Denmark planted ninety thousand oak trees with which to replenish their navy ships; two hundred years later, in 2007, the Danish Nature Agency (which succeeded the Royal Forester) told their Defence Ministry that the trees were ready for use [60]. Whilst modern navies now prefer other materials and no longer use trees for their fleets, Denmark has profited from the growth of Gribskov Forest [61] as this is now one of the country's largest natural areas [62]. To demonstrate the usefulness of long-view sustainability to space-related activities, the following discussion will lay out how this approach might be usefully applied when planning for the future use of LEO.

In this generation, we recognise that the exploitation of space can address the need for fast, efficient, and reliable communications between our communities; megaconstellations can provide this to areas of the world where there is limited connectivity for services such as calls and internet. Societal views can be sought, and values can be derived from that consultation. A possible finding could be that it is permissible to launch megaconstellations to address the problem of connectivity *now*, but a meaningful commitment must be made prior to their launch to achieve the goal of removing satellites *later* in a timely manner when they have reached the end of their working life. Such steps may proactively anticipate and act upon the foreseeable future problem of space debris accumulation. It could be agreed that such an undertaking should recognise that innovation does not come without an environmental cost, but that costs must not be allowed to be so unrestrained so as to be detrimental. Projects inclusive of accommodations for foreseeable impacts must be meaningfully planned for, along with the secured allocation of adequate funding with which the following generations can achieve any clean-up task that we have set them.

If LEO is a desirable, useful, and finite resource, there is value in considering coordinated international efforts when attempting to achieve identical goals. There is precedence of this in many projects, but the ISS is one of the most well-known. The ISS is a harmonised international effort that allows multiple common goals to be simultaneously achieved on a single shared platform. One wonders if the same international cooperation could be achieved when aiming for the common goal of the removal of space debris and the organisation and use of communications via megaconstellations. If all countries wish to achieve the same ends, would a collaborative project offer greater financial and environmental efficiencies than the duplication of systems in orbit with a corresponding (and potentially unnecessary) increase of objects in LEO?

5 Conclusion

This paper's discussion has sampled only a tiny number of the thousands of humanity's space activities, but the problem presented is clear. Only a few actors affect space and space-related locations at present, and these few predominantly decide how our shared space resource may be treated.

There are no easy solutions. Guidance and regulation can only ever go so far, and ultimately actors choose how they will play out their projects. To address this, we need to collectively and respectfully recognise our species' contribution to the environments in which we venture before they are irredeemably occupied with remnants of our early explorations and activities. If we are to advance as a species, we cannot avoid adding to the multitude of objects in LEO and beyond; but we can enquire of, define, and use societal values to carefully consider the impact of each additional object from here on and how each will be decommissioned. By doing this, we may begin to secure a lasting and healthy relationship to not only utilise, but also preserve humanity's last great wilderness for our benefit now and for those who follow us.

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