SUSTAINABILITY IN SPACE

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https://www.SustainableSpaceInitiative.org/

1. The New Space economy

Historically, activity in space has been driven by geopolitical competition ("the space race") between the U.S. and Russia, initiated by the launch of Sputnik in 1957 by the Soviet Union. This is often referred to as the beginning of the Space Age. Large governmental agencies like NASA have since directed the scientific research and exploration initiatives in space. Recent years have seen increasing public-private partnerships, such as SpaceX contracts to deliver payloads to the International Space Station. The global space industry is now transitioning to an era of increased access to space through commercial launch providers like SpaceX and Rocket Lab. This era is referred to as New Space. Most of the money generated by the space industry today ($469 billion US as of 2022) comes from the commercial sector. There are 90 nations operating in space, with 1,022 spacecraft placed in orbit between January – June 2022. More than $224 billion US is from products and services delivered by companies using satellite data.

The New Zealand space sector began its rapid development with the establishment of the nation's space agency in 2016, following Rocket Lab's proposal to commence commercial space launches. The SpaceBase Directory identifies 231 unique organizations as of 2022, characterised by a mixture of start-up and well-established companies, educational and research institutions, and special interest groups.

Rocket Lab's presence in New Zealand reflects the geographic advantages of the country for space operations, with its clear seas and skies and access to a wide range of launch angles, a skilled workforce, and strong government financial incentives. In 2019, NZ's space sector was estimated to have generated $1.75 billion NZD per year in revenue, representing 0.5% of the New Zealand economy and 0.27% of the global space economy. Rocket Lab alone attracts 1.5% of global investments in New Space.

Consistent with global trends, more growth is prescribed, with an aim to reach a value of $10 billion NZD per annum by 2030. To achieve this, there is a clear prerogative to position the New Zealand government both as an enabler and customer of aerospace products and services. This further reinforces the global trend of mutually beneficial public-private partnerships, as societies become increasingly reliant on aerospace-enabled technologies.

1.1. Aerospace-enabled Data

Trends in the Earth observation global markets show that defence and intelligence-based markets are driving the need for high-resolution data. The derived data is becoming increasingly important for managing natural resources, informing industries like the agricultural sector in the face of climate-related challenges, and monitoring environmental policy compliance. This includes weather monitoring, climate disasters, warning systems and rapid response capabilities to environmental and social challenges, and telecommunication, broadcasting, and navigation.

Using outer space for Earth observation has become a way to manage terrestrial sustainability. Satellite use reduces the need for infrastructure on Earth and provides cost-effective options for increased global connectivity and accurate monitoring services, while contributing to the 17 SDGs.

For example, Aotearoa New Zealand's first Government-funded space mission, MethaneSAT, is part of a global collaboration detecting methane emissions. Additionally, the UN Committee for the Peaceful Uses of Outer Space (UN COPUOS) has also established expert groups to provide guidelines on how space can be used sustainably to support sustainable development on Earth.

2. Earth for Space

2.1 Consequences for the orbital environment

The increased number of satellites for remote sensing and Earth observations has led to issues such as radio and other spectrum interference, orbital crowding, privacy and surveillance, and competition with established space operators.

In 2020 alone, the world registered 1,260 new satellites and other space objects with the United Nations Office for Outer Space Affairs (UNOOSA). That is almost 10% of all objects ever registered with the UN since the beginning of the Space Age in 1957.

The European Space Agency (ESA) estimates there are approximately 136 million objects larger than 1mm currently in orbit, included discarded parts of rocket bodies and satellites. The largest contributors are China, Russia and the U.S.

Voluntary guidelines for the mitigation of space debris have been in effect since 2007, endorsed by the UN COPUOS. These guidelines include considerations for limiting the potential for accidental collisions and for de-orbiting defunct objects in a controlled fashion, for example, through re-entry into Earth's atmosphere where they would burn up. However, it is difficult to implement voluntary guidelines without imposing consequences for those who violate them.

For example, in 2007, China conducted an anti-satellite weapons (ASAT) test that destroyed once of its own weather satellites and created over 3,500 pieces of debris. This action was widely condemned by international space bodies and demonstrates how complex geopolitical issues can derail space sustainability initiatives.

Thus, the norms of engagement, growth and governance are biased towards those with structural and economic power. As the New Space race compels more nations to participate as investors, innovators, regulators and end-users, the responsibility to avoid a "tragedy of the commons" exposes historical geo-political tensions and generates new conflicts of interest.

The ESA's projections indicate that current levels of compliance with space debris mitigation measures are not good enough to limit the growth of space debris. They recommend a radical, zero debris approach to future space missions.

This issue has motivated a fast-growing industry around space debris monitoring and removal, projected to be worth more than $1.5 billion US by 2029. Active debris removal (ADR) is also being explored so that existing debris can be removed, or future debris is consistently being removed. This could include space recycling. ADR is currently being tested, such as Northrop Grumman's Mission Extension Vehicle-1 (MEV-1), the Japanese company Astroscale's ELSA-d project, and the European RemoveDEBRIS mission. New Zealand adopted an orbital debris mitigation policy based on standard international guidelines and recently introduced a world-first Active Debris Removal and On-Orbit Servicing Missions policy.

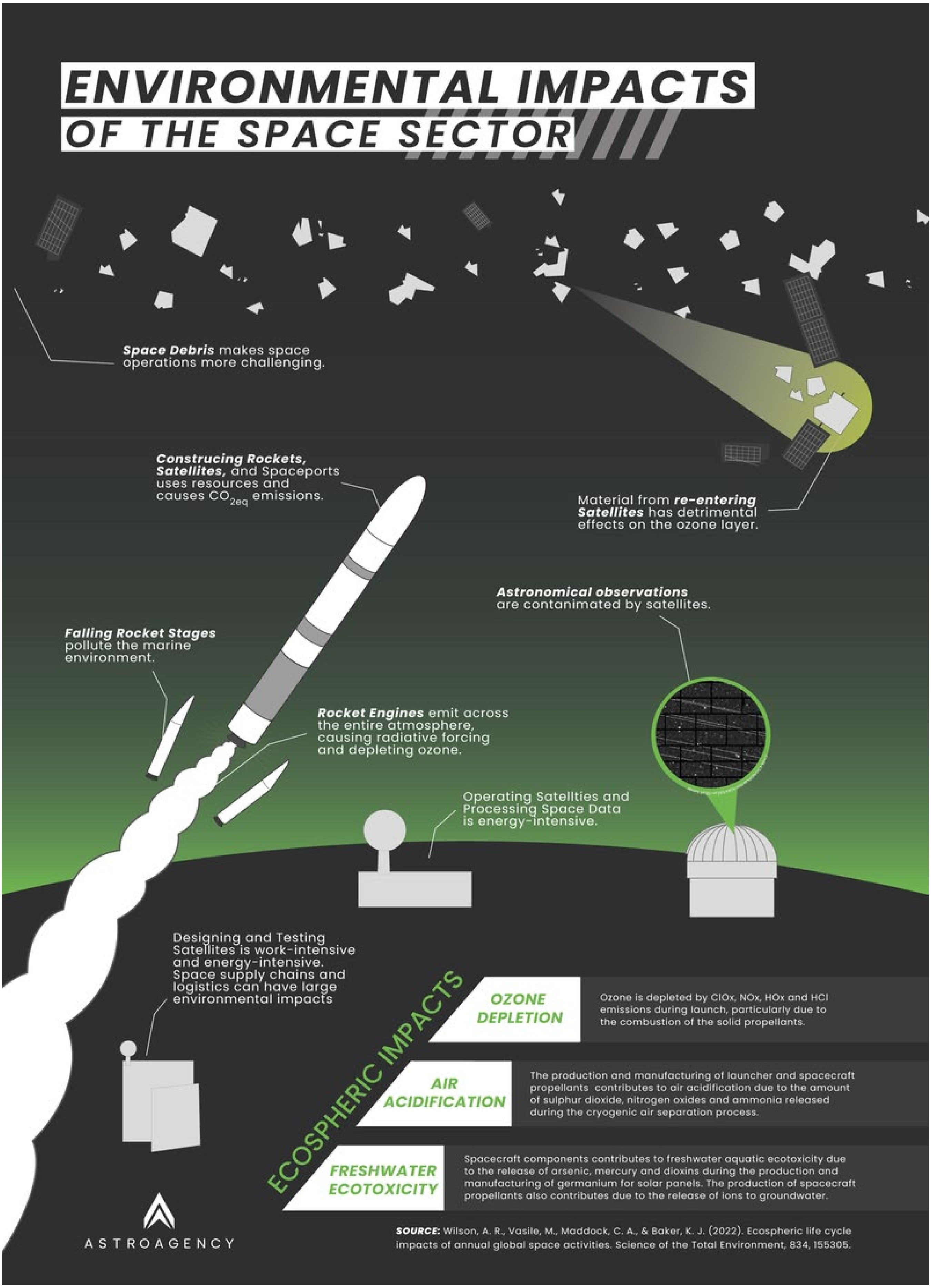

Image source: [Space Scotland Space Sustainability Road Map]

2.2 Consequences for the terrestrial environment, society and culture

Addressing space debris is a critical issue, however, a sole focus on space debris fails to understand how it is connected to a global space market, or even to other aspects of environmental sustainability, for e.g., lifecycle emissions to perform eco-design of space infrastructure. There is a need for a broader, systems-thinking approach to sustainability so that the long-term use and access of space is governed and managed responsibly.

Many commercial space launch providers use a type of kerosene fuel for their engines, known as Liquid Rocket Engines (LREs). In an environmental impact statement for their planned 2020 Mars missions, NASA noted the need for considerable further research into the global impact of LREs on the ozone layer. Global ozone loss from rocket launches will become more concerning as the number of rocket launches increases.

Falling rocket stages can pollute the marine environment. The construction of rockets, satellites and launch pads uses natural resources and emits carbon dioxide, which further leads to ozone depletion. In particular, the manufacturing of fuels contributes to air acidification due to the amount of sulphur dioxide, nitrogen oxides and ammonia released during the process. Therefore, we need an evidence-based approach to performing cost-benefit trade-offs across all parts of a space missions, from the design of satellite payloads to launch and end-of-life. Visit RNZ for more.

The bicultural foundation set in Te Tiriti o Waitangi means having authentic partnerships with tangata whenua, the Indigenous peoples. It means ensuring Māori voices are welcomed and respected at the decision-making stage and on what we choose to do in space – especially when faced with such a wicked problem as the comprehension of sustainability around the space environment. It requires transformative solutions at the intersection of Indigenous knowledges and the common western understanding of space sustainability issues.

However, a recent report authored by leading Māori climate and environmental experts warns that applying an Indigenous lens requires understanding the entire system of customs and practices, rather than appropriating the most desirable values, such as kaitiakitanga, into Government policy. This is to honour Treaty obligations but also to ensure that the integrity of Māori knowledge is not distorted.

Māori are already paving a new way to space and deep tech. They are gaining significant funding and inspiring the next generation of rangatahi (young people) to be space professionals, while simultaneously grounded in their Māori astronomy. Broadening our view of sustainability could be the difference between oppression and recognition of Māori interests in the domestic space sector.

3. Paradigms* of sustainability

In the sustainable development discussion, the environment and commonly available natural resources are expressed as markets and prices. However, there are differences in the interpretations of sustainability and the philosophical and ethical values that guide the interpretations. One example is the categorisation of weak and strong sustainability measured using the idea of capital, assets, or wealth, shown in Figure 1.

Weak sustainability is based on economic value principles, where natural capital (e.g. biodiversity) is not important as it can be substituted with human-made capital (e.g. labour and knowledge) or rely on technological advancements to mitigate negative impacts. In such a system,

* A paradigm is a way of looking at something. This could include models, theories, perspectives or ideas.

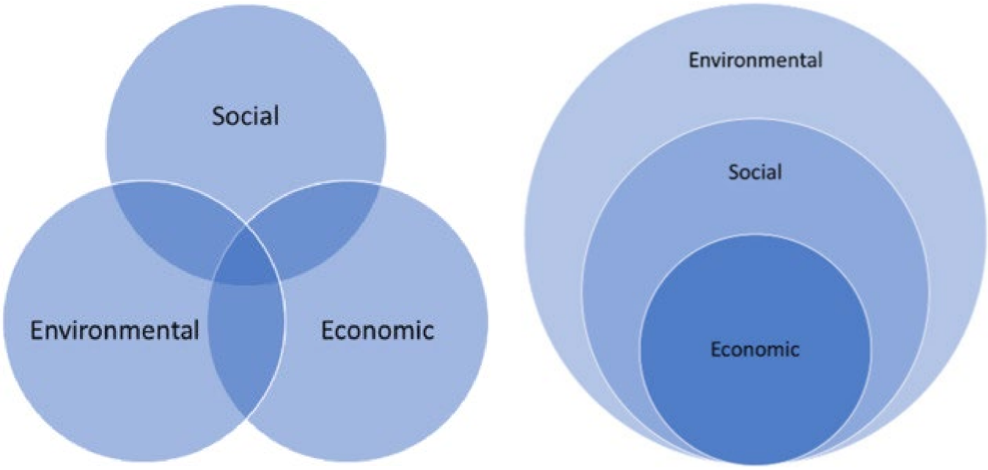

Figure 1: Examples of weak sustainability (left) and strong sustainability (right) paradigms

consumption must be constant over time, so the sum of natural and human-made capital must remain intact. This has been interpreted as the three interdependent 'pillars' or 'domains'. It is the intersection between social, economic, and environmental tradeoffs.

Strong sustainability, however, is based on ecological principles that emphasise the environment and natural capital. For sustainable development for the next generation, natural and man-made capital must remain intact. The economy, environment and social and cultural themes are given different weightings. The environment is given the greatest weighting, indicating that nothing can develop outside of the biosphere. We cannot grow an ocean or a forest from scratch.

But the term "capital" and the capitalistic view of nature brought on by a needs-based perspective is also a limitation of the weak-strong sustainability argument. A generation's needs can change, influencing economic markets. It can also be argued that sustainable development discussions have already shifted from addressing the *needs* of a generation to the *rights* of a generation.

The discussion around sustainability is about power, distribution of wealth, and equity. These interpretations show that the difference in opinion determines the value of what a sustainable space sector could and should look like.

4. Considerations for space sustainability

There have been some clear drivers of change which have led to our contemporary views of sustainability. Those drivers initially arose from an awareness during the environmental movement of specific issues caused by human activities, such as pollution, which further developed into an understanding that whole planetary systems were in fact being impacted, particularly because of our rapidly growing economies. These systems-level impacts, like climate change, are complex challenges that have many interdependencies, and affect all aspects of environment, society, culture and economy.

Responses to such systems-level impacts were initially focused on growth, for example sustainable development concepts. These responses have since matured into a broader, more holistic view of sustainability, which involves recognising and understanding the connections between the needs of society, economy, and our different cultures, as well as the terrestrial and space environment which frames the limits to which we can live and operate in. Hence, there is a need to take broader approaches to address systems-level challenges, not only in developing solutions but also in understanding the issues that we are trying to address, which can lead to strong sustainability approaches.

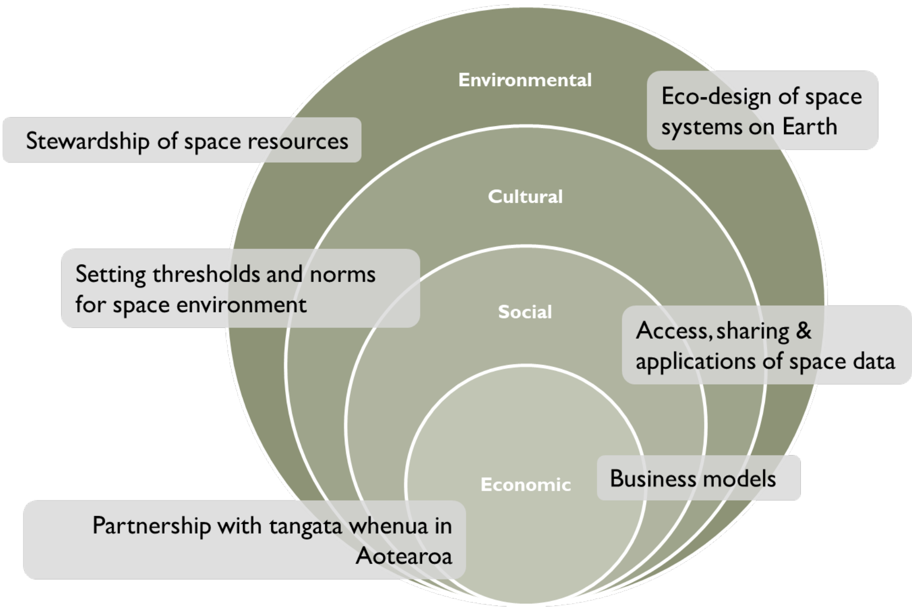

Figure 2: Sustainability considerations for aerospace activity using a strong sustainability paradigm, as a starting point for more comprehensive models.

Arguably, the intersection of space and sustainability is at a similar stage as the environmental movement, where the focus is on specific critical issues, most notably orbital space debris. But as we have experienced on Earth, increased activities in space will result in increased impacts on its varying environments. In Aotearoa New Zealand, we currently have a unique opportunity to think ahead about potential impacts and how we might mitigate those before they become issues, particularly at systems-levels, which could adversely affect the long-term commercial, scientific and cultural value of space.

Clearly, space sustainability is complex and goes beyond the issues brought on by space debris and the overcrowding of usable orbital space.

Space sectors in Aotearoa New Zealand and in other countries could consider the following, also depicted in Figure 2:

- How space-enabled data can be used for terrestrial sustainability (Section **1.1 Aerospace Enabled Data**) This needs more thinking around inclusive business models that allow for public access to and sharing of satellite data, e.g. equitable sharing of climate data between New Zealand and non-spacefaring Pacific nations. It may also require careful considerations of how space-enabled data is used in economic investment and environmental policy decisions.

- The role of Earth in the sustainability (preservation and utilisation) of the space environment (Section **2 Earth for Space**) This may require more international cooperation efforts on UN COPUOS space debris guidelines and reconciling value tensions between economic growth of the commercial sector and lifecycle impacts of space infrastructure.

- Policy design that promotes the sustainability of the Aotearoa New Zealand space sector. Any policies implemented for space activity need to balance private and public interests. Operating from Aotearoa New Zealand should be advantageous for national and international market participants while simultaneously being environmentally responsible and addressing a bicultural approach.

- The definitional frame that will inform the values and scale of space sustainability initiatives (Section **3 Paradigms of sustainability**). This involves social, cultural and environmental considerations in terms of who is involved with defining the norms and thresholds for the space environment, e.g. industry, government, communities and Indigenous peoples.

- How Indigenous knowledges can enable the sector to rethink their sustainable development approach and implement a bi-cultural strategy that honours the constitutional framework. This involves developing genuine, non-transactional, ongoing partnerships and processes for Māori participation, including the expression of tino rangatiratanga (sovereignty) and kaitiakitanga (stewardship). Refer to Sections 5.2 and 6.1 in Annex.

These considerations determine how Aotearoa New Zealand's space policies evolve; therefore, the sector must develop, implement, and adapt its sustainability strategy to attract and retain actors to operate in the country.

It is also a timely opportunity to think of space as a commons – something more than just a resource to exploit. Space is something we all have a stake in, together on our pale blue dot.

"There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known."

Carl Sagan, 1994

A photograph of Earth taken by NASA's Voyager 1 at a distance of 6 billion km from the Sun in 1990, which inspired Carl Sagan's 1994 book, A Pale Blue Dot: A Vision of the Human Future in Space.

Annex

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5. What do we mean by sustainability?

The worsening impacts of climate change and biodiversity loss have taught us that we cannot easily clean up our messes retrospectively and that pollution has inter-generational consequences.

But factoring in sustainability is usually an afterthought as we continue to compromise environmental, societal and cultural wellbeing for the sake of economic development. The ambiguity in what we mean by sustainability is part of the problem. Without clarity, it is difficult to develop techniques and targets for sustainability or to be held accountable for missing them.

5.1 Environmental movement in the West

The second half of the 20th Century, post-World War II, saw the rise of economic development and growth as a policy goal. It promoted optimism as progress raised living standards and affluence, but also a realisation of the wealth gap between developed and developing nations. There was a growing recognition and concern about the damage that scientific and technological progress and industrial expansion was having on the natural environment by the 1960s. Concerns were related to the threats posed by rapid population growth, pollution and resource depletion. This is highlighted in published books like Rachael Carson's 'Silent Spring' (1962), Paul R. Ehrlich's 'The Population Bomb' (1968) and work by Gareth Hardin (1968) in which the Tragedy of the Commons is discussed. From this period, we see the growth of the environmental and green movements, increased depiction of ecological crises in film, media and pop music, as well as the establishment of non-governmental environmental groups such as Greenpeace and Friends of the Earth.

Environmental concerns grew more acute because of fear that economic growth might endanger the survival of the human race and the planet. Most notably, "The Limits to Growth (LTG)" was published by The Club of Rome in 1972. The LTG modelled the interdependency of the economy and the environment and identified the collapse of civilisation. The rapid collapse scenarios could be mitigated if technological advances and social changes could be made early enough.

The United Nations responded to the LTG report by establishing the Brundtland Commission in 1982 and the 'Our Common Future" report in 1987. The purpose of the Brundtland Commission report was to propose strategies that would encourage international cooperation to bring about change and sustainable development. The report highlights the frustration amongst the international community about environmental degradation and the associated economic and social issues. The Brundtland Commission report was widely credited with showing that resources could be managed to bring about intergenerational equity. It defined sustainability as,

> *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs".*

Since the 1980s, the issues that sparked debate and public attention about sustainability continued through to the UN Conference of Environment and Development (UNCED) in 1992, otherwise known as The Earth Summit. The Brundtland Commission report identified that sustainability was not limited to just environmental issues but would be a compromise between the environment and development (ambitions, actions and needs) that would improve the status quo. Decisions for sustainability would be a compromise; often, economic and politically powerful countries would hold that responsibility. The term was a tradeoff between environmental preservation and economic development, understanding that an anthropocentric view was imperative for growth. One could argue that the idea of sustainable development is an oxymoron that market economics imposed on the global environment.

One example of value-driven sustainability plans on the global stage was the Millennium Development Goals (MDG). At the start of the Millennium, the United Nations set eight international MDGs, including several targets to reduce or eradicate extreme poverty and its effects – ensuring environmental sustainability. The General Assembly established these goals on values such as freedom, equality, solidarity, tolerance, respect for nature, and shared responsibility. The MDGs have since been updated to the Sustainable Development Goals (SDGs) with 17 new United Nations approved goals between 2015 and 2030. It is interesting to note that the sustainability of the space sector has not been an issue that has captured the attention of policymakers at this level. While the space sector is considered critical to achieving the SDGs, it has not been the subject of similar scrutiny.

5.2 Indigenous Knowledges†

In Aotearoa New Zealand, cultural wellbeing is tied to the Crown's treaty obligations. It can explain behaviour, what they find desirable, and how people derive meaning from their place in their environment. Indigenous researchers Watene and Yap emphasised that sustainable development often excludes culture and its value for Indigenous peoples and their survival. This contrasts with the value of culture, which is often seen as a commodity and measured by profitability in aspects like tourism, cultural performances, and art.

An Indigenous way of thinking provides a framework for collaborating across disciplines because its practice is embedded in intergenerational self-determination and interconnections between the people, environment, and the larger community.

Te Ao Māori (Māori worldview) considers land, resources, knowledge and tikanga (customs) as taonga or treasures that require kaitiakitanga (guardianship) or protectors. The Māori view of the world is inherently interconnected, intergenerational, and sacredly holistic, where the health of the natural world and its resources are connected to their wellbeing, spiritually and physically. The environment's mauri (life force) is central to understanding the importance of the relationships, their genealogy from Ranginui and Papatūānuku, and the spiritual connection that binds them. The Rauora framework, commissioned by the Ministry for the environment, acknowledges that the Māori knowledge system is not based on the minimum level of operation needed for survival. The framework defines relationships through a lens of abundance, how wellbeing contributes to identity and a premise that the colonial mindset is grounded in consumerism and exploitation, leading to an extractive economy.

In te ao Māori, the idea of sustainability is not rooted in an extractive economy, but arises from a relational view of the world (Kennedy et al., 2020).

> *"It appears that Indigenous knowledge differs from scientific knowledge in being moral, ethically based, spiritual, intuitive and holistic; it has a large social context. Social relations are not separate from relations between humans and non-human entities. The individual self-identity is not distinct from the surrounding world. There often is no separation of mind and matter. Traditional knowledge is an integrated system of knowledge, practice and beliefs (Berkes et al., 1994, p.283)."*

† Disclaimer: I am neither Māori nor hold expertise in topics related to Indigenous knowledges or knowledge systems. I am aware and acknowledge the complications about writing in and around an Indigenous framework.

The Mauri Model (Figure 3.) was developed by Kēpā Morgan (2004) for the region of Tauranga, Aotearoa New Zealand. The model uses the region's values for water management to inform an evaluation tool, which can then be used to assess how actions impact the mauri of each domain. For e.g., to determine if a rāhui (prohibition) is placed on an area or a resource that is under threat. The mauri model considers the wellbeing of the various aspects and embeds the value of culture. The mauri of the environment is prioritised over the hapū, community or the individual, demonstrating the relationship with the environment due to its mana (prestige).

It can be argued that the western view of sustainability is anthropocentric at its core and will still allow exploitation for economic gain. Economic growth highlights sustainable development, whereas a Māori perspective considers the effect on the interdependent human nature of relationships. From Figure 3, when natural resources and the environment are not looked after, their mauri is weakened. The interconnectedness of the domains of wellbeing represents a holistic systems approach and highlights the broader impacts of our activities.

6. What do we mean by space?

Human have always looked up and outwards. So when we describe "space," we might mean the night sky and our observations of the objects in it. Or, we may mean Earth's orbital environment and beyond – and our activities in this "space". Once again, clarity on what we mean helps us understand what is being included and what is being excluded, so we better understand the value of space - and account for it in our sustainability models.

6.1 A repository of Indigenous knowledges

For millennia, the night sky has been a sacred environment, a repository of knowledges and a source of connection for people. It is now threatened by increasing light pollution from mega constellations of satellites and accumulating space debris.

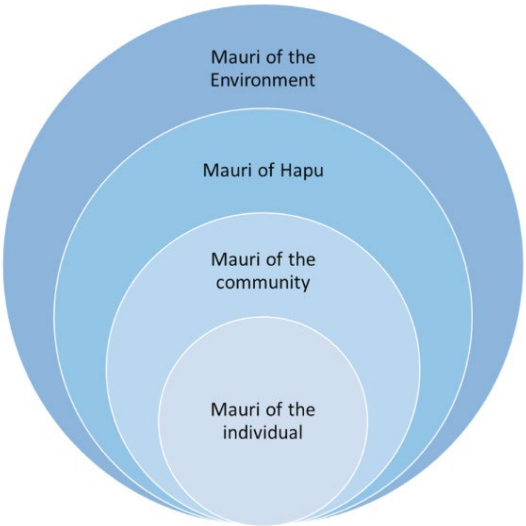

Figure 3: The Tangata Whenua Mauri Model by K. Morgan (2003)

In Australia, Aboriginal oral traditions provide a unique insight into what the sky may have looked like more than 10,000 years ago – and what that teaches us about human history. In Aotearoa, the ongoing revitalisation of Māori astronomical traditions symbolises the necessary bicultural constitutional foundations, as set out in Te Tiriti o Waitangi, for a rapidly emerging space sector.

An example of mātauranga Māori (Māori knowledge) in relation to space is the Maramataka. The Maramataka is a stellar, lunar, ecological calendar developed by Māori. It was used to guide the planting and harvesting of crops, fishing and hunting. Maramataka translates as 'moon rotating'. The phases of the moon were combined with the movement of the sun and stars, along with other environmental and biological indicators to track the passage of time. It continues to provide a connection to ancestral knowledges and promotes tikanga (customs).

> *"When I look up into the sky, that's the same sky that my ancestor viewed. I love the narratives of the stars... their meanings and their purpose."*
>
> *– Dr Rangi Mātāmua*

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6.2 Where does space begin?

An ongoing challenge for any international treaty or legislation, and crucially for understanding sustainability in the context of space, is that no globally accepted boundary separates a country's airspace from outer space. There are several arguments that make it a complicated geopolitical issue for international lawyers to determine where national exclusivity of space ends. A recent review of internationally used boundaries places 80 km above mean sea level as the lowest altitude used by NASA and the US Military. This boundary is different from the commonly accepted definition of 100km above mean sea level, known as the Kármán line.

An example of geopolitical challenges comes from the international community's failure to recognise the Bogotá Declaration of 1976, where the equatorial countries of Brazil, Colombia, Congo, Ecuador, Indonesia, Kenya, Uganda, and Zaire claimed sovereignty over the geosynchronous earth orbit (GEO) territories above their countries' marked airspace. The most considerable contention to the Bogotá Declaration was from the western industrial powers of the 1970s and demonstrates how space powers and dominating actors influence space law. It also illustrates how the ownership and control of space continues to be influenced by colonial thinking, despite space being a global commons.

Aotearoa New Zealand's approach to defining outer space is not necessarily straightforward as legislation for space activities are enacted at altitudes above flight level 600 (approximately 18,288 m) and above the upper limit of controlled airspace. However, the Outer Space and High-altitudes Activity Act 2017 does not actually define "outer space" as it does for high-altitude activities. Operating in the commercialised space industry requires boundaries for space sustainability activities (local, national, global, solar system) to inform key decision makers about the values and geopolitical tensions that need to be considered for national space sustainability strategies. Therefore, solving the issue of "where does space begin" requires a transdisciplinary approach by players within space policy, politics, law, science, and technology. The need for boundaries might only heighten as national sovereignty is threatened with the growth of the space industry.