




Examining possible future trajectories of global space sectors

Ronda Geise^{*} , Priyanka Dhopade

University of Auckland, Auckland CBD, Auckland, 1010, New Zealand

ARTICLE INFO

Keywords:

Space sustainability
Futures studies
Space governance
Geopolitics

ABSTRACT

Governments have a significant influence in shaping the trajectory of the space industry as investors, operators, regulators and customers. This research analyses the space strategies of twelve governments around the globe, mapping them onto four potential future scenarios. Based on these scenarios, the authors suggest actions towards an equitable future of Earth-Space sustainability. Results indicate that Brazil and Russia lean towards a scenario where space is seen as a limitless resource to be marketed, neglecting environmental sustainability. Europe, the African Union and India tend to utilise space for national development and sustainability on Earth, but not in space. The USA leans towards viewing space as a new paradise for settlements, assuming Earth's uninhabitability is inevitable. China and Germany are inclined to regard Earth as part of a larger system, prioritising the inter-connected sustainability on Earth and in space. France, the UK, New Zealand and Australia fall in between multiple scenarios.

List of abbreviations

Abbreviation	Meaning
CLA	Causal Layered Analysis
CNES	Centre National d'Études Spatiales
COPUOS	United Nations Committee on Peaceful Uses of Outer Space
DOGE	Department of Government Efficiency
ESA	European Space Agency
GDP	Gross Domestic Product
MBIE	Ministry of Business, Innovation & Employment
R&D	Research and Development
SMEs	Small and Medium-sized Enterprises
UN	United Nations

1. Introduction

“What we excel at becomes our downfall. And we do not see this because we are busy focusing on our strategic plans.”

– Sohail Inayatullah (2008)

This quote from the Futures Studies researcher Sohail Inayatullah holds relevance for the space sector. Valued at 570 billion USD in 2023, the global space economy increased by 7.4% from 2022 and appears to be excelling. Over the last five years, the sector has averaged a growth rate of 7.3% per year. Compared to its value ten years ago, it has almost

doubled (Space Foundation, 2024). This is reflected by a significant increase in the number of spacecraft in recent years, which is accompanied by a drastic rise in the number of orbital debris: As of 2024, around 35,000 objects are tracked. 9100 of these are active spacecrafts, while around 26,000 are orbital debris larger than 10 cm. When counting all debris larger than 1 cm, the number rises to over one million (ESA, 2024). Orbital debris encompasses “all [...] [human-made] objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional” (OECD, 2020, p. 19). These objects hinder the operation of spacecrafts and thus put missions at risk (Eberle et al., 2023; Eberle and Sebesvari, 2023; Bickerton et al., 2024). The self-sustaining nature of space debris due to collisions causing further debris could potentially lead to the worst scenario described as the ‘Kessler syndrome’, in which certain orbits become unusable and access to space limited (OECD, 2024). Interpreting this through Inayatullah's words, this could become the “downfall” of the space sector. Instead of solely focussing on strategic plans, he suggests taking ownership of one's action in the present and prioritising the steps necessary to realise the strategic plans through allocating appropriate resources. He emphasises that “the vision must link to the day-to-day realities [and] our day-to-day measures must reflect the vision” (Inayatullah, 2008, p. 6). This also means adapting current measures to changing conditions. One approach to achieve this is through Futures Studies. Exploring potential futures can reveal desirable and undesirable possibilities and allows shaping today's actions in a way

^{*} Corresponding author.

E-mail addresses: rgei304@aucklanduni.ac.nz (R. Geise), priyanka.dhopade@auckland.ac.nz (P. Dhopade).

<https://doi.org/10.1016/j.esg.2026.100324>

Received 24 June 2025; Received in revised form 28 February 2026; Accepted 11 March 2026

Available online 6 April 2026

2589-8116/© 2026 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

that leads to a desirable future (Inayatullah, 2012; Cuhls, 2003).

This research aims to explore potential futures of global space sectors, providing the basis for defining a desirable future and actions that need to be taken to achieve it. It thus centred on analysing how governments around the world visualise the future of space and space sustainability and how this shapes the future space sector. Drawing upon these findings, suitable governmental approaches to cultivate an equitable future of Earth-Space sustainability are explored, which was found to be a desirable future for the global collective.

The paper is structured as follows. Section two provides a literature review, examining sustainability issues of the space sector, their root causes and underlying worldviews as well as the research field of Futures Studies and its application to the space sector. The third section explains this research's methodology. The results are presented and discussed in section four, while the fifth section summarises the conclusion of this paper's findings.

2. Literature review

2.1. Root causes for sustainability issues

In 1987, the United Nations Brundtland Commission defined the term 'sustainability' as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). Besides the accumulation of space debris and orbital congestion, the space sector's sustainability issues include detrimental effects on Earth through rocket launch emissions as well as particles arising from reentering spacecrafts (Miraux, 2022; Bickerton et al., 2024). Uncontrolled reentries of upper rocket stages pose risks to people on the ground, at sea and in aeroplanes (Byers et al., 2022). Satellites contribute to light pollution by creating an indistinct starlight background that reduces the visibility of celestial objects and negatively affects wildlife, human health, astronomical research and the night sky heritage (Kocifaj et al., 2021; Zielinska-Dabkowska and Xavia, 2021; DarkSky International, 2024). Dark night skies are the basis for millennia-old sky traditions, mythology and storytelling for many Indigenous Peoples and ancient cultures, thus being intangibly valuable (Venkatesan and Barentine, 2023). One example is the practice of wayfinding in Polynesian cultures as part of traditional navigation that relies on stars (Eberle and Sebesvari, 2023).

One of the root causes for these issues are global demand pressures due to the digitisation of services. Specifically in rural areas where terrestrial systems might not provide high-speed Internet connectivity, satellites serve as an accessible alternative. Since the sector's sustainability issues are of a global nature, international collaboration is essential for addressing them. However, collaboration is often lacking due to competition or legal and geopolitical disputes (Eberle and Sebesvari, 2023). The insufficient collaboration is also noticeable on a policy level. The current global governance regime is largely fragmented and lacks enforcement mechanisms (Yap and Truffer, 2022; Isnardi, 2020). This is exacerbated by an increasing reliance on the private sector, resulting in a mutual reinforcement of privatisation and fragmentation (see Fig. 1). Due to the lack of a cohesive institutional framework, private actors are able to implement their own – mostly growth-driven – rules, also referred to as self-driven governance. This leads to an unjust exploitation of space resources and in turn creates further institutional fragmentation, where the cycle begins again (Yap and Kim, 2023) (see Fig. 2).

Apart from the increasing reliance on the private sector, the fragmentation can also be attributed to Earth's orbits and the electromagnetic spectrum being 'common pool resources', meaning that no single actor can establish control over the good and that the usage by one actor reduces the amount available to others. This can lead to space being taken advantage of by individuals that strive for short-term gains, compromising its long-term sustainability as well as causing over-exploitation and degradation in the process. This phenomenon is

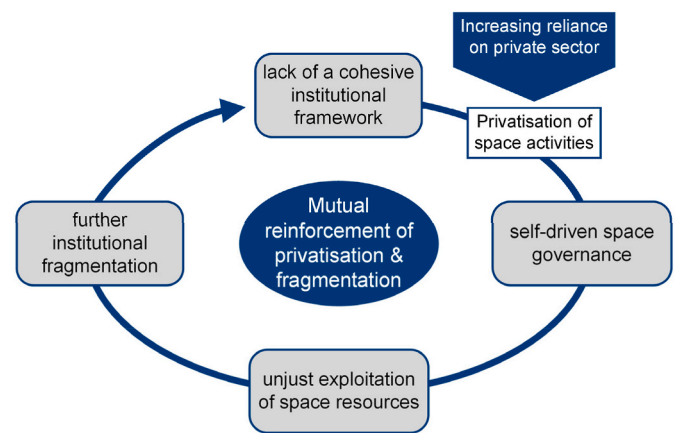


Fig. 1. Mutual reinforcement of privatisation and fragmentation in space governance, own illustration based on (Yap and Kim, 2023).

referred to as the 'tragedy of the commons'. Market mechanisms for managing common pool resources are "highly imperfect or completely absent" (OECD, 2020, p. 16), necessitating the implementation of institutions and rules for the governance of common global resources. When formulating regulations it needs to be taken into account that they might increase the costs of space activities and thus restrict access for certain actors like low-income countries (OECD, 2020; Eberle and Sebesvari, 2023).

Related to this is another root cause of sustainability issues: colonialism, which is defined as "the practice of extending and maintaining a nation's political and economic control over another people or area" (Merriam-Webster Dictionary, n.d.). Access to space is not equitable as orbits are being claimed and congested by nations with spacefaring capabilities, thereby excluding those who are not yet able to conduct orbital launches (Eberle and Sebesvari, 2023). Excluded nations are thus not able to meet their needs e.g. for national missions, which is not sustainable according to the UN sustainability definition cited above. This is exacerbated by actors using colonisation rhetoric (Venkatesan et al., 2023). For example, Elon Musk, who aims to build a Martian city with the means of his company SpaceX, claims that "if we can establish a Mars colony, we can almost certainly colonise the whole Solar System, because we'll have created a strong economic forcing function for the improvement of space travel" (Robson, 2014).

2.2. Indigenous Māori worldviews

Futures Studies describes the "systematic study of possible, probable and preferable futures" (Inayatullah, 2012, p. 37), which includes the worldviews underlying each future. One method to look beyond immediately visible developments to unravel root causes and underlying worldviews is the 'causal layered analysis' (CLA, see section 3.1) (Inayatullah, 2008). Central to this approach is challenging existing power structures, which is particularly relevant for this research, given that colonialism is one of the root causes for sustainability issues in space (see section 2.1). Integrating diverse ways of knowing allows new and alternative futures to emerge (Inayatullah, 2009).

Since this research was conducted at a New Zealand university, this exploration of Indigenous worldviews focusses on Māori worldviews, Aotearoa New Zealand's Indigenous population. Māori culture and society have significantly shaped New Zealand's history and politics, including contemporary discussions around co-governance and 'Te Tiriti o Waitangi' (the 'Treaty of Waitangi'), an agreement between Māori and the British Crown from 1840 (Varughese et al., 2023). Māori worldviews thus not only offer alternative ways of knowing but have also informed the authors' personal lenses. It should be noted that the authors are not Māori and do not hold expertise in topics related to Indigenous

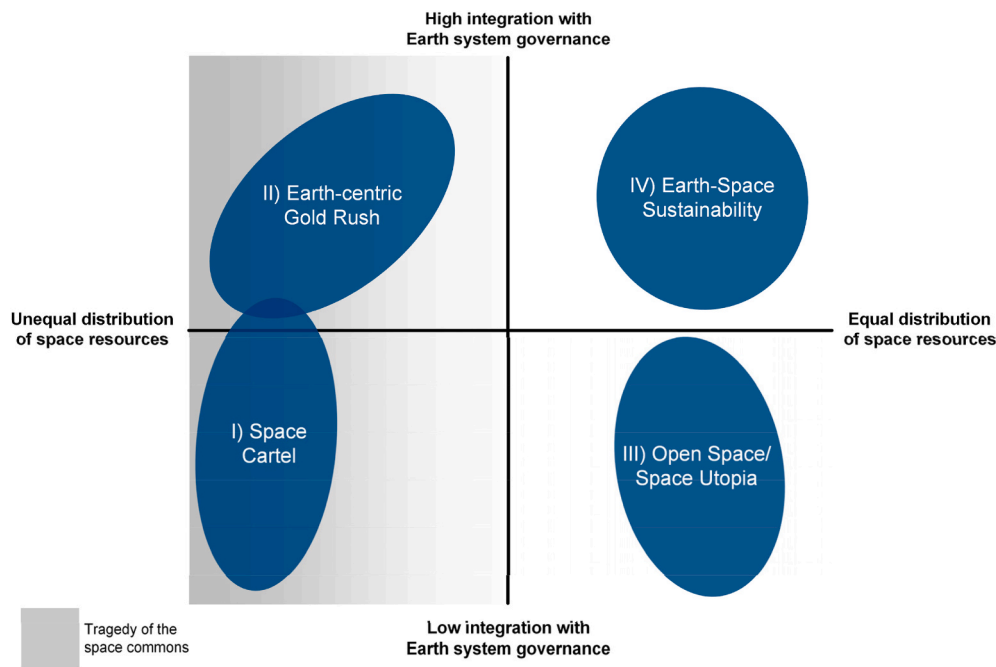


Fig. 2. Four alternative scenarios on the future of commons in space (Yap et al., 2023).

knowledges or knowledge systems. The authors are aware of and acknowledge the complications about writing in and around an Indigenous framework.

“Reciprocity amongst Māori peoples and the natural world” (Rewi and Hikuroa, 2023, p. 1) forms the basis of Māori worldviews. Acknowledging that Indigeneity is defined in various ways, one similarity is the emphasis of the interconnectedness of humans and the natural world. Disturbances in this relationship and the exclusion of Indigenous resource management practices negatively impact Indigenous health and well-being. Central to this are the genealogical ties amongst humans and the environment, understood as ‘whakapapa’. It describes a network of relationships between the human, natural and spiritual world as well as the living, their ancestors and their descendants (Lythberg and Woods, 2016). Hence, it promotes “reciprocity, responsibility, and respect” (Rewi and Hikuroa, 2023, p. 1). The evolvement of the whakapapa of life is seen as an ongoing process based on mutual exchanges between diverse life forms within an “all-encompassing set of kin networks” (Salmond, 2021). Such perspectives can contribute to unique environmental management approaches that strive to establish balance between natural resources and life forms. In the context of whakapapa, this decision-making takes ancestors and future generations into account (Rewi and Hikuroa, 2023; Lythberg and Woods, 2016). It can thus be described as “the practices informed by centuries of observation of achieving the principle of intergenerational sustainability” (McAllister et al., 2023, p. 3).

Worldviews such as those of Indigenous Māori can provide alternatives to the dominant colonial frameworks and should be considered when developing desirable future scenarios and outcomes for space governance.

2.3. Futures Studies in the context of space governance

Possible futures can be studied through the development of different scenarios, taking into account the uncertainty of the future. Establishing these alternatives allows determining a desirable future and the necessary steps to get there (Inayatullah, 2008). Yap et al. (2023) adopted the method of scenario generation to the space sector. They utilised the deductive method of intuitive logics scenario building, identifying two critical uncertainties that are causally independent and thus generating

a two-by-two matrix. As the first factor, the researchers defined the ‘governance of resource access and distribution’, plotting it on the x-axis. This dimension is marked by two opposing extremes, with unequal distribution on one side and equal distribution on the other. The second factor, allocated to the y-axis, is the ‘integration of space resource governance with Earth system governance’, ranging from low to high integration. Earth system governance is defined as managing societal development within Earth system boundaries while ensuring global justice. The emerging scenarios were then further described with a range of descriptors including actors, behaviours, events and chronological structures. Additionally, underlying causal processes were examined to offer new perspectives regarding the future, challenging conventional mindsets (Yap et al., 2023). The resulting matrix is shown in the figure below.

The first scenario is the SPACE CARTEL, located at the bottom left. It describes a scenario where space resources are primarily ruled by rich and technologically advanced private actors. Scenario two is an EARTH-CENTRIC GOLD RUSH, located on the top left. The ‘Gold-Rush’ mentality shows in the way that a mix of public and private actors is competing for space resources on a ‘go get it as fast as you can’-basis. Developments on Earth are undertaken at the expense of sustainability in space, ultimately restricting future use of space. The third scenario on the bottom right is called OPEN SPACE (also SPACE UTOPIA). Space benefits on Earth are unequally distributed because activities in space are disconnected from sustainability considerations on Earth, leading to the depletion of Earth-bound resources. Located on the top right is the fourth scenario of EARTH-SPACE SUSTAINABILITY, primarily characterised by an internationally shared sustainability goal in a multi-planetary context amongst all space actors. This goal encompasses sustainability challenges both on Earth and in space through an integrated Earth-Space governance model. Justice and equity are prioritised over economic growth and profit (Yap et al., 2023). Thus, this scenario closely aligns with the United Nations sustainability definition of “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations, 1987). As such, it can be considered as a desirable future for the global collective.

For this study, the alternative scenarios provided a suitable framework for examining governmental strategies, their implications for space sustainability and the trajectory of their countries’ space sectors,

while delving further into the worldviews informing the strategies through a causal layered analysis (Inayatullah, 2008).

3. Methodology

Answering the research question of governmental visions for the future of the space sector was approached in three steps: First, the four future scenarios of the space sector envisioned by Yap et al. (2023) were analysed in greater depth, utilising the framework of the ‘causal layered analysis’ developed by Inayatullah (2008). Secondly, a quantitative content analysis of space strategy documents published by different governments was conducted, informed by the insights from the CLA and a previously conducted qualitative content analysis (Geise and Dhopade, 2024). Finally, the content analysis results were mapped onto the four future scenarios of the space sector developed by Yap et al. (2023).

3.1. Causal layered analysis

The causal layered analysis not only provides insights regarding surface-level developments but also deep-rooted causes and underlying worldviews. CLA visualises the future as a pyramid (see Fig. 3) (Inayatullah, 2008).

Moving from top to bottom, the four layers gradually increase in their depth and the steps required to achieve changes on these layers become more long-term. At the top, ‘litany’ encompasses the most visible and thus external observations of reality (Inayatullah, 2017). The second layer explores systemic causes from an economic, cultural, political and/or historic perspective. Thirdly, deeper assumptions are explored in the form of worldviews. Lastly, layer four adds a “gut/emotional level experience to the worldview” (Inayatullah, 2009, p. 8) by creating visual images with metaphors/myths. When using CLA, the layers should not be considered in isolation. If the story is changed only on the worldview or metaphor layer without adapting the system and litany level, it remains a story. Likewise, if only the litany level is addressed, the problem will arise again in the future. Hence, all layers need to be addressed to effect long-lasting change (Mulligan et al., 2024).

The reason for conducting the CLA was twofold: Differentiating the scenarios into the different layers informed the subsequent category definition for the content analysis and enabled recognising indicators for governments’ underlying worldviews rather than just focussing on their visible actions and decisions. Secondly, it provides the basis for

holistically effecting change since all layers in the pyramid need to be addressed for long-lasting change (Mulligan et al., 2024). For example, if the problem of space debris is solely addressed on a litany level, ways of cleaning it up will be introduced without solving the root causes. Due to the lack of an incentive for avoiding debris accumulation in the first place, it is likely for more debris to be created since actors are convinced that “somebody will clean it up”. This is rooted in the worldview that littering space is considered acceptable.

CLA was implemented in this project by sorting Yap et al.’s (2023) scenario descriptions into the different layers as well as adding suitable metaphors on the fourth layer. For example, the impact on Earth’s and the space environment were classified as the litany level since it can be observed externally. Governance aspects like stakeholders or frameworks (e.g. multilateralism) were sorted to the second layer as systemic causes, while e.g. the perception of Earth and space as interconnected was identified as a worldview. Based on this structured understanding, metaphors were added for each scenario. The results are presented in section 4.1.

3.2. Content analysis

The schematic process of conducting a content analysis is illustrated in Fig. 4.

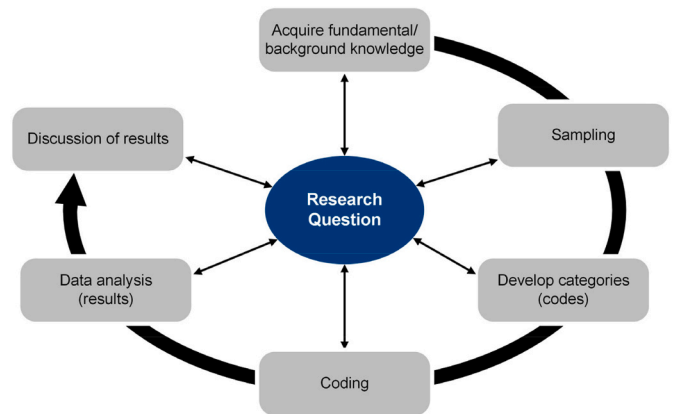


Fig. 4. Schematic process of a content analysis, based on (Kuckartz, 2018, p. 45; Drisko and Maschi, 2015, pp. 97–113).

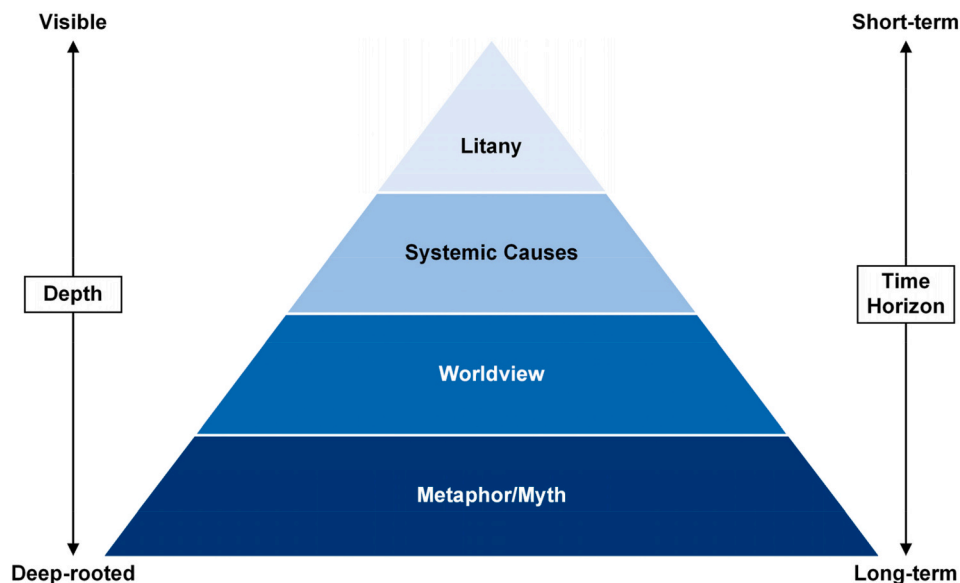


Fig. 3. Causal Layered Analysis (CLA) Pyramid, adapted from (Inayatullah, 2009).

The acquisition of background knowledge is an essential first step and informs the subsequent steps, particularly the category development. Sampling describes the process of selecting the material to be analysed and is dependent on the research question, which also determines the themes that need to be analysed and thus represented by the categories. These can be developed in different ways: deductive category development is based on existing literature and thus independent of the content that is being analysed, whereas inductively developing categories directly draws on the empirical material. Both approaches can be combined to deductive-inductive category development, which can be implemented through commencing coding with a defined set of categories that is iteratively refined while analysing the material (Drisko and Maschi, 2015; Kuckartz, 2018).

For the current study, a quantitative content analysis of government strategies was conducted. Despite increased interactions with the private sector, space as a domain, continues to have high levels of state involvement due to its strategic, regulatory, and security dimensions, as well as its reliance on public funding and international governance. Consequently, government-authored strategies, white papers, and policy statements provide the most authoritative description of long-term priorities, policy assumptions, and intended institutional interventions. Twenty documents from 12 major spacefaring states and regional organisations were selected for the current study, shown in Fig. 5.

As per the latest space economy data, government space budgets as a share of gross domestic product (GDP) remain concentrated among a subset of countries (OECD, 2020). For example, The United States and Russia traditionally allocate more than 0.2% of gross domestic product (GDP) to space activities, with France exceeding 0.1 % and other significant contributors including China and India (OECD, 2020). These investments imply extensive civil, defence, and innovation agendas. Thus, the selected entities exert substantial influence on global space governance and market formation through government spending on their space and research and development (R&D) budgets.

There is a plethora of available of policy statements and white papers pertaining to these spacefaring countries and organisations; for instance, the OECD Space Portal lists 222 documents worldwide and 110 documents for the 12 selected countries (OECD, 2026). The current study focussed specifically on government-authored documents that articulated long-term visions encapsulating underlying values and worldviews, as well as planned actions. This directly relates to the conducted causal layered analysis and allows analysing governments' stances on

the four pyramid layers. Countries were also chosen due to their relative influence within their geographic regions. For instance, while China and Japan spend a similar percentage of their GDP on their space budgets, China is the largest economy and military in the Asia Pacific (Silver et al., 2024) and therefore exerts more influence than Japan. Similarly, the African Union was included due to its emerging influence, e.g. the African Space Agency was formed in Cairo in 2025 (bne IntelliNews, 2025). Australia and New Zealand (NZ), while spending less than 0.01% of their GDP on space, constitute a significant influence in the Oceania region, with NZ having conducted the fourth highest number of launches in the world in 2023 (New Zealand Government, 2024).

Due to a lack of recent and publicly available information, two African space industry reports and the Russian space industry are exceptions to the government-authored inclusion criteria (Space in Africa, 2023a; 2023b; Luzin, 2024). These secondary sources were published by a consulting company and a foreign policy research institute respectively.

While there is a small sampling bias among the selected countries and documents, collectively, these 20 documents constitute a diverse mix of influence both economically and geographically. They provide a reasonable view of the current state and future trajectories of the major spacefaring nations and organisations, as well as a view towards the trajectory of the global space sector.

The United States of America (USA), China, Russia and European Union (EU) were analysed as key players in the space sector. The latter was studied based on ESA documents since the member countries significantly overlap. For NZ, strategy documents from both 2023 and 2024 were analysed as the latter was published during the course of this research. Due to the United Kingdom's (UK) membership of ESA but not the EU and its close relations to New Zealand, it was analysed separately. France and Germany were individually included in the analysis as specific EU examples and due to close relations with New Zealand. Brazil was chosen since it is the largest participant in the Latin American space sector (Guzman, 2021).

Using the software 'NVivo', the twenty documents were analysed, the majority of which were primary sources published by governments between 2019 and 2024. A list of all twenty documents can be found in Appendix 28 and in the replication package (Geise and Dhopade, 2025).

The categories were based on a prior qualitative content analysis using the deductive-inductive method developed by the authors. For example, one inductively developed category was 'goals for space activities', consisting of sub-categories like 'workforce development',

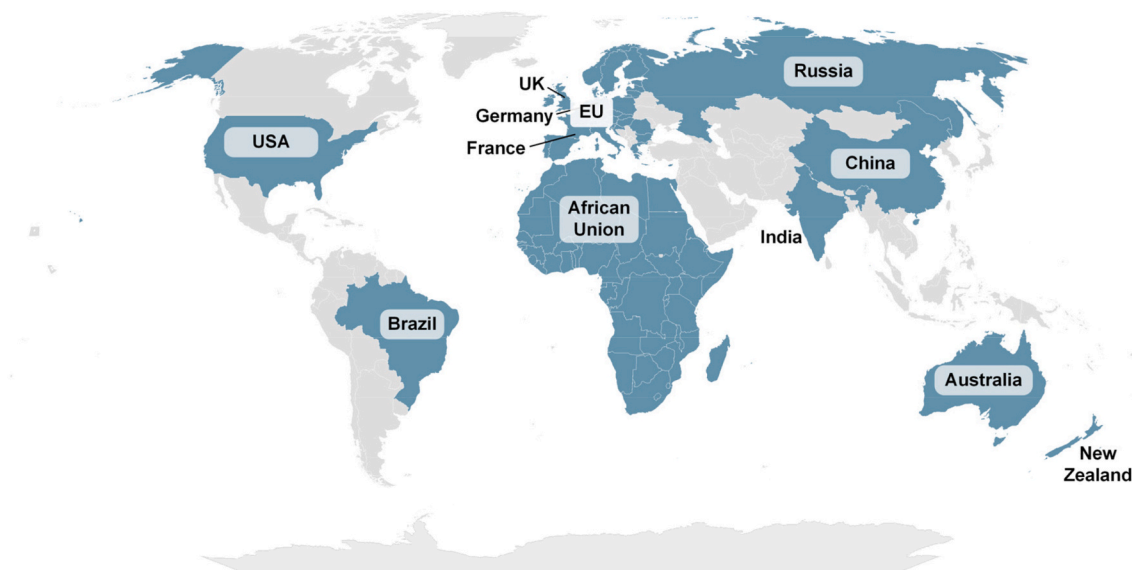


Fig. 5. Selected governments for the analysis.

‘diversity and inclusion’ and ‘indigenous rights’ (Geise and Dhopade, 2024). Detailed category definitions are provided in Appendix 1 to Appendix 21 as well as in a replication package (Geise and Dhopade, 2025). For the coding process, keywords were defined as indicators for each code. These keywords were informed by the priorly conducted content analysis as well as the background knowledge acquired through the literature review. A list of these keywords is provided in Appendix 22 to Appendix 27. The list is not exhaustive and only provided a starting point. Whether a passage matched to a category was inferred from the context. All documents were still thoroughly read and coded to cover all passages missed by searching for the keywords.

3.3. Scenario mapping

The scenario mapping approach is based on the decision matrix method used to evaluate 2x2 matrices for decision making (Lowy and Hood, 2004). This method was adapted to Yap et al.’s (2023) scenario matrix by developing the scoring system outlined below.

First, the future scenario descriptors developed by Yap et al. (2023) were matched with the previously defined coding categories as provided in Table 1. Based on the relevant categories, specific coding indicators were derived. For example, five categories were deemed relevant for the descriptor ‘Actor composition of governance’. To capture the different attributes of this descriptor for each scenario as defined by Yap et al. (2023), three coding indicators were defined. One of them was ‘Developing Economies (Proportional)’. ‘Proportional’ in this case means ‘in proportion to all relevant categories of a specific descriptor’. The coding indicator ‘Developing Economies (Proportional)’ is thus calculated as follows:

$$\text{Developing Economies (Proportional)} = \frac{\text{Developing Economies}}{\sum \text{All Actors}} = \frac{\text{Developing Economies}}{\text{Startups \& SMEs} + \text{Lrg Co.} + \text{Govts} + \text{Dev.Econ.} + \text{Int.Orgs}} \quad (1)$$

Some coding indicators covered multiple scenario descriptors, which is why only nine out of the eleven descriptors were used for the analysis to ensure equal weighting.

Since the length and word-count of the strategy documents is not

standardised, a coding ratio was defined to compare the documents against each other:

$$\text{Coding Ratio} = \frac{\text{Number of Words Coded}}{\text{Total Word Count}} \quad (2)$$

As some governments were analysed based on multiple documents, the total word count was calculated as the sum of each document’s word count per government. Each document’s word count was standardised by subtracting irrelevant content. Irrelevant content comprised tables of contents, glossaries, lists of abbreviations and definitions, acknowledgements, contacts, copyright, references, lists of contributors and authors, board of director, government composition, and governmental agencies since not every publication across the analysed governments included these segments. Additionally, New Zealand was the only government combining space and advanced aviation in its strategy. Since aviation is not part of this project, it was not coded and the parts addressing it were subtracted from the word count. The total number of relevant words per government is provided in Appendix 29 as well as the replication package (Geise and Dhopade, 2025).

Following the content analysis, a scoring-system was developed to map the governments onto the four scenarios. In this system, Yap et al.’s (2023) two-by-two scenario matrix was overlaid with a coordinate system to allow placing each government onto the matrix. Governments’ coordinates were constructed through an indicator-specific analysis: Through analysing their tendencies towards the four scenarios separately for each indicator, a sub-total x- and y-axis score per indicator was derived. Given that Yap et al. did not specify how the scenario descriptors relate to the matrix’s horizontal and vertical axis, all nine analysed descriptors were deemed relevant for both axes. The minimum and maximum score was arbitrarily defined as -1 and +1 respectively

Table 2
General Scoring System for each Coding Indicator depending on the Four Scenarios.

Axis	Space Cartel	Earth-centric Gold Rush	Open Space/Space Utopia	Earth-Space Sustainability
X	-1	-1	+1	+1
Y	-1	+1	-1	+1

Table 1
Matching the content analysis codes to the scenario descriptors.

Scenario Descriptor	Relevant Categories	Coding Indicators
Actor composition of governance	Start-ups and SME’s Large Companies Governments Developing Economies International Organisations	1.1) Developing Economies (Proportional) 1.2) International Organisations (Proportional) 1.3) Ratio of ‘Start-ups and SMEs’ to ‘large companies’
Governance characteristics	Multilateral and/or Global Minilateral Bilateral	2.1) Multilateral and/or Global (Proportional) 2.2) Ratio of proportional ‘bilateral’ to proportional ‘minilateral’
Industry structure	Economic Sustainability	3.0) Economic sustainability
Space-based or ground infrastructures	Space as Common Global Resource Ownership Equity as a priority	4.1) Space as Common Global Resource 4.2) Ownership 4.3) Equity as a priority
Global justice and/or development gap	Diversity and Inclusion Indigenous Rights Sustainable Development Goals (SDGs)	5.1) Diversity and Inclusion 5.2) Indigenous Rights 5.3) sustainable Development Goals (SDGs)
Strategies of private actors	Profit-driven Incentives Value-driven Incentives	6.0) Ratio of ‘profit-driven incentives’ to ‘value-driven incentives’
Impact on Earth’s environment	Sustainability on Earth Using Space for Earth’s Sustainability Impact of Space Activities on Earth	7.0) Sustainability on Earth in combination with ratio of ‘using space for Earth’s sustainability’ to ‘impact of space activities on Earth’
Impact on Space Environment	Sustainability in Space	8.0) Sustainability in space
Earth-Space inter-dependency	Sustainability on Earth Sustainability in Space	9.0) Ratio of sustainability on Earth to in space

for each coding indicator on both the x- and y-axis. Considering the scenarios' positions in the two-by-two matrix, the scores were allocated as shown in Table 2.

Since nine descriptors were used for the analysis, the highest achievable score on each axis was 9, while the lowest achievable score on each axis was -9. Each descriptor was to be weighted equally, meaning that the weighting w of those descriptors with multiple matched coding indicators needed to be adjusted. For example, the first descriptor ('Actor composition of governance') had three matched indicators, resulting in a weighting of $1/3$ for each indicator. The calculation of each government's score can be summarised with the following formulas:

$$X_{Government} = \sum \bar{x}_n * w_n \tag{3}$$

$$Y_{Government} = \sum \bar{y}_n * w_n \tag{4}$$

The arithmetic means \bar{x} and \bar{y} are taking into account that some indicators could not be uniquely mapped to only one scenario due to the way the scenario descriptors were defined by Yap et al. (2023).

After establishing these axis ranges, a scoring scale for each indicator was determined. This was achieved by first deriving an auxiliary ordinal scale for each coding indicator based on the descriptors defined by Yap et al. (2023). The ordinal scale was then converted into a numerical scale by analysing the minimum and maximum values for each indicator across all analysed governments and allocating specific values or intervals to the respective ordinal level. The resulting numerical scale can be found in Appendix 30. For example, the descriptor 'strategies of private actors' was matched with the categories 'profit-driven incentives' and 'value-driven incentives'. As a measurement, the ratio of the coding for profit-driven to value-driven incentives was used. Three ordinal levels were defined as low (Earth-Space Sustainability scenario), mid (Open Space/Space Utopia) and high (Space Cartel and Earth-centric Gold Rush), indicating the prioritisation of profit compared to values like environmental sustainability or equity. The minimum analysed value for the ratio across all governments was 0.2, while the maximum value was 4.5. Reflecting the three ordinal levels, this range of approximately 4.5 was divided into three intervals with a range of 1.5 respectively. This resulted in a numerical scale of 0 to 1.5 (Earth-Space Sustainability scenario), 1.5 to 3 (Open Space/Space Utopia) and 3 to 4.5 (Space Cartel and Earth-centric Gold Rush). A detailed explanation for the scale determination can be found in Appendix 31 as well as the replication package (Geise and Dhopade, 2025).

Using this scoring scale, each government was mapped onto the four scenarios. Table 3 provides an example for this process by continuing the one above of the descriptor 'strategies of private actors' in the case of Brazil.

As shown in Table 3, Brazil tends towards both the Space Cartel and Earth-centric Gold Rush scenario in the descriptor 'strategies of private actors'. The mean x- and y-scores of the two scenarios are -1.00 and 0.00. Since this descriptor is only matched to one indicator, its weighting is 1, resulting in a sub-total x- and y-score of -1.0 and 0.00 (see Table 4) (see Table 5).

Lastly, the sub-total scores for each indicator were summed up to obtain a total score for each government. Appendix 32 to Appendix 34 shows three examples (the African Union, Brazil and the USA) of the

Table 3

Example of mapping Brazil onto the scenarios with the example of the descriptor 'strategies of private actors', using the ratio of profit-driven to value-driven incentives as measurement.

Measurement	Value	Space Cartel	Earth-centric Gold Rush	Open Space/Space Utopia	Earth-Space Sustainability
		X = -1 Y = -1	X = -1 Y = +1	X = +1 Y = -1	X = +1 Y = +1
Ratio of profit- to value-driven incentives	Scale 3.86	✓	3 to 4.5 ✓	1.5 to 3	0 to 1.5

Table 4

Example of calculating Brazil's score with the example of the descriptor 'strategies of private actors', using the ratio of profit-driven to value-driven incentives as measurement.

Mapped x-score (mean)	Mapped y-score (mean)	Weighting	Sub-total x-score	Sub-total y-score
-1.00	0.00	1	-1.0	0.00

complete mapping for all coding indicators, which can also be found in the replication package (Geise and Dhopade, 2025).

Using the total scores as coordinates, governments were placed in the two-by-two scenario matrix complemented by the metaphors that emerged from the CLA. The final mapping result can be found in section 4.2.

4. Results and discussion

This section presents and discusses the results that emerged from the causal layered analysis as well as the scenario mapping.

4.1. Causal layered analysis of future scenarios

Structuring the scenarios developed by Yap et al. (2023) as per the different layers of the CLA pyramid revealed underlying worldviews and metaphors in each. These are summarised in the following table, including examples for the litany and systemic cause layer. Layer one represents the top of the CLA pyramid while layer four symbolises its bottom. The blue gradient illustrates that the four layers gradually increase in their depth (see section 3.1). The emerging worldviews and metaphors of each scenario are summarised in the following paragraphs.

4.1.1. Space Cartel – 'Survival of the Richest'

In this scenario, nature is considered to be separate from humans ('Human-Nature Dichotomy'). Space is seen as a limitless resource and a new frontier that needs to be conquered, colonised and marketed. This race for power is based in the metaphor 'Survival of the Richest', while the majority of society will eventually be "trapped in a rotating cage of space debris" (Venkatesan et al., 2023). Actors are operating on a 'first-come-first-serve'-principle and governments are adopting a passive approach, refraining from interfering in economic matters.

4.1.2. Earth-centric Gold Rush – 'Go get it as fast as you can'

While nature is considered connected to humans in this scenario in the sense that space resources are used to address environmental challenges on Earth, space is viewed as separate from Earth ('Earth-Space Dichotomy'). A fitting metaphor is the Gold-Rush mentality to 'Go get it as fast as you can', rooted in a mindset of scarcity and the 'first-come-first-serve' principle. Governments mostly focus on national development within their own borders rather than international collaboration (Yap et al., 2023).

4.1.3. Open Space/Space Utopia – 'Nach uns die Sintflut (After us, the flood)'

Similarly to the Earth-centric Gold Rush, this scenario's worldview also evolves around the Earth-Space Dichotomy. However, Earth's

Table 5
CLA revealing the worldview and metaphor behind the scenarios developed by Yap et al. (2023).

Layer	Space Cartel	Earth-centric Gold Rush	Open Space/Space Utopia	Earth-Space Sustainability
1) Litany, visible (examples)	environmental degradation on Earth and in space	environmental degradation in space	environmental degradation on Earth	min. environmental degradation on Earth and in space
2) Systemic Causes (examples)	self-regulation (privatised governance)	minilateralism	multi-level governance and varied institutional frameworks	shared sustainability goal amongst centralised, multilateral agreements
3) Worldview	Human-Nature Dichotomy	Earth-Space Dichotomy	Earth-Space Dichotomy	Earth-Space Interconnectedness
4) Metaphor/Myth	'Survival of the Fittest/Richest'	'Go get it as fast as you can'	'Nach uns die Sintflut' – 'After us, the flood'	'The Ecosystem of the Universe'

Table 6
Government scores based on space resource governance (x-axis) and Earth-system integration (y-axis).

	AU	AUS	BR	CN	EU	FR	DE	IND	NZ	RU	UK	USA
X	-1.7	-1.0	-6.0	1.0	-3.3	2.0	4.0	-1.7	-0.3	-4.0	-0.7	2.7
Y	3.0	-1.5	-1.5	5.0	2.3	0.0	0.7	3.0	-4.7	-3.5	-4.7	-2.3

development is not prioritised since its uninhabitability is viewed as inevitable. Instead, space is seen as a paradise (utopia) where settlements need to be built. The indifference regarding Earth's future can be illustrated by the German saying "Nach uns die Sintflut" ("After us, the flood"). The term "Sintflut" originated in the biblical story of Noah's Ark, where God imposes a global flood to destroy everything on Earth except the people and animals on Noah's Ark (*Nach mir die Sintflut, n.d.*).

4.1.4. Earth-Space Sustainability – 'The Ecosystem of the Universe'

This scenario views humans, Earth and space as deeply interconnected, which is a common understanding in Indigenous worldviews like the Māori worldviews explored in section 2.2 (Yap et al., 2023; Lythberg and Woods, 2016). In this scenario, Earth is not seen as isolated but as part of a larger system, the 'Ecosystem of the Universe'. Hence, actors unite with an internationally shared sustainability goal that encompasses both sustainability on Earth and in space.

4.2. Scenario mapping result and considerations

Integrating the CLA insights with the subsequent content analysis and scenario mapping as described in section 0 resulted in the following final scores for each government in the form of an x- and y-value (see Table 6).

Mapping these values in a coordinate-system and complementing it with the two-by-two matrix developed by Yap et al. (2023) as well as the metaphors for each scenario that emerged from the CLA generates the graph shown Fig. 6.

Notably, the significant space actors Russia, Europe, the USA and China all fall into different quadrants: Russia leans towards the Space Cartel scenario, as does Brazil. Europe tends towards the Earth-centric Gold Rush, along with the African Union and India, both of which resulted with the same coordinates. The USA is the only country close to Open Space/Space Utopia. China as well as Germany incline towards Earth-Space Sustainability. The UK and New Zealand are close together in between the Space Cartel and Open Space on the lower half of the matrix. Australia and France are relatively neutral in the centre of the

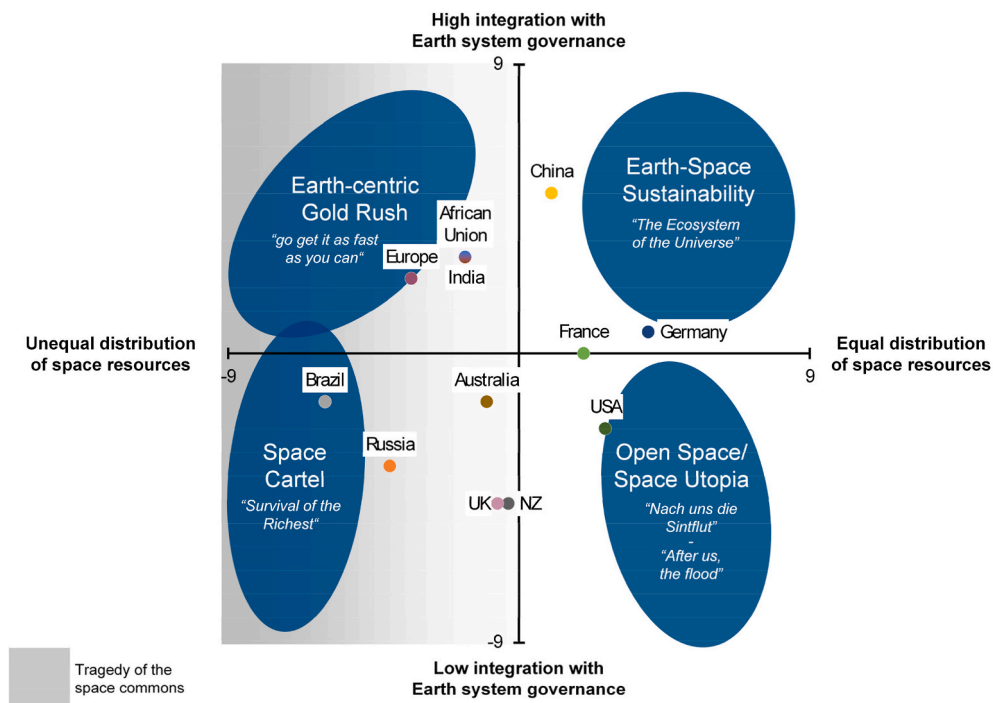


Fig. 6. Governments mapped onto Yap et al.'s (2023) two-by-two matrix, complemented with CLA metaphors.

Table 7
Scenario Mapping – Indicator Results of Russia, Europe, the United States of America and China.

Scenario Descriptor	Coding Indicator incl. Weight	Space Cartel				Earth-centric Gold Rush				Open Space/Space Utopia				Earth-Space Sustainability				
		RU	EU	US	CN	RU	EU	US	CN	RU	EU	US	CN	RU	EU	US	CN	
Actor composition of governance	Developing Economies	1/3	•	•			•	•				•	•				•	•
	International Organisations	1/3	•	•	•		•	•	•									•
	Start-ups and SMEs	1/3									•	•	•	•	•	•	•	•
Governance characteristics	Multilateral and/or Global	1/2	•				•				•	•						•
	Comparison of multi-, mini- or bilateral	1/2					•	•				•						•
Industry structure	Economic sustainability	1	•	•	•		•	•	•		•	•	•					•
Space-based or ground infrastructures	Space as Common Global Resource	1/3	•	•	•		•	•	•				•					•
	Ownership	1/3			•				•						•	•		•
	Equity as a priority	1/3	•				•								•	•	•	•
Global justice and/or development gap	Diversity and Inclusion	1/3	•	•		•			•									
	Indigenous Rights	1/3	•	•	•	•												
	Sustainable Development Goals (SDGs)	1/3	•	•	•	•												
Strategies of private actors	Prioritisation of profit- over value-driven incentives	1									•				•	•	•	•
Impact on Earth's environment	Sustainability on Earth	1	•		•			•		•		•						
Impact on Space Environment	Sustainability in space	1	•	•		•	•		•			•				•		
Earth-Space interdependency	Ratio of sustainability on Earth over sustainability in space	1	•				•		•			•						
Weighted Count per Scenario and Government			6.8	4.0	3.7	2.0	4.3	5.5	2.3	3.0	3.3	1.8	5.7	1.0	0.7	2.0	3.0	5.0

matrix, leaning towards the Space Cartel and a combination of Earth-Space Sustainability and Open Space.

To provide more details as to where these governments stand in respect to the scenario descriptors defined by Yap et al. (2023), one government from each quadrant has been selected for a more detailed discussion: Russia, Europe, the USA and China. Another reason for choosing these is the significant size of their space programs (Space Insider, 2023). Table 7 shows the governmental tendencies towards the scenarios in more detail, split into the assessed coding indicators. Each row shows which scenarios the four governments lean towards for each indicator, highlighted by a dot in the respective cells. Notably, governments show indications of multiple scenarios and do not exclusively tend towards just one. The last row counts the tendencies per government and scenario while taking into account the varying weights among the indicators. This provides insight into each government's overall tendency. The detailed inclinations of the other eight analysed governments are outlined in Appendix 35 and Appendix 36.

4.2.1. Russia

Russia falls within the Space Cartel quadrant, reflected by the matrix (see Fig. 6) and its highest weighted count in this scenario (6.8) relative to the other three (see Table 7). The country's primary sustainability motivation is driven by economic reasons. There is no mention of sustainability in space, while sustainability on Earth is briefly addressed in the form of reusable launch vehicles, whose motivations are also influenced by economic reasons (Machado, 2022; NSTXL, 2024). The Space Cartel classification is strongly reinforced by Russia's real-world policy behaviour towards cost reduction, military prioritisation and limited engagement with multilateral sustainability initiatives beyond formal treaty compliance. For instance, the Russian space industry is characterised by cancelled agreements due to failure to comply with technical

requirements and its invasion of Ukraine in 2022 (Luzin, 2024; McClintock and Lebret, 2024). Russia thus aims to reduce costs and focusses on military space activity as opposed to (human) space exploration, the latter of which is more seen as a way maintain the country's international status as an impactful space actor rather than gaining revolutionary scientific insights. One measure of reducing costs is the expansion of Russia's satellite constellations with a quantity-over-quality approach, designing satellites with a lifespan of maximal four years and increasing the production rate to replace them in a timely manner. The country's space capabilities are also restricted by workforce shortages and sanctions that limit access to industrial equipment. Thus, Russia is relying on consumer-grade electronics rather than space- and military-grade components (Luzin, 2024). Since Russia does not have sufficient means to achieve tangible results in space exploration, Luzin (2024) as well as McClintock and Lebret (2024) suggest that the country might aim to maintain and advance its "status of space power" (Luzin, 2024, p. 9) by undermining other actors' achievements. This illustrates the worldview of the Space Cartel scenario, where space activities are seen as a path to supremacy, wealth and development, and rooted in the human-nature dichotomy.

4.2.2. Europe

Europe leans towards the Earth-centric Gold Rush scenario (see Fig. 6), underlined by its highest weighted count appearing in this scenario (5.5, see Table 7). Viewing space as a means to foster autonomy, Europe aims to develop sovereign capabilities and advance the competitiveness of its space industry while promoting responsible economic growth by prioritising value-driven incentives over profit-driven incentives (ESA, 2023). The EU values sustainability on Earth over sustainability in space. It is mostly focussing on using space for Earth's sustainability, emphasising the role of space activities to overcome

environmental, social and economic challenges (ESA, 2022). This reflects the scenario's worldview of the Earth-Space Dichotomy. Europe's real-world policy behaviour largely reinforces this Earth-centric Gold Rush orientation. Its proposed EU Space Act and competitive launch and procurement provisions are designed to strengthen European industrial competitiveness and market position, for instance, through reduced regulatory uncertainty for commercial actors (European Commission, 2025; Greenacre, 2023).

However, some sustainable measures that indicate a tendency towards Earth-Space Sustainability were not mentioned in the analysed documents and thus are not reflected by the results. For example, the European Space Agency's 'Clean Space Initiative' was implemented in 2012, advocating for holistic life cycle analyses of space missions (ESA, n.d.). Additionally, a technical booklet was recently published, outlining technologies that will aid in achieving Zero Debris by 2030 as well as promoting a circular space economy (Zero Debris Community, 2024; ESA, 2025). The EU Space Act also emphasises the assessment and reduction of the environmental impact of space activities by operators by supporting more sustainable in-space activities such as debris removal and in-orbit servicing (European Commission, 2025). Thus, further analyses of additional documents are necessary to develop an accurate understanding of Europe's priorities and potential future of the space sector.

4.2.3. United States of America

The USA is representative for the Open Space/Space Utopia scenario (see Fig. 6). With its peak weighted count occurring in this scenario (5.7), this alignment is supported by the detailed results in Table 7. It has the highest coding ratio for sustainability in space, prioritising this sustainability aspect over economic and Earth-centric sustainability. Measures include orbital debris mitigation, space situational awareness, space traffic coordination, in-space servicing assembly and enhancing spacecraft endurance. The USA aims to define concrete assessment metrics to track and assess sustainability in Earth's orbit and NASA acknowledges its exemplary function for policymakers around the world (NASA, 2024). While profit-driven incentives are outweighed by value-driven ones, the USA plans to support the private sector and especially start-ups and SMEs to align the ambitions of small businesses with governmental space missions (National Science and Technology Council, 2023). The underlying worldview in the Open Space/Space Utopia scenario is embodied by Elon Musk, founder of the US-American company 'SpaceX' that manufactures rockets and spacecrafts. Reaching Mars has been a lifelong goal for him, shaping the majority of his businesses. According to Grind (2024), Musk "plans to use [the launch vehicle] Starship as sort of a Noah's Ark, carrying plants and animals on the initial voyage" to Mars. This directly reflects the metaphor of "Nach uns die Sintflut – After us, the flood" that emerged from the CLA and is prevalent in the Open Space scenario (see section 4.1). Additionally, his language of intending to "colonise" the planet to build a "Martian colony" (Grind, 2024) further reinforces the worldview of space being distinct from Earth.

As of March 2025 however, the latest political developments in the USA indicate a tendency towards the Space Cartel scenario. Shortly after the analysis was conducted, Donald Trump was elected president of the USA. Since then, he has signed over 50 executive orders, named Elon Musk as one of his senior advisors and appointed him as the leader of the newly established 'Department of Government Efficiency' (DOGE). DOGE strives to decrease government spending by restructuring federal agencies and reducing "excess regulations" (Ngo and Fahrenthold, 2024), gaining broad access to sensitive information about businesses and millions of individuals (Elliot, 2025). This enables Musk to shape the regulations that his own businesses are subject to, including SpaceX (Robins-Early, 2024). Given that the company has been grounded various times due to regulatory violations, Musk is likely to favour deregulation and reduced governmental oversight in the commercial sector (Robins-Early and Leingang, 2024). This is also reflected in the

March 2025 closure of NASA's Office of Technology, Policy, Strategy (OTPS), author of NASA's Space Sustainability Strategy 2024 and one of the key strategy documents in the current paper. At the time of writing, it remains to be seen whether the OTPS will be reinstated after a future change in government (Foust, 2025).

Additional ambitions include weakening climate and pollution protections through staffing the Environmental Protection Agency with individuals who have backgrounds as legal representatives and lobbyists in oil, gas and chemical industries (Friedman et al., 2025). This indicates a potential tendency towards the Space Cartel scenario, which involves self-regulation by rich and technologically advanced private actors, also supported by President Trump's December 2025 Executive Order titled "Ensuring American Space Superiority" which directs a market-driven expansion in space by prioritising "American free enterprise" and shifting space traffic management from a free public service to a commercial service (The White House, 2025).

Additional indicators for the USA's tendency towards the Space Cartel scenario are numerous executive orders that discontinue diversity, equity and inclusion (DEI) programs within the federal government and the revocation of the 1965 executive order aimed at fostering racial equality in federal contractors (Mark et al., 2025). This suggests a decline in global justice, which is a characteristic of the Space Cartel. The scenario's worldview of perceiving space as the "new frontier to be conquered, colonised and marketed" (Yap et al., 2023) is reflected in Trump's goal to "pursue our manifest destiny into the stars, launching American astronauts to plant the Stars and Stripes on the planet Mars" (Feldscher, 2025) and the establishment of a "permanent lunar outpost" under the Artemis Program (The White House, 2025).

4.2.4. China

China tends towards the Earth-Space Sustainability scenario (see Fig. 6), also indicated by its highest weighted count in this scenario (5.0, see Table 7). While the country mentions initiatives to advance the private sector and promote new business models, it distinguishes itself with a low prioritisation of economic sustainability. The country places emphasis on sustainability on Earth in the form of climate research, environmental disaster management and aligning its efforts with the UN sustainable development goals. Additionally, it has the third highest coding ratio for sustainability in space, aiming to implement measures like debris removal, in-orbit maintenance, satellite life extension vehicles and automated spacecraft management. Furthermore, China stands out with its ambition towards global agreements in the form of international governance frameworks to ensure peaceful and inclusive use of space including future generations (The State Council Information Office of the People's Republic of China, 2022). This also aligns with its publicly stated views in the COPUOS forum delivered as part of the Group of 77 (G-77) and China. For instance, at the 63rd session of the UN COPUOS Scientific and Technical Subcommittee, the G-77 and China emphasised that the "deployment of mega-constellations, if not carried out sustainably and equitably, may pose a risk of congestion of Low Earth Orbit (LEO), which would be a significant disadvantage in the use and exploration of space by developing countries." (UN COPUOS, 2026) China has consistently endorsed such views on orbital sustainability and capacity building, alongside India, Egypt, Kenya, Brazil and other developing space countries in the G-77.

China has also supported developing economies through assisting in professional training and advancing their space science and research capabilities. This demonstrates how China is actively working towards ensuring equitable access to space. However, China's limited ability to extend its network of space partnerships due to US-led export control rules has to be taken into account. Morin and Tepper (2023) state that this is the main reason for China's collaboration with developing economies that have limited spacefaring capabilities or are in disagreement with the USA. Additionally, "China's structural reach is notably less extensive than that of the United States" (Morin and Tepper, 2023, p. 11), significantly hindering its ambitions to establish international rules.

For example, in the pursuit of preventing an arms race in space, China and Russia have advocated for a corresponding treaty in the United Nations framework for over 20 years, ultimately failing to achieve its enactment (Morin and Tepper, 2023).

However, in the current geopolitical climate, Toft (2025) argues that China as well as Russia and the USA are promoting a shift back to power politics as well as aiming to exert and expand spheres of influence. These are regions under a state's economic, military and political control, potentially beyond the borders of formal sovereignty. If these states as well as Europe follow independent directions, this could lead to a multipolar order, as supported by the findings of this research. Particularly, China's expanding capabilities in missions, lunar exploration, and multilateral partnerships could create parallel spheres of influence that attract states seeking alternative cooperation frameworks, especially outside the Artemis Accords-led USA framework (Steer, 2026; Del Canto Viterale, 2025). In this case, other countries like India, Japan and Australia would act as counterbalancing powers.

This presents an interesting dichotomy where public forums such as the national strategy documents considered in the current study and UN COPUOS statements generate largely normative statements on sustainability discourse from traditional space powers such as USA, China and Russia. Actual policy trajectories of these countries are shaped by strategic competition and asymmetric accumulation of capabilities. The empirical findings therefore highlight a growing gap between collective governance principles and the political-economic realities of space power.

4.2.5. Key characteristics of the other analysed governments

The African Union (AU) primarily focusses on sustainability on Earth, having the highest coding ratio for this category across the analysed governments. Within this category, it prioritises using space for Earth's sustainability with the aim of improving the AU's living standard through natural disaster management, climate change mitigation, digital inclusion including telehealth, and securing the food production. Additionally, the AU strives to be a peaceful and responsible actor in space to ensure the long-term access to space. It aims to develop sovereign capabilities to minimise its reliance on foreign support by developing local expertise and skills as well as supporting its private sector (African Union, 2019; Space in Africa, 2023b; 2023a).

Australia has a low coding ratio for all sustainability aspects. The country focusses on using space to improve digital health care, sustainable agriculture, climate change research and mitigation as well as natural disaster management. Sustainability in space is minimally mentioned and includes space debris mitigation, space traffic management and space situational awareness. Australia aims to build sovereign capabilities to reduce dependencies on foreign space-derived services by growing the private sector and particularly start-ups. Additionally, workforce development and the strengthening of international collaboration is prioritised to enable its businesses to become part of global value chains. Across governments, Australia has the highest coding ratio for diversity and inclusion, which is largely focussed on workforce development but also striving towards the equitable distribution of benefits emerging from space like public health. Indigenous rights for its Indigenous population of Aboriginal and Torres Strait Islander people are moderately mentioned with measures staying rather vague (Australian Academy of Science, 2022; Australian Space Agency, 2019).

Brazil values economic over environmental sustainability and does not mention sustainability in space. In the context of sustainability on Earth, the country solely focusses on using space for Earth's sustainability instead of the impact of space activities on Earth. Aspects include remote sensing, environmental data collection and Earth observation. Brazil strives to develop the leading space market across South America by increasing sovereign capabilities while establishing a global presence and becoming part of international value chains. Specific measures include attracting foreign investment through partnerships, facilitating entrepreneurship and investing in workforce development initiatives

(Brazilian Space Agency, 2022).

France puts emphasis on sustainability on Earth, followed by economic sustainability and a comparatively low coding ratio for sustainability in space. It stands out with its prioritisation of addressing the impact of space activities on Earth, having the highest coding ratio for this sub-category across governments. Goals primarily include reducing the environmental footprint of the agency's facilities and throughout its value chain as well as developing reusable launch vehicles. The country closely intertwines its space activities with the SDGs, emphasising how each activity contributes to them. France has one of the highest coding ratios for diversity and inclusion, demonstrating its commitment to aspects like gender equality and disability awareness. The country views the space sector as an important sector to advance its economic growth. Thus, the development of the private sector is facilitated, e.g. through establishing incubators for start-ups and SMEs. France addresses sustainability in space by aiming for a circular space economy, designing zero-debris satellites and active debris removal as well as space traffic management (CNES, 2022).

Germany shows the second highest coding ratios for both sustainability in space and considering the impact of space activities on Earth. It stands out with a holistic approach to sustainability, striving to implement sustainable principles throughout the whole life cycle of space missions. This includes analysing and reducing the impact of rocket launches and satellite re-entries on Earth and its atmosphere, minimising the emissions in the value chain and reducing light pollution. Additionally, Germany emphasises the need for space traffic management and active debris removal to ensure the access to space for future generations. Similar to China, Germany underscores the importance of establishing internationally binding rules to ensure the sustainable and peaceful use of space through international institutions like UN COPUOS. On a national level, the country prioritises both value- and profit-driven incentives, e.g. through a national Space Act to support the sector's sustainability and dedicated funds to support the private sector, particularly start-ups (Federal Ministry for Economic Affairs and Climate Action, 2023).

India prioritises sustainability on Earth and economic sustainability over sustainability in space, while still having a comparatively high coding ratio for the latter, which encompasses initiatives like international frequency coordination, space situational awareness and space debris mitigation. The country also focusses on measures like disaster management, resource management and environmental protection. India seeks to support the development of the private sector and specifically start-ups as well as to facilitate international collaboration by establishing national and international partnerships with academia and industry (Indian Space Research Organisation, 2023).

When comparing the 2023 and 2024 strategies from New Zealand, a trend towards increased prioritisation of economic sustainability is notable. The country aims to foster collaboration amongst the government, industry and academia, aligning industry ambitions with government policies. While New Zealand aims to establish value-driven incentives like a regulatory regime that ensures sustainable space access, these are outweighed by profit-driven incentives for reducing barriers to sector growth and supporting start-ups. Prioritisation of addressing the impact of space activities on Earth is significantly lower in 2024 compared to the strategy published in the year prior. New Zealand stands out with the highest prioritisation of Indigenous rights, proposing concrete plans of engaging with Māori in policy development. However, these aspects are absent in the 2024 strategy (MBIE, 2023a, 2023b, 2024). Consequently, Māori worldviews of reciprocity, respect and responsibility amongst humans and the natural world are not prioritised (Rewi and Hikuroa, 2023). The Māori Working Group on Aerospace has voiced their concern over the exclusion of Māori interests in the latest strategy. (Māori Working Group on Aerospace, 2024) In order to generate an accurate representation of the strategy development from 2023 to 2024, it is recommended to map both separately onto the scenarios in future analyses.

The UK has the highest coding ratio of economic sustainability amongst the analysed governments, which is reflected by a prioritisation of profit-over value-driven incentives. Measures include workforce development, facilitating entrepreneurialism, increasing private investment into the sector as well as fostering international exports. The government is intended to function as an anchor customer, providing initial funding and signalling confidence in the industry and thus encouraging further investment. Additionally, the UK intends to consult SMEs in policy development. However, value-driven incentives are also elaborated to support the interests of future generations and establish sustainable practices across the international space industry (Government of the United Kingdom, 2023; 2024). Specifically, the 'Astra Carta' initiative frames space and Earth as an interconnected ecosystem but is not mentioned in detail in the analysed strategies (Sustainable Markets Initiative, 2023). Hence, further analysis is needed to enable an accurate understanding of the UK's vision for its future space sector.

4.3. Moving to Earth-Space Sustainability

As explained in section 2.3, the Earth-Space sustainability scenario ensures the equitable distribution of space resources and a sustainable environment both on Earth and in space, closely aligning with the United Nations sustainability definition. The Earth-Space Sustainability scenario is thus considered as a desirable future for the global collective.

In the context of the causal layered analysis, Inayatullah advocates for holistically addressing all of the pyramid layers to progress towards a desirable future (Mulligan et al., 2024). The Disruptive Futures Institute identifies the following four levers for effective change, sorted from the weakest to the strongest: patterns and trends, structures, foresight, education and mindsets (Spitz and Zuin, 2023). This coincides with the CLA pyramid layers. Eberle and Sebesvari emphasise this using the example of space debris, stating that "if we only implement solutions to clean up debris and incentivise appropriate action, these actions will face constant pressure from the behaviours, values and systems that have created the problem in the first place" (Eberle and Sebesvari, 2023, p. 19).

4.3.1. Worldview and metaphor

Moving to the Earth-Space Sustainability scenario on a worldview and metaphor layer means shifting the view of space as "an inexhaustible source of resources and an indiscriminate dumping ground" (Yap and Kim, 2023, p. 2) towards the interconnectedness of humans and the environment. Yap and Kim also advocate for a new governance model for the effective integration of Earth and space as well as shifting the sustainability discourse from a planetary perspective to a multi-planetary perspective. This could be achieved through establishing a shared sustainability goal and appropriate co-governance models with Indigenous Peoples, which is further outlined here with the example of New Zealand and engaging with mātauranga Māori (see following section).

4.3.2. Systemic causes and structures

Successful co-governance with Indigenous people could take Tāwhaki as an example. This joint venture is a commercial partnership between Te Taumutu Rūnanga and Wairewa Rūnanga and the Crown, owning 1000 ha of land near Christchurch at Kaitorete. Its purpose is twofold: "heal[ing] and rejuvenat[ing] the unique whenua at Kaitorete" (MBIE, 2022) and fostering Aotearoa New Zealand's aerospace industry. Such co-governance models could be developed utilising frameworks like "He Awa Whiria (a braided rivers approach)" (Wilkinson et al., 2020, p. 606), the "IBRLA [Initiation, Benefits, Representation, Legitimation, Accountability] framework" (Wilkinson et al., 2020, p. 606) or the Treaty-based planning framework proposed by Harmsworth and Awatere (2013). Instead of adapting mātauranga Māori to fit existing planning approaches and policies in the space sector, co-governance

should facilitate "transformative solutions at the intersection of Indigenous knowledge" (Varughese et al., 2023, p. 696), giving equal consideration to both Māori and European approaches (Varughese et al., 2023). For example, for many Indigenous people, resource harvesting practices are rooted in profound ecological and behavioural knowledge of their local environments, passed down through generations. These practices demonstrate the close relationship between Indigenous Peoples and the environment, striving to maintain the long-term sustainability of a resource and the environment. Furthermore, for Māori, the distribution of resources between communities reflects one of the many values across governance and stewardship that has ensured Māori survival and well-being for centuries (Rewi and Hikuroa, 2023). This approach could be the basis for discussions around space resource mining.

Other measures on this layer could include regulations to ensure accountability, integrating enforcement mechanisms and establishing incentives like the Space Sustainability Rating and introducing space as the eighteenth UN sustainable development goal (Yap and Truffer, 2022).

4.3.3. Litany

Since the Litany encompasses externally visible aspects of reality, monitoring practices can be introduced on this layer. This increases transparency and creates a feedback loop, aspects emphasised in this context by Spitz and Zuin (2023). Specifically, metrics and key parameters could be defined for a sustainability assessment of activities in Earth's orbit, as stated in the first volume of NASA's space sustainability strategy. Additionally, the 'Mauri Model' is a tool that assesses an action's impact on the 'mauri' of an area, considering various indicators across environmental, social, cultural and economic aspects. Mauri describes "an ethereal bond that links all elements of the natural world, the binding force between the physical and the metaphysical, the life-supporting capacity of soil and water" (Wilkinson et al., 2020, p. 607). It is important to note that the model was developed for environmental decision-making in Aotearoa New Zealand. It is thus necessary to explore its applicability to the space sector in cooperation with Māori.

4.4. Limitations of current study

The selection of countries analysed in this study does not encompass all spacefaring nations and thus does not provide a comprehensive perspective on all global space sectors' possible trajectories. However, the selection of countries based on economic and geographic influence provides a good approximation of the possible trajectories. The content analysis, the interpretation of Yap et al.'s (2023) scenarios and their differentiation into the four layers as part of the causal layered analysis may have been influenced by potential bias. Consequently, as the scale used for mapping the governments onto the scenarios is based on the content analysis results, the scale itself includes corresponding uncertainties.

The current study assumes government documents to represent the views and values of each country. However, without residing in the countries or being present in the drafting process of these documents, this assumption poses risk for error.

5. Conclusion and outlook

The present study centred on examining potential future trajectories of space sectors around the world. Building upon the respective findings, suitable governmental approaches to cultivate an equitable future of Earth-Space Sustainability were identified, which is a desirable future for the global collective. This was achieved by first conducting a causal layered analysis of the potential future scenarios of the space sector developed by Yap et al. (2023). Subsequently, a quantitative content analysis was carried out to examine the space strategies of twelve

different governments with deductively derived categories. Based on the content analysis results, the governments were mapped on the potential future scenarios by developing a system that transforms Yap et al.'s qualitative scenario descriptors and matrix into a quantitative scale.

Results for the first research question show that the significant space actors Russia, Europe, the USA and China each fall into different quadrants of the future space scenarios matrix. Russia tends towards Space Cartel scenario, along with Brazil. In this scenario, space is seen as a limitless resource and a new frontier that needs to be conquered and marketed, rooted in the human-nature dichotomy. It can be described with the metaphor 'Survival of the Fittest/Richest'.

Europe shows a tendency towards the Earth-centric Gold Rush, as does the African Union. While India is located near the centre of the matrix, it also slightly leans towards this scenario, which is characterised by the Earth-Space dichotomy, where space is seen as separate from Earth. The metaphor 'Go get it as fast as you can' demonstrates the mentality in this scenario. Space resources are considered to be a tool in addressing environmental challenges on Earth and advancing national development within the borders of each government.

The USA is located near the Open Space/Space Utopia scenario. Similar to the Earth-centric Gold Rush, it is rooted in the Earth-Space dichotomy. However, instead of focussing on Earth's development, space is seen as the new paradise where settlements need to be built due to the Earth's 'inevitable' uninhabitability. This is illustrated by the metaphor "Nach uns die Sintflut" ("After us, the flood"). However, in light of the political shift in the USA and President Trump's various Executive Orders, there is a pronounced acceleration towards market-driven governance and preferential access to space technology and domains. These behaviours reflect Space Cartel dynamics by driving uneven control over infrastructure and resources.

China as well as Germany are located near the Earth-Space Sustainability scenario, which is characterised by viewing humans, Earth and space as deeply intertwined. The metaphor 'Ecosystem of the Universe' depicts that Earth is not seen as isolated but as part of a larger system. Actors thus aim to unite with an internationally shared sustainability goal. However, China's real-world space policy simultaneously advances state-led infrastructure, strategic autonomy, and parallel governance mechanisms. China's interventions in COPUOS, particularly through the G-77, consistently stress equity, capacity building, and opposition to orbital congestion from mega-constellations, aligning with sustainability norms at the rhetorical level while operating within a competitive, sphere-of-influence logic in practice.

France is located between Earth-Space Sustainability and the Open Space scenario, whereas the UK and New Zealand fall in between the Space Cartel and the Open Space scenario. Australia is located close to the centre of the matrix in between all four scenarios.

In terms of sustainability aspects, the AU, France, India and Germany stand out with their prioritisation of Earth-centric sustainability. In this category, the sub-category of using space for Earth's sustainability is prioritised over the impact of space activities on Earth except in Russia and the US. In Russia's case, this is negligible since the coding ratio is below 1%. The USA's case can be attributed to the fact that NASA published a strategy that is specifically devoted to space sustainability, which also explains why the USA stands out with its prioritisation of sustainability in space. It is followed by Germany, China, India and the UK. Economic sustainability is emphasised the most by the UK, followed by the EU, Brazil, India, France, New Zealand, Australia and Russia.

For the United States and China in particular, the scenarios derived from the empirical analysis do not fully align with their observable policy behaviour. This points to a phase in international space governance where sustainability rhetoric is increasingly disconnected from how power, access, and benefits are distributed. Cooperative language and multilateral norms continue to be promoted, for instance, via UN COPUOS statements and national strategy documents, but they now sit uneasily alongside practices that reinforce asymmetric control, cartel-like dynamics, and competing spheres of influence in space. This

divergence is more pronounced where commercialisation and geopolitics appear to intersect, for example with the USA's new administration explicitly asserting American dominance over markets, and with China's state-led infrastructure and capacity building.

Results for the second research question show that holistic changes are necessary on all layers of the CLA pyramid in order to move towards Earth-Space Sustainability as a desirable future for the global collective. One approach to achieve a shift on the worldview and metaphor layer towards interconnectedness of humans and the environment could be appropriate co-governance models with Indigenous Peoples. Frameworks like the braided rivers approach or the Treaty-based planning framework can aid in developing such co-governance models. Other measures on the layer of systemic causes could include accountability-ensuring regulations and enforcement mechanisms as well as incentives like the Space Sustainability Ranking. On the Litany layer, monitoring practices could be introduced to increase transparency and creating feedback loops. Engaging with Indigenous knowledge on this layer could mean introducing the Māori 'Mauri Model' into discussions around assessing environmental, social, cultural and economic aspects of an action.

Further analysis of other spacefaring countries is necessary, e.g. the United Arab Emirates and Japan. To refine the analysis presented in this paper, additional documents for each government should be analysed. This could also allow a comparison of governments' strategies over time. Furthermore, the coding for sustainability could further be refined, especially in the context of considering the impact of space activities on Earth to gain more insights into specific priorities. Drawing on the findings of this research can enable making informed decisions and creating flexible strategic plans as well as defining and implementing tangible actions to work towards a future where the aspiration for growth in the space sector does not become humanity's "downfall".

CRedit authorship contribution statement

Ronda Geise: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Priyanka Dhopade:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Financial Support statement

This research was conducted during the master's degree of one of the authors, the pursuit of which was supported by scholarships of the German Academic Exchange Service (DAAD) and the Dr. Friedrich Jungheinrich Foundation. The funders had no role in the design of the study, the collection, analysis, or interpretation of data, or in the writing of the article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank Mark Buntzen for their insightful

discussion on causal layered analysis and Stevie Katavich-Barton for their robust feedback during the development of the methodology.

Appendices

Appendix 1

Category Definition – Start-ups and SME's

Scenario Descriptor	Actor composition of governance
Coding Indicator	Start-ups and SME's
Content description	Mentioning of start-ups and SMEs, both in the context of collaboration and governance
Application of the category	Either if specifically mentioned or if “industry” or “private sector” addressed as a whole
Examples of applications	“[...] while Australia will need to grow capabilities through its start-up and growing space businesses” (Australian Space Agency, 2019 , p. 7)
Differentiation from other categories (optional)	/

Appendix 2

Category Definition – Large Companies

Scenario Descriptor	Actor composition of governance
Coding Indicator	Large Companies
Content description	Mentioning of large and advanced companies
Application of the category	Either if specifically mentioned or if “industry” or “private sector” addressed as a whole
Examples of applications	“Create the conditions for increased diversity and competitiveness of medium and large-scale companies to better balance the size distribution of space companies in the UK” (Government of the United Kingdom, 2024 , p. 10)
Differentiation from other categories (optional)	/

Appendix 3

Category Definition – Governments

Scenario Descriptor	Actor composition of governance
Coding Indicator	Governments
Content description	Collaboration with other countries and governments on an international level
Application of the category	e.g. export and trade agreements or other bi-, mini and/or multilateral agreements
Examples of applications	“Fostering international cooperation within Africa and with the rest of the world as a means of realizing the full value proposition of the space sector.” (African Union, 2019 , p. 4)
Differentiation from other categories (optional)	/

Appendix 4

Category Definition – Developing Economies

Scenario Descriptor	Actor composition of governance
Coding Indicator	Developing Economies
Content description	Collaboration with developing economies, also referred to as ‘emerging spacefaring nations’
Application of the category	e.g. support of developing economies with workforce development
Examples of applications	“Strengthening international space cooperation that is based on common goals and serves the Belt and Road Initiative, and ensuring that the space industry benefits the Initiative’s participating countries, especially developing countries” (The State Council Information Office of the People’s Republic of China, 2022)
Differentiation from other categories (optional)	If coded to this category, then not coded to ‘Governments’

Appendix 5

Category Definition – International Organisations

Scenario Descriptor	Actor composition of governance
Coding Indicator	International Organisations
Content description	Collaboration with international organisations
Application of the category	e.g. with UN COPUOS

(continued on next page)

Appendix 5 (continued)

Scenario Descriptor	Actor composition of governance
Examples of applications	“NASA was a founding member of the Inter-Agency Space Debris Coordination Committee and led the committee to establish the first consensus-based international guidelines for mitigating orbital debris.” (NASA, 2024, p. 4)
Differentiation from other categories (optional)	/

Appendix 6

Category Definition – Multilateral and/or Global

Scenario Descriptor	Governance characteristics
Coding Indicator	Multilateral and/or Global
Content description	Multilateral and or global collaboration
Application of the category	Collaboration based on shared values and potentially through international organisations like the United Nations
Examples of applications	“New Zealand will continue to advocate for effective international rules, norms and standards in space. New Zealand is party to the main international space treaties which are reflected in our domestic laws and policies. [...] New Zealand supports ongoing efforts to advance international agreement on norms, rules and principles of responsible behaviour in space.” (MBIE, 2024, p. 11)
Differentiation from other categories (optional)	If just “International cooperation” mentioned and not inferable from the context whether bi-,mini- and/or multi-lateral, then all of them are coded

Appendix 7

Category Definition – Minilateral

Scenario Descriptor	Governance characteristics
Coding Indicator	Minilateral
Content description	Minilateral collaboration amongst a sub-set of countries
Application of the category	European Union, African Union and United Kingdom are inherently minilateral. Collaboration with these is thus coded as minilateral.
Examples of applications	“Aotearoa New Zealand is a signatory to the Artemis Accords, an international arrangement led by the National Aeronautics and Space Administration (NASA) to support peaceful exploration and activity in space” (MBIE, 2023a, p. 21)
Differentiation from other categories (optional)	If just “International cooperation” mentioned and not inferable from the context whether bi-,mini- and/or multi-lateral, then all of the are coded. Every collaboration/governance initiative that is not clearly global is coded as minilateral.

Appendix 8

Category Definition – Bilateral

Scenario Descriptor	Governance characteristics
Coding Indicator	Bilateral
Content description	Bilateral collaboration
Application of the category	Includes partnerships
Examples of applications	“Through UKSA, we are investing in an International Bilateral Fund, which will fund UK space projects with our strategic partners, as well as emerging space nations.” (Government of the United Kingdom, 2023, p. 21)
Differentiation from other categories (optional)	If just “International cooperation” mentioned and not inferable from the context whether bi-,mini- and/or multi-lateral, then all of them are coded

Appendix 9

Category Definition – Economic Sustainability

Scenario Descriptor	Industry structure
Coding Indicator	Economic Sustainability
Content description	Measures and plans to advance economic growth and feasibility
Application of the category	Measures to increase growth, support of the private sector, start-up incubators, workforce development
Examples of applications	“Foster industry according to its ability to sustainably exploit economic potentials.” (Brazilian Space Agency, 2022, p. 11)
Differentiation from other categories (optional)	/

Appendix 10

Category Definition – Space as Common Global Resource

Scenario Descriptor	Space-based or ground infrastructures
Coding Indicator	Space as Common Global Resource
Content description	Indicators that space is viewed as a common global resource
Application of the category	Assumption that the Artemis Accords do not acknowledge space as a global commons
Examples of applications	“Australia can become a medium to major player in managing the global commons of space” (Australian Academy of Science, 2022, p. 28)
Differentiation from other categories (optional)	/

Appendix 11

Category Definition – Ownership

Scenario Descriptor	Space-based or ground infrastructures
Coding Indicator	Ownership
Content description	Indicators that governments plan to claim ownership over space resources
Application of the category	e.g. the Artemis Accords
Examples of applications	“Any NGE engaged in such process shall be entitled to possess, own, transport, use, and sell any such asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of India.” (Indian Space Research Organisation, 2023, p. 7)
Differentiation from other categories (optional)	/

Appendix 12

Category Definition – Equity as a priority

Scenario Descriptor	Space-based or ground infrastructures
Coding Indicator	Equity as a priority
Content description	Indicators that governments aim for equitable conditions in the context of the space sector
Application of the category	e.g. equitable sharing of resources, equitable access to space today and for future generations (intergenerational equity)
Examples of applications	“further messaging that space is for all humankind” (National Science and Technology Council, 2023, p. 13)
Differentiation from other categories (optional)	Does not include workforce equity because this category solely focusses on the view of space. Instead, workforce equity is coded in category ‘Diversity and Inclusion’.

Appendix 13

Category Definition – Diversity and Inclusion

Main category name	Global justice and/or development gap
Sub-category	Diversity and Inclusion
Content description	Goals and measures aimed at diversity and inclusion
Application of the category	e.g. creating opportunities for a more diverse range of people, addressing barriers for under-represented people
Examples of applications	“[...] fostering an inclusive and supportive environment for African NewSpace founders.” (Space in Africa, 2023b, p. 10)
Differentiation from other categories (optional)	This category does not include Indigenous rights as they are distinguished from diversity and inclusion unless a connection is specifically mentioned by the government. The Sustainable Development Goals (SDGs) are also not included in this category – Diversity and Inclusion measures have to be specifically mentioned.

Appendix 14

Category Definition – Indigenous Rights

Scenario Descriptor	Global justice and/or development gap
Coding Indicator	Indigenous Rights
Content description	Goals and measures aimed at Indigenous rights
Application of the category	e.g. partnerships with companies run by Indigenous people, addressing barriers for Indigenous people from education to employment
Examples of applications	“We will foster partnerships with Māori in aerospace through: - our work with Māori businesses and collectives on using aerospace technologies to further regional and national economic development - ensuring Māori can excel in sector opportunities, employment and training - developing sector development initiatives that engage Māori expertise.” (MBIE, 2023a, p. 9)
Differentiation from other categories (optional)	Distinct from diversity and inclusion unless a connection is specifically mentioned by the government. The Sustainable Development Goals (SDGs) are not included in this category – Indigenous rights have to be specifically mentioned.

Appendix 15

Category Definition – Sustainable Development Goals (SDGs)

Scenario Descriptor	Global justice and/or development gap
Coding Indicator	Sustainable Development Goals (SDGs)
Content description	Mentioning of the UN Sustainable Development Goals
Application of the category	e.g. how space activities contribute to SDGs
Examples of applications	"[...] meeting the requirements of the sustainable development goals formulated by the United Nations in coordination with the Ministry of External Affairs" (Indian Space Research Organisation, 2023 , p. 10)
Differentiation from other categories (optional)	Only coded if SDGs are specifically mentioned.

Appendix 16

Category Definition – Profit-driven Incentives

Scenario Descriptor	Strategies of private actors
Coding Indicator	Profit-driven Incentives
Content description	Incentives that are motivated by profit and growth
Application of the category	e.g. business incubation centres
Examples of applications	"In February 2023 we announced c. £5 million in funding to 18 projects which will help the UK space economy to grow and drive levelling up across the UK." (Government of the United Kingdom, 2023 , p. 9)
Differentiation from other categories (optional)	Does not include workforce development initiatives because these are covered by category Economic Sustainability. Collaboration with other governments is not included either since this category focusses on actions within one country/government

Appendix 17

Category Definition – Value-driven Incentives

Scenario Descriptor	Strategies of private actors
Coding Indicator	Value-driven Incentives
Content description	Incentives that are driven by specific values, especially sustainability
Application of the category	e.g. more financial support if space missions sustainable; Space Sustainability Ranking
Examples of applications	"Supporting the intent of His Majesty King Charles III's initiatives in the Astra Carta, which aims to convene the private sector in creating and accelerating sustainable practices across the global space industry." (Government of the United Kingdom, 2024 , p. 14)
Differentiation from other categories (optional)	Excludes general UN conventions or other global agreements since these are coded in categories 'Multilateral and/or Global' and 'International Organisations'

Appendix 18

Category Definition – Sustainability on Earth

Scenario Descriptor	Impact on Earth's environment
Coding Indicator	Sustainability on Earth
Content description	Aggregate of the two sub-categories 'Using Space for Earth's Sustainability' and 'Impact of Space Activities on Earth'
Application of the category	Not coded separately but aggregating the two sub-categories
Examples of applications	"fast-growing sector that can make a vital contribution to addressing the continent's challenges" (African Union, 2019 , p. 7)
Differentiation from other categories (optional)	/

Appendix 19

Category Definition – Using Space for Earth's Sustainability

Scenario Descriptor	Earth-Space interdependency
Coding Indicator	Using Space for Earth's Sustainability
Content description	Ways of using space activities to enhance sustainability on Earth
Application of the category	e.g. Earth observation. Space Weather not coded since this category encompasses activities that are aimed to enhance Earth's sustainability and space weather rather influences systems in space
Examples of applications	"fast-growing sector that can make a vital contribution to addressing the continent's challenges" (African Union, 2019 , p. 7)
Differentiation from other categories (optional)	/

Appendix 20

Category Definition – Impact of Space Activities on Earth

Scenario Descriptor	Earth-Space interdependency
Coding Indicator	Impact of Space Activities on Earth
Content description	Acknowledgement of the impact of space activities on Earth as well as goals and measures to reduce it
Application of the category	e.g. reusable launch vehicles, impact of rocket launches and satellite re-entries, light pollution
Examples of applications	“In the process, sustainability principles will be applied throughout the entire life cycle of the system” (Federal Ministry for Economic Affairs and Climate Action, 2023 , p. 18)
Differentiation from other categories (optional)	/

Appendix 21

Category Definition – Sustainability in Space

Scenario Descriptor	Impact on Space Environment
Coding Indicator	Sustainability in Space
Content description	Goals and measures to reduce the impact of space activities on the space environment and preserving it for future generations
Application of the category	e.g. orbital debris mitigation, space traffic management, in-orbit satellite servicing
Examples of applications	“UNDERScores that a sustainable and safe space environment is the indispensable condition for continuing humankind’s exploration and use of space” (ESA, 2023 , p. 4)
Differentiation from other categories (optional)	/

Appendix 22

List of Keywords for Actor composition of governance

Start-ups und SME’s	Large Companies	Governments	Developing Economies	International Organisations
start-up, startup small medium SME*	business commercial size enabling private industry compan*	cooperat* Agreement OR agreements signatories collaborat* countr* consult* EU, ESA, Europe* NASA, US	developing, developed BRI (Belt and Road Initiative) emerging	UN United Nations SDG sustainable development organisation, organization

Appendix 23

List of Keywords for Governance characteristics

Bilateral	Minilateral	Multilateral and or Global
partner* bilateral	trade export minilateral Artemis Accords	United Nations UN treat* multilateral SDG sustainable development

Appendix 24

List of Keywords for Space-based or ground infrastructures

Space as Common Global Resource	Ownership	Equity as a priority
common	Artemis Accords	equit*
commons	own*	access
resource	in-situ resource*	benefit
domain	ISRU	inclusive
		humanity
		humankind
		future generations

Appendix 25

List of Keywords for Global justice and/or development gap

Diversity and Inclusion	Indigenous Rights	Sustainable Development Goals
women	Indigenous	SDG
gender	Māori	sustainable development
inclus* (inclusion, inclusive, inclusiveness)	Aboriginal	
divers* (divers, diversity)	Torres Strait Islander people	
disability, disabilities		
	marginalised	

Appendix 26

List of Keywords for Incentives

Profit-driven Incentives	Value-driven Incentives
invest*	policy OR policies
subsidi*	standard OR standards OR standardisation OR standardization
	incentiv*
barrier OR barriers	practices OR practises
fund*	regulation OR regulatory OR regulate
incubat*	best practice
stimulat*	norm OR norms
foster*	behav*
accel*	
finance OR financing	
scale-up OR upscale	

Appendix 27

List of Keywords for Sustainability Aspects

Using Space for Earth's Sustainability	Impact of Space Activities on Earth	Sustainability in Space	Economic Sustainability
	environment		grow*
	impact		cost
	climate		feasib*
	conserv*		market
	preserv*		revenue
	planet		barrier(s)
	protect	space traffic management	workforce
	reusab*	STM	skill*
Observation; EO		frequenc*	educat*
challenge		space situational awareness; SSA	sovereign
SDG		SDG	jobs
space weather		debris	economic
monitor			invest
Earth			commercial

Appendix 28

List of analysed Documents including Word-Count

Government	Documents	Number of Words	Irrelevant Words
African Union	Space in Africa. (2023). African Space Industry Annual Report, 2023 Edition – Space in Africa. https://spaceinafrica.com/2023/08/28/african-space-industry-annual-report-2023-edition/	984	0
	Space in Africa. (2023). <i>African Space Industry Report 2023—Excerpt</i> .	1885	639
	African Union (2019). African Space Strategy—For Social, Political and Economic Integration. https://au.int/sites/default/files/documents/37434-doc-au_space_strategy_isbn-electronic.pdf	8710	464
Australia	Australian Academy of Science (2022). <i>Australia in space: A decadal plan for Australian space science 2021-2030</i> . Australian Academy of Science.	22305	2780
	Australian Space Agency. (2019, April). <i>Australian Civil Space Strategy 2019-2028</i> .	5570	403
Brazil	Brazilian Space Agency (2022). <i>PNAE Compact Version—National Program For Space Activities 2022-2031</i> .	8383	1352
China	The State Council Information Office of the People's Republic of China. (2022, January 28). <i>Full Text: China's Space Program: A 2021 Perspective</i> . https://english.www.gov.cn/archive/whitepaper/202201/28/content_WS61f35b3dc6d09c94e48a467a.html	7683	49
Europe	ESA (2022). <i>ESA Space Economy 2022 – Creating Value for Europe</i> . https://esamultimedia.esa.int/multimedia/publications/Space_economy_creating_value_for_Europe/esa_space-economy_brochure.pdf	3758	99
	ESA (2023). <i>Lifting Europe's Ambitions for a Green and Sustainable Future, Access to Space and Space Exploration</i> . https://esamultimedia.esa.int/docs/resolution_summit2023_EN.pdf	3176	0
France	CNES (2022). <i>Annual Report 2022</i> .	19437	667
Germany	Federal Ministry for Economic Affairs and Climate Action. (2023). <i>The German Federal Government's Space Strategy</i> .	21217	304
India	Indian Space Research Organisation (2023). <i>Indian Space Policy—2023</i> .	2860	561
New Zealand	MBIE. (2023). <i>Aotearoa New Zealand Aerospace Strategy 2023-2030 = Te rautaki Ātea-ā-rangi o Aotearoa 2023-2030</i> .	8024	1901
	MBIE. (2023, November 27). <i>Briefing for the Incoming Minister for Space</i> .	13249	2704
	MBIE (2024). <i>New Zealand Space and Advanced Aviation Strategy 2024-2030</i> .	2935	425
Russia	Luzin, P. (2024). <i>Russia's Space Program after 2024</i> .	7131	1591
UK	Government of the United Kingdom. (2023). <i>National Space Strategy in Action</i> .	13623	229
	Government of the United Kingdom. (2024, March). <i>Space Industrial Plan from ambition to action – advancing UK Space Industry</i> .	7746	157
USA	National Science and Technology Council. (2023, March). <i>National Low Earth Orbit Research and Development Strategy</i> .	5308	915
	NASA (2024). <i>NASA's Space Sustainability Strategy</i> .	9954	755

Appendix 29

Total Relevant Words per Government

Governments	Total Relevant Words
African Union	10476
Australia	24692
Brazil	7031
China	7634
Europe	6835
France	18770
Germany	20913
India	2299
NZ	19178
Russia	5540
UK	20983
US	13592

Appendix 30
Numerical Coding Indicator Scale for Mapping the Governments onto the Scenarios

Scenario Descriptor	Coding Indicators	Measurement	Space Cartel	Earth-centric Gold Rush	Open Space/Space Utopia	Earth-Space Sustainability
Actor composition of governance	Developing Economies	Coding Ratio		0%	>0%	
	International Organisations	Coding Ratio		0% to 10%	10% to 20%	>20%
	Comparison of Start-ups and SMEs vs. large companies	Ratio of start-ups and SMEs to large companies		<0.75	>0.75	
Governance characteristics	Multilateral and/or Global	Coding Ratio		0% to 16.5%	16.5% to 33%	>33%
	Comparison of multi-, mini- or bilateral	Ratio of bilateral to minilateral	≥1	≤1	~1 (0.7-1.3)	if multilateral >33%
Industry structure	Economic sustainability	Coding Ratio		>6.5%	<6.5%	
	Space-based or ground infrastructures	Space as Common Global Resource Ownership		0%	>0%	
	Equity as a priority	Coding Ratio		>0% & global resource = 0%	>0% & global resource >0%	0%
				0% & global resource = 0%	0% & global resource >0%	>0%
Global justice and/or development gap	Diversity and Inclusion	Coding Ratio	0% to 0.84%	0.84% to 1.67%	1.67% to 2.5%	2.5% to 3.34%
	Indigenous Rights	Coding Ratio	0% to 0.57%	0.57% to 1.14%	1.14% to 1.71%	1.71% to 2.27%
	Sustainable Development Goals (SDGs)	Coding Ratio	0% to 0.44%	0.44% to 0.88%	0.88% to 1.32%	1.32% to 1.7%
Strategies of private actors	Prioritisation of profit- over value-driven incentives	Ratio of profit- to value-driven		3 to 4.5	1.5 to 3	0 to 1.5
Impact on Earth's environment	Sustainability on Earth	Coding Ratio	<10%	>10%	<10%	>10%
		Ratio of using space to impact	-	>16.3	-	<16.3
Impact on Space Environment	Sustainability in space	Coding Ratio		<10%	>10%	
	Earth-Space interdependency	Ratio of sustainability on Earth to in space	~1 (0.7 to 1.3) & both <10%	≥1	≤1	~1 (0.7 to 1.3) & both >10%

Appendix 31

Detailed Explanations for the Scale Determination

Nr	Indicator	Scale Determination
1.1	Developing Economies (proportional)	Mentioned (>0%) or Not (=0%)
1.2	International Organisations (proportional)	5 types of governance actors (start-ups/SMEs, large companies, governments, developing economies and international organisations) → even distribution amongst them would be 1/5 of 100% = 20% → focus on international organisation greater in Earth-Space Sustainability (>20%) than Open Space Scenario (10-20%)
1.3	Ratio of 'Start-ups and SMEs' to 'large companies'	Assumption: If SMEs amount to at least ¼ of the total number of large companies, they are likely to exert significant influence.
2.1	Multilateral and or Global (proportional)	3 types of governance characteristics (bilateral, minilateral, multilateral/global) → even distribution amongst them would be 1/3 of 100% = 33% → focus on shared sustainability (global agreements) greater in Earth-Space Sustainability (>33%) than Open Space Scenario (16.5-33%)
2.2	Ratio of proportional 'bilateral' to proportional 'minilateral'	Space Cartel prioritises bilateral agreements, while Gold Rush prioritises minilateral agreements. Open Space involves mixture of both, whereas Earth-Space focusses on multilateral agreements, making this indicator obsolete if indicator 2.1 is greater than 33% (in that case, indicator 2.2 is automatically scored as Earth-Space Sustainability)
3	Economic sustainability	Total indifference of economic growth would be 0% coding, max. value coded is 26.02% → since it is four scenarios, the threshold for indifference was defined as: $\frac{1}{4} * 26.02\% \approx 6.5\%$
4.1	Space as Common Global Resource	Mentioned (>0%) or Not (=0%)
4.2	Ownership	– Space Cartel & Gold Rush: ownership mentioned (>0%) and space not seen as global commons (indicator 4.1 = 0%) – Open Space: ownership mentioned (>0%) but space seen as global commons (indicator 4.1 > 0%) since this potentially leads to unequal distribution and ineffective coordination between in-space and on Earth – Earth-Space: ownership not mentioned (=0%)
4.3	Equity as a priority	– Space Cartel & Gold Rush: equity not mentioned (=0%) and space not seen as global commons (indicator 4.1 = 0%) – Open Space: equity not mentioned (=0%) but space seen as global commons (indicator 4.1 > 0%) since this potentially leads to unequal distribution and ineffective coordination between in-space and on Earth – Earth-Space: equity mentioned (>0%)
5.1	Diversity and Inclusion	Development Gap gradually decreases in the scenarios from Space Cartel to Gold Rush to Open Space to Earth-Space → thresholds were defined as increments of one-quarter of the coding-range, with the minimum value set to 0% to represent the widest development gap $\frac{1}{4} * 3.34\% \approx 0.84\%$
5.2	Indigenous Rights	Similar approach as for indicator 5.1 → thresholds were defined as increments of one-quarter of the coding-range, with the minimum value set to 0% to represent the widest development gap $\frac{1}{4} * 2.27\% \approx 0.57\%$
5.3	Sustainable Development Goals (SDGs)	Similar approach as for indicators 5.1 and 5.2 → thresholds were defined as increments of one-quarter of the coding-range, with the minimum value set to 0% to represent the widest development gap $\frac{1}{4} * 1.76\% \approx 0.44\%$
6	Ratio of 'profit-driven incentives' to 'value-driven incentives'	Priority of profit gradually decreases in the scenarios from Space Cartel (high priority) and Gold Rush (high) to Open Space (medium) to Earth-Space (low) → thresholds were defined as increments of one-third of the coding-range, with the minimum value set to 0% to represent absence of profit-driven incentives $\frac{1}{3} * 4.5 = 1.5$
7	Sustainability on Earth	With a coding range of roughly 30% and the scenarios differentiating between the two states of severe and minimal degradation of Earth's environment, a threshold of 10% coding ratio was assumed to be sufficient to avoid Earth's degradation
	Ratio of 'using space for Earth's sustainability' to 'impact of space activities'	This indicator was applied in combination with category 'Sustainability on Earth' to distinguish between the Gold Rush and Earth-Space Sustainability scenario. While the former prioritises Earth's development, the latter prioritises both Earth's development and the impact of space activities. The threshold was defined as ½ of the range: $\frac{1}{2} * 32.6 = 16.3$
8	Sustainability in space	Similar to category 'Sustainability on Earth', the scenarios distinguish two states of the impact on the space environment (severe and minimal degradation). Thus, the same threshold of 10% was applied to this indicator despite the coding range being higher than for category 'Sustainability on Earth' (roughly 40%)
9	Ratio of 'sustainability on Earth' to 'sustainability in space'	– Space Cartel: low interdependence (prioritises neither sustainability on Earth nor in space) → ratio ≈ 1 and coding for both categories below threshold of 10% – Gold Rush: low interdependence (does not prioritise sustainability in space) → ratio ≫ 1 – Open Space: low interdependence (does not prioritise sustainability on Earth) (ratio ≪ 1) – Earth-Space: high interdependence (prioritises sustainability on Earth and in space equally) → ratio ≈ 1 and coding for both categories above threshold of 10%

Appendix 32

Mapping the African Union.

Nr	Descriptor	Indicator	Value	Space Cartel	Earth-Centric Gold Rush	Open Space/ Space Utopia	Earth-Space Sustainability	X-Score (Mean)	Y-Score (Mean)	Weighting	Weighted X-Score	Weighted Y-Score
					X = -1 Y = +1	X = +1 Y = -1	X = +1 Y = +1					
1.1	Actor composition of governance	Developing Economies (proportional)	0.00%	x	x			-1.00	0.00	0.33	-0.33	0.00
1.2		International Organisations (proportional)	23.81%				x	1.00	1.00	0.33	0.33	0.33
1.3		Ratio of 'Start-ups and SMEs' to 'large companies'	1.11			x	x	1.00	0.00	0.33	0.33	0.00
2.1	Governance characteristics	Multilateral and or Global (proportional)	34.79%				x	1.00	1.00	0.5	0.50	0.50
2.2		Ratio of proportional 'bilateral' to proportional 'minilateral'	1.74				x	1.00	1.00	0.5	0.50	0.50
3	Industry structure	Economic sustainability	9.95%	x	x	x		-0.33	-0.33	1	-0.33	-0.33
4.1	Space-based or ground infrastructures	Space as Common Global Resource	0.00%	x	x			-1.00	0.00	0.33	-0.33	0.00
4.2		Ownership	0.00%				x	1.00	1.00	0.33	0.33	0.33
4.3		Equity as a priority	0.67%				x	1.00	1.00	0.33	0.33	0.33
5.1	Global justice and/or development gap	Diversity and Inclusion	1.26%		x			-1.00	1.00	0.33	-0.33	0.33
5.2		Indigenous Rights	0.37%	x				-1.00	-1.00	0.33	-0.33	-0.33
5.3		Sustainable Development Goals (SDGs)	0.74%		x			-1.00	1.00	0.33	-0.33	0.33
6	Strategies of private actors	Ratio of 'profit-driven incentives' to 'value- driven incentives'	2.09			x		1.00	-1.00	1	1.00	-1.00
7	Impact on Earth's environment	Sustainability on Earth	27.84%		x			-1.00	1.00	1	-1.00	1.00
		Ratio of 'using space for Earth's sustainability' to 'impact of space activities on Earth'	25.18									
8	Impact on Space Environment	Sustainability in space	3.73%	x	x			-1.00	0.00	1	-1.00	0.00
9	Earth-Space interdependency	Ratio of sustainability on Earth to in space	7.46		x			-1.00	1.00	1	-1.00	1.00
Total											-1.67	3.00

Appendix 33
Mapping Brazil.

Nr	Descriptor	Indicator	Value	Space Cartel	Earth-Centric Gold Rush	Open Space/ Space Utopia	Earth-Space Sustainability	X-Score (Mean)	Y-Score (Mean)	Weighting	Weighted X-Score	Weighted Y-Score
					X = -1 Y = +1	X = +1 Y = -1	X = +1 Y = +1					
1.1	Actor composition of governance	Developing Economies (proportional)	0.00%	x	x			-1.00	0.00	0.33	-0.33	0.00
1.2		International Organisations (proportional)	0.00%	x	x			-1.00	0.00	0.33	-0.33	0.00
1.3		Ratio of 'Start-ups and SMEs' to 'large companies'	1.18			x	x	1.00	0.00	0.33	0.33	0.00
2.1	Governance characteristics	Multilateral and or Global (proportional)	9.15%	x	x			-1.00	0.00	0.5	-0.50	0.00
2.2		Ratio of proportional 'bilateral' to proportional 'minilateral'	2.37	x				-1.00	-1.00	0.5	-0.50	-0.50
3	Industry structure	Economic sustainability	15.18%	x	x	x		-0.33	-0.33	1	-0.33	-0.33
4.1	Space-based or ground infrastructures	Space as Common Global Resource	0.00%	x	x			-1.00	0.00	0.33	-0.33	0.00
4.2		Ownership	0.00%				x	1.00	1.00	0.33	0.33	0.33
4.3		Equity as a priority	0.00%	x	x			-1.00	0.00	0.33	-0.33	0.00
5.1	Global justice and/or development gap	Diversity and Inclusion	0.38%	x				-1.00	-1.00	0.33	-0.33	-0.33
5.2		Indigenous Rights	0.00%	x				-1.00	-1.00	0.33	-0.33	-0.33
5.3		Sustainable Development Goals (SDGs)	0.00%	x				-1.00	-1.00	0.33	-0.33	-0.33
6	Strategies of private actors	Ratio of 'profit-driven incentives' to 'value- driven incentives'	3.86	x	x			-1.00	0.00	1	-1.00	0.00
7	Impact on Earth's environment	Sustainability on Earth	3.75%	x		x		0.00	-1.00	1	0.00	-1.00
		Ratio of 'using space for Earth's sustainability' to 'impact of space activities on Earth'	3.15									
8	Impact on Space Environment	Sustainability in space	0.00%	x	x			-1.00	0.00	1	-1.00	0.00
9	Earth-Space interdependency	Ratio of sustainability on Earth to in space	3.75		x			-1.00	1.00	1	-1.00	1.00
Total											-6.00	-1.50

Appendix 34
Mapping the USA.

Nr	Descriptor	Indicator	Value	Space Cartel	Earth-Centric Gold Rush	Open Space/ Space Utopia	Earth-Space Sustainability	X-Score (Mean)	Y-Score (Mean)	Weighting	Weighted X-Score	Weighted Y-Score
					X = -1 Y = +1	X = +1 Y = -1	X = +1 Y = +1					
1.1	Actor composition of governance	Developing Economies (proportional)	0.86%			x	x	1.00	0.00	0.33	0.33	0.00
1.2		International Organisations (proportional)	6.01%	x	x			-1.00	0.00	0.33	-0.33	0.00
1.3		Ratio of 'Start-ups and SMEs' to 'large companies'	1.11			x	x	1.00	0.00	0.33	0.33	0.00
2.1	Governance characteristics	Multilateral and or Global (proportional)	21.49%			x		1.00	-1.00	0.5	0.50	-0.50
2.2		Ratio of proportional 'bilateral' to proportional 'minilateral'	0.91			x		1.00	-1.00	0.5	0.50	-0.50
3	Industry structure	Economic sustainability	9.74%	x	x	x		-0.33	-0.33	1	-0.33	-0.33
4.1	Space-based or ground infrastructures	Space as Common Global Resource	0.00%	x	x			-1.00	0.00	0.33	-0.33	0.00
4.2		Ownership	0.04%	x	x			-1.00	0.00	0.33	-0.33	0.00
4.3		Equity as a priority	2.46%				x	1.00	1.00	0.33	0.33	0.33
5.1	Global justice and/or development gap	Diversity and Inclusion	1.49%		x			-1.00	1.00	0.33	-0.33	0.33
5.2		Indigenous Rights	0.00%	x				-1.00	-1.00	0.33	-0.33	-0.33
5.3		Sustainable Development Goals (SDGs)	0.00%	x				-1.00	-1.00	0.33	-0.33	-0.33
6	Strategies of private actors	Ratio of 'profit-driven incentives' to 'value- driven incentives'	0.19				x	1.00	1.00	1	1.00	1.00
7	Impact on Earth's environment	Sustainability on Earth Ratio of 'using space for Earth's sustainability' to 'impact of space activities on Earth'	2.94% 0.24	x		x		0.00	-1.00	1	0.00	-1.00
8	Impact on Space Environment	Sustainability in space	41.57%			x	x	1.00	0.00	1	1.00	0.00
9	Earth-Space interdependency	Ratio of sustainability on Earth to in space	0.07			x		1.00	-1.00	1	1.00	-1.00
Total											2.67	-2.33

Appendix 35

Scenario Mapping – Indicator Results of Australia, Brazil, the United Kingdom and New Zealand.

Scenario Descriptor	Coding Indicator incl. Weight	Space Cartel				Earth-centric Gold Rush				Open Space/Space Utopia				Earth-Space Sustainability				
		AUS	BR	UK	NZ	AUS	BR	UK	NZ	AUS	BR	UK	NZ	AUS	BR	UK	NZ	
Actor composition of governance	Developing Economies	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
	International Organisations	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
	Start-ups and SMEs	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Governance characteristics	Multilateral and/or Global	1/2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
	Comparison of multi-, mini- or bilateral	1/2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Industry structure	Economic sustainability	1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Space-based or ground infrastructures	Space as Common Global Resource	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
	Ownership	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
	Equity as a priority	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Global justice and/or development gap	Diversity and Inclusion	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
	Indigenous Rights	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
	Sustainable Development Goals (SDGs)	1/3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Strategies of private actors	Prioritisation of profit- over value-driven incentives	1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Impact on Earth's environment	Sustainability on Earth	1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Impact on Space Environment	Sustainability in space	1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Earth-Space interdependency	Ratio of sustainability on Earth over sustainability in space	1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Weighted Count per Scenario and Government			4.5	7.3	5.7	5.5	4.5	5.8	2.7	2.7	4.5	2.3	4.7	4.8	1.3	0.7	1.3	1.3

Appendix 36

Scenario Mapping – Indicator Results of India, the African Union, France and Germany.

Scenario Descriptor	Coding Indicator incl. Weight	Space Cartel				Earth-centric Gold Rush				Open Space/Space Utopia				Earth-Space Sustainability				
		IND	AU	FR	DE	IND	AU	FR	DE	IND	AU	FR	DE	IND	AU	FR	DE	
Actor composition of governance	Developing Economies	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	International Organisations	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Start-ups and SMEs	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Governance characteristics	Multilateral and/or Global	1/2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Comparison of multi-, mini- or bilateral	1/2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Industry structure	Economic sustainability	1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Space-based or ground infrastructures	Space as Common Global Resource	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Ownership	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Equity as a priority	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Global justice and/or development gap	Diversity and Inclusion	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Indigenous Rights	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Sustainable Development Goals (SDGs)	1/3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Strategies of private actors	Prioritisation of profit- over value-driven incentives	1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Impact on Earth's environment	Sustainability on Earth	1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Impact on Space Environment	Sustainability in space	1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Earth-Space interdependency	Ratio of sustainability on Earth over sustainability in space	1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Weighted Count per Scenario and Government			4.7	3.0	2.3	1.7	5.0	5.3	3.5	2.5	1.3	2.3	4.5	4.8	3.3	2.3	2.7	4.0

References

African Union, 2019. African space strategy—for social, political and economic integration. https://au.int/sites/default/files/documents/37434-doc-au_space_strategy_isbn-electronic.pdf.

Australian Academy of Science, 2022. Australia in space: a decadal plan for. In: Australian space science, 2021–2030. Australian Academy of Science, pp. 1–64.

Australian Space Agency, 2019. Australian Civil Space Strategy 2019–2028.

Bickerton, S., Varughese, C., Mankelov, C., Katavich-Barton, S., Dowling, T., Wijayatunga, M., Qualtrough, C., Kirolos, B., Henry, L., Rattenbury, N., Morris, A., Dhopade, P., 2024. Sustainability within Aotearoa New Zealand's aerospace sector: current state and implications for the future. J. Roy. Soc. N. Z. 1–20. <https://doi.org/10.1080/03036758.2024.2377316>.

bne IntelliNews, 2025. Africa sets up Cairo-based space agency. <https://www.intellinews.com/africa-sets-up-cairo-based-space-agency-382718/>.

Brazilian Space Agency, 2022. PNAE Compact Version—National Program for Space Activities 2022–2031.

Byers, M., Wright, E., Boley, A., Byers, C., 2022. Unnecessary risks created by uncontrolled rocket reentries. Nat. Astron. 6 (9), 1093–1097. <https://doi.org/10.1038/s41550-022-01718-8>.

CNES, 2022. Annual Report 2022. Centre national d'études spatiales.

Cuhls, K., 2003. From forecasting to foresight processes—New participative foresight activities in Germany. J. Forecast. 22 (2–3), 93–111. <https://doi.org/10.1002/for.848>.

DarkSky International, 2024. What is Light Pollution? DarkSky International. <https://darksky.org/resources/what-is-light-pollution/>.

Del Canto Viterale, F., 2025. Global power dynamics in the contemporary space system. Systems 13 (4), 276. <https://doi.org/10.3390/systems13040276>.

Drisko, J., Maschi, T., 2015. Content Analysis. Oxford University Press. <http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780190215491.001.0001/acprof-9780190215491>.

Eberle, C., O'Connor, J., Narvaez, L., Benavides, M.M., Sebesvari, Z., 2023. UNU-EHS interconnected disaster risks 2023: risk tipping points—main report. https://s3.eu-central-1.amazonaws.com/interconnectedrisks/reports/2023/UNU_Tipping-Point_s.231017_no-watermark.pdf.

Eberle, C., Sebesvari, Z., 2023. UNU-EHS Interconnected Disaster Risks 2023: Risk Tipping Points—Space Debris. United Nations University - Institute for Environment and Human Security. https://s3.eu-central-1.amazonaws.com/interconnectedrisks/reports/2023/TR_231115_Space_Debris.pdf.

Elliot, V., 2025. The Young. Inexperienced Engineers Aiding Elon Musk's Government Takeover. <https://www.wired.com/story/elon-musk-government-young-engineers/>.

ESA. (n.d.). Clean Space Projects and Core Activities. Retrieved 22 October 2024, from https://www.esa.int/Space_Safety/Clean_Space_Projects_and_Core_Activities.

ESA, 2022. ESA space economy 2022 – creating value for Europe. https://esamultimedia.esa.int/multimedia/publications/Space_economy_creating_value_for_Europe/esa_space-economy_brochure.pdf.

ESA, 2023. Lifting Europe's ambitions for a green and sustainable future. Access to Space and Space Exploration. https://esamultimedia.esa.int/docs/resolution_summit2023_EN.pdf.

ESA, 2024. ESA's annual space environment report. https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf.

ESA, 2025. Technological 'to-do list' to reach zero Debris created. https://www.esa.int/Space_Safety/Technological_to-do_list_to_reach_Zero_Debris_created.

European Commission, 2025. EU space act—strengthening safety, resilience and sustainability in space. https://defence-industry-space.ec.europa.eu/eu-space-act_en.

Federal Ministry for Economic Affairs and Climate Action, 2023. The German Federal Government's Space Strategy.

Feldscher, J., 2025. Trump's first 100 days of space policy. Payload. <https://payloadspace.com/trumps-first-100-days-of-space-policy/>.

Foust, J., 2025. NASA closes offices, lays off staff as it prepares for larger workforce reductions. Space News. <https://spacenews.com/nasa-closes-offices-lays-off-staff-as-it-prepares-for-larger-workforce-reductions/>.

Friedman, L., Tabuchi, H., Davenport, C., 2025. Trump Stocks E.P.A. with Oil, Gas and Chemical Lobbyists. The New York Times. <https://www.nytimes.com/2025/01/25/climate/epa-staff-oil-gas-chemical-industry-lobbyists.html>.

Geise, R., Dhopade, P., 2024. Analysing National Priorities in the Space Sector Across the Globe. The University of Auckland.

Geise, R., Dhopade, P., 2025. Replication package for 'Examining Possible Future Trajectories of Global Space Sectors'. Zenodo. <https://doi.org/10.5281/zenodo.17067434>.

Government of the United Kingdom, 2023. National Space Strategy in Action.

Government of the United Kingdom, 2024. Space Industrial Plan from Ambition to Action – Advancing UK Space Industry.

Greenacre, M., 2023. European space agency looks to private sector to stay competitive | Science|Business. <https://sciencebusiness.net/news/aerospace/european-space-agency-looks-private-sector-stay-competitive>.

Grind, K., 2024. Elon Musk's Plan to Put a Million Earthlings on Mars in 20 Years.

- Guzman, Ms J., 2021. Space Programs in Latin America: History, Current Operations, and Future Cooperation.
- Harmsworth, G.R., Awatere, S., 2013. Indigenous Māori Knowledge and Perspectives of Ecosystems.
- Inayatullah, S., 2008. Six pillars: futures thinking for transforming. *Foresight* 10 (1), 4–21. <https://doi.org/10.1108/14636680810855991>.
- Inayatullah, S., 2009. Causal Layered Analysis.
- Inayatullah, S., 2012. Futures studies: theories and methods. In: *There's a Future. Visions for a Better World*. BBVA.
- Inayatullah, S., 2017. Causal Layered Analysis. <https://www.metafuture.org/library/2019/CLATOOLBOX2017FUTURIBLES.pdf>.
- Indian Space Research Organisation, 2023. Indian Space Policy—2023.
- Isnardi, C., 2020. Problems with enforcing international space law on private actors. *Columbia J. Transnat. Law* 58 (2), 489–530.
- Kocifaj, M., Kundracik, F., Barentine, J.C., Bará, S., 2021. The proliferation of space objects is a rapidly increasing source of artificial night sky brightness. *Mon. Not. R. Astron. Soc. Lett.* 504 (1), L40–L44. <https://doi.org/10.1093/mnras/lsab030>.
- Kuckartz, U., 2018. *Qualitative Inhaltsanalyse: Methoden, Praxis, Computerunterstützung* (4. Auflage). Beltz Juventa.
- Lowy, A., Hood, P., 2004. The Power of the 2 X 2 Matrix: Using 2 X 2 Thinking to Solve Business Problems and Make Better Decisions. John Wiley & Sons, Inc.
- Luzin, P., 2024. Russia's Space Program After 2024.
- Lythberg, B., Woods, C., 2016. When the River Ran Purple': Reframing Indigenous Economics in a Global City.
- Machado, R., 2022. The economy of reusable launch system. Universidade Lusófona do Porto 1–8.
- Māori Working Group on Aerospace, 2024. *Statement from the Māori working group on aerospace on the govt's launch of aerospace and advanced aviation strategy*. Scoop media. <https://www.scoop.co.nz/stories/SC2409/S00052/statement-from-the-maoiri-working-group-on-aerospace-on-the-govts-launch-of-aerospace-and-advanced-aviation-strategy.htm>.
- Mark, J., Telford, T., Svriluga, S., 2025. In first days, Trump deals 'death blow' to DEI and affirmative action. *Wash. Post*. <https://www.washingtonpost.com/business/2025/01/23/trump-dei-affirmative-action/>.
- MBIE, 2022. Tāwhaki – a unique partnership focused on aerospace and environmental outcomes | Ministry of Business, Innovation & Employment. <https://www.mbie.govt.nz/science-and-technology/science-and-innovation/international-opportunities/new-zealand-r-d/innovative-partnerships/project-tawhaki>.
- MBIE, 2023a. Aotearoa New Zealand Aerospace Strategy 2023–2030 = Te Rautaki Ātea-a-rangi O Aotearoa 2023–2030.
- MBIE, 2023b. Briefing for the Incoming Minister for Space.
- MBIE, 2024. New Zealand Space and Advanced Aviation Strategy 2024–2030.
- McAllister, T., Hikuroa, D., Macinnis-Ng, C., 2023. Connecting science to Indigenous knowledge: kaitiakitanga, conservation, and resource management. *N. Z. J. Ecol.* <https://doi.org/10.20417/nzjcol.47.3521>.
- McClintock, B., Leuret, M., 2024. 8. Russian Space Strategy and Capabilities: a Tale of Decline.
- Merriam-Webster Dictionary. (n.d.). Definition of Colonialism. Retrieved 6 November 2024, from <https://www.merriam-webster.com/dictionary/colonialism>.
- Miroux, L., 2022. Environmental limits to the space sector's growth. *Sci. Total Environ.* 806, 150862. <https://doi.org/10.1016/j.scitotenv.2021.150862>.
- Morin, J.-F., Tepper, E., 2023. The empire strikes back: comparing US and China's structural power in outer space. *Global Studies Quarterly* 3 (4), ksad067. <https://doi.org/10.1093/isagsq/ksad067>.
- Mulligan, V., Inayatullah, S., Directors, 2024. *Episode three: Sohail inayatullah on CLA* [Broadcast]. https://thefuturesworkshop.substack.com/p/episode-three-sohail-inayatullah?utm_campaign=post&utm_medium=web&triedRedirect=true.
- Nach mir die Sintflut. (n.d.). Vivat! magazin. Retrieved 25 October 2024, from <https://www.vivat.de/magazin/bibel/redewendungen/nach-mir-die-sintflut/>.
- NASA, 2024. Nasa's Space Sustainability Strategy.
- National Science and Technology Council, 2023. National Low Earth Orbit Research and Development Strategy.
- New Zealand Government, 2024. New Zealand on stage at global space symposium | Beehive.govt.nz. <https://www.beehive.govt.nz/release/new-zealand-stage-global-space-symposium>.
- Ngo, M., Fahrenthold, D.A., 2024. Musk wants to slash \$2 trillion in federal spending. Is that possible? *N. Y. Times*. <https://www.nytimes.com/2024/11/16/us/politics/dep-t-government-efficiency-explainer.html>.
- NSTXL, 2024. Reducing the cost of space travel with reusable launch vehicles. NSTXL. <https://nstxl.org/reducing-the-cost-of-space-travel-with-reusable-launch-vehicles/>.
- OECD, 2020. *Space sustainability: the economics of space debris in perspective* (OECD science, technology and industry policy papers 87). https://www.oecd-ilibrary.org/science-and-technology/space-sustainability_a339de43-en.
- OECD, 2024. The Economics of Space Sustainability: Delivering Economic Evidence to Guide Government Action. OECD. <https://doi.org/10.1787/b2257346-en>.
- OECD, 2026. Space portal. <https://stip.oecd.org/stip/space-portal>.
- Rewi, S., Hikuroa, D., 2023. He karanga Maha. Investigating relational resource management in aotearoa, New Zealand. *Int. J. Environ. Res. Publ. Health* 20 (8), 5556. <https://doi.org/10.3390/ijerph20085556>.
- Robins-Early, N., 2024. Trump Announces Plan for Elon Musk-led. *government efficiency commission*. The Guardian. <https://www.theguardian.com/us-news/article/2024/sep/05/trump-musk-efficiency-commission>.
- Robins-Early, N., Leingang, R., 2024. Elon musk is Trump's biggest cheerleader. How could he affect election results? *Guardian*. <https://www.theguardian.com/us-news/ng-interactive/2024/oct/18/elon-musk-trump-election-influence>.
- Robson, D., 2014. The expert guide to space colonies. <https://www.bbc.com/future/article/20141002-time-to-plan-a-space-colony>.
- Salmond, A., 2021. *Dame Anne salmond: iwi vs kiwi*. SEWN – Social Equity & Wellbeing network. <https://hail.to/sewn/article/evBVoDy>.
- Silver, L., Huang, C., Clancy, L., Prozorovsky, A., 2024. How People in the Asia-Pacific Region View China's Role on the World Stage. Pew Research Center. <https://www.pewresearch.org/global/2024/07/09/how-people-in-the-asia-pacific-region-view-chinas-role-on-the-world-stage/>.
- Space Foundation, 2024. Space Foundation Announces \$570B Space Economy in 2023, Driven by Steady Private and Public Sector Growth. *Space Foundation*. <https://www.spacefoundation.org/2024/07/18/the-space-report-2024-q2/>.
- Space in Africa, 2023a. African Space Industry Annual Report. *2023 Edition – Space in Africa*. <https://spaceinafrica.com/2023/08/28/african-space-industry-annual-report-2023-edition/>.
- Space in Africa, 2023b. *African Space Industry Report 2023—Excerpt*.
- Space Insider, 2023. Countries with Space Programs: an Overview. *Space Insider*. <http://spaceinsider.tech/2023/11/27/countries-with-space-programs-an-overview/>.
- Spitz, R., Zuin, L., 2023. Driving systemic change & assumptions. In: *The Definitive Guide to Thriving on Disruption: Volume IV - Disruption as a Springboard to Value Creation*. Disruptive Futures Institute. <https://static1.squarespace.com/static/6307c394855bb0c329001d1/t/632e8c6d558e851f22534f80/1663994994073/Driving+Systemic+Change+-+Assumptions+%5BSample+Slides+from+The+Definitive+Guide+to+Thriving+on+Disruption%5D.pdf>.
- Steer, C., 2026. Variable Geometry in Orbit: Canada's Middle-Power Moment in Space. Centre for International Governance Innovation. <https://www.cigionline.org/articles/variable-geometry-in-orbit-canadas-middle-power-moment-in-space/>.
- Sustainable Markets Initiative, 2023. Astra Carta—Summarium. https://www.sustainable-markets.org/AstraCarta_summarium.pdf.
- The State Council Information Office of the People's Republic of China, 2022. Full text: china's space program: a 2021 perspective. https://english.www.gov.cn/archive/whitepaper/202201/28/content_WS61f35b3dc6d09c94e48a467a.html.
- The White House, 2025. Ensuring American space superiority. The White House. <https://www.whitehouse.gov/presidential-actions/2025/12/ensuring-american-space-superiority/>.
- Toft, M.D., 2025. The return of spheres of influence. *Foreign Aff.* <https://www.foreignaffairs.com/united-states/return-spheres-influence>.
- UN COPUOS, 2026. Statement of the G-77 and China during the sixty-third session of the scientific and technical subcommittee of the united nations committee on the peaceful uses of outer space. <https://www.g77.org/vienna/wp-content/uploads/2026/02/All-statements.pdf>.
- United Nations, 1987. Sustainability. United Nations, United Nations. <https://www.un.org/en/academic-impact/sustainability>.
- Varughese, C., Henry, L., Morris, A., Bickerton, S., Rattenbury, N., Mankelov, C., Gorman, A., Katavich-Barton, S., Dhopade, P., 2023. The intersection of space and sustainability: the need for a transdisciplinary and bi-cultural approach. *Acta Astronaut.* 211, 684–701. <https://doi.org/10.1016/j.actaastro.2023.07.009>.
- Venkatesan, A., Barentine, J.C., 2023. Noctalgia (Sky Grief): Our Brightening Night Skies and Loss of Environment for Astronomy and Sky Traditions.
- Venkatesan, A., Chayne, K., Directors, 2023. *Aparna Venkatesan: protecting space as ancestral global commons (Ep402)* [Broadcast]. In: *Green Dreamer*. <https://www.greendreamer.com/podcast/aparna-venkatesan-we-have-always-been-in-and-of-space>.
- Wilkinson, C., Hikuroa, D.C.H., Macfarlane, A.H., Hughes, M.W., 2020. Mātauranga Māori in geomorphology: existing frameworks, case studies, and recommendations for incorporating Indigenous knowledge in Earth science. *Earth Surf. Dyn.* 8 (3), 595–618. <https://doi.org/10.5194/esurf-8-595-2020>.
- Yap, X.-S., Janssen, M.A., Aganaba, T., Tutton, R., Korpershoek, K., Profitiotis, G., Rabitz, F., Subbiah, M.S., Wagenknecht, L., 2023. Four alternative scenarios of commons in space: prospects and challenges. *Int. J. Commons* 17 (1), 390–410. <https://doi.org/10.5334/ijc.1272>.
- Yap, X.-S., Kim, R.E., 2023. Towards earth-space governance in a multi-planetary era. *Earth System Governance* 16, 100173. <https://doi.org/10.1016/j.esg.2023.100173>.
- Yap, X.-S., Truffer, B., 2022. Contouring 'earth-space sustainability'. *Environ. Innov. Soc. Transit.* 44, 185–193. <https://doi.org/10.1016/j.eist.2022.06.004>.
- Zero Debris Community, 2024. *Zero Debris technical booklet—issue 1.0*. https://esa-multimedia.esa.int/docs/spacesafety/ZeroDebris_TechnicalBooklet.pdf.
- Zielinska-Dabkowska, K.M., Xavia, K., 2021. Looking up to the stars. A call for action to save New Zealand's dark skies for future generations to come. *Sustainability* 13 (23), 13472. <https://doi.org/10.3390/su132313472>.