Proceedings of the 5th International Conference on Art, Design and Social Sciences
DOI: 10.54254/2753-7064/2026.HT36217

The STS Framework for Evaluating the Necessity and Luxuries of Space Exploration

Xiyu Lin

North London Collegiate School（Singapore), Singapore, Singapore
xiyulinmhjk@gmail.com

Abstract. Space activities are still one of the most contentious issues for science and technology policy because of their high cost and impact on social development. Using STS, this paper examines whether space exploration is a social necessity or merely a privilege for the rich. The three components of the analytical system proposed in this paper are space utilisation, space exploration and space spectacles, and their respective legitimacies. In short, the legitimacy of any Space project should not be based on its large scale or inspirational quality, but on whether it can generate real public goods, support the long-term social values of choice, and establish an enduring and fair governance system. Space activities should benefit the general public, be open to all sectors of society, have transparent organisation, and fairly distribute the right of participation and benefits among everyone. Only then will they meet the criteria of legality and necessity and be considered legal public investments.

Keywords: Space exploration, Public goods, Space governance, Sociotechnical imaginaries, Distributive justice

1. Introduction

The division of public funds for space programmes remains an outstanding problem in science and technology policy. On the one hand, space programmes are exceptionally expensive and high-risk, and are often viewed as displays of national power or costly indulgences for an elite few [1]. On the other hand, space-based facilities are now so deeply integrated into the existing infrastructure of contemporary society that people do not pay much attention to them any longer [2]. STS generally investigates both the reasons for considering these main technological projects "socially necessary" and the questions of authority over them in the course of assessing the technical feasibility or economic costs of space endeavors [3]; that is to say, whether these projects serve the public interest or become symbols of national prestige, tools for commercial monopoly, or instruments of consumption for the elite.

Given the above, this paper will present a three-part system of analysis: space utilisation, space exploration and space spectacle. Space utilisation refers to the application of orbital and suborbital technology for the purpose of achieving direct, tangible benefits for life on Earth [4]. Space exploration is the study and exploration of outer space by science and people. Space spectacle shows activities that are mainly motivated by symbols, commerce or the elite [1]. No large-scale

DOI: 10.54254/2753-7064/2026.HT36217

development plan can be justified solely by its inherent value or idealistic aspirations. Such projects need to show that they can create tangible public goods, protect the long-term strategic and economic competitiveness of society as a whole, and be under institutional frameworks that ensure sustainability and fairness [5, 6]. Using a Science, Technology and Society (STS) perspective to explore the social construction of technological necessity, this paper hopes to provide a normative foundation for differentiating legitimate public space investment from expenditures serving narrow and less defensible interests.

2. Space utilisation as present necessity

Space utilisation is the use of orbital and suborbital technologies in daily life on Earth. Contrary to the view that space capabilities are distant scientific luxuries, the space economy today is a large-scale ecosystem of activities covering exploration, research and development, resource management and operational services [7, 8]. Space-based systems have been integrated into the modern infrastructure to some extent, and their withdrawal would cause a system-wide collapse of all sectors in society. GPS and other satellite navigation systems worldwide support the operation of private cars, are used in the construction of the global supply chain, ensure the safety of flights and ships, and support high-precision agriculture [4]. The absence of these capabilities would not merely inconvenience modern economies; it would severely compromise public administration, disaster resilience, food security, and environmental governance. functions as critical infrastructure, a space utilisation domain in which the production and equitable distribution of public goods justifies continued collective investment. It is also necessary for maintaining social order, public security, and the general administration of countries.

However, from an STS perspective, the claim that space technology is "necessary" also requires examination. Such systems have certain power relations, institutional priorities and distribution choices that are often hidden by their very ubiquity [9]. As technology becomes ubiquitous and its political connotations gradually disappear, significant problems such as regulation, distribution, control and power, rights of opposition for the monitored group, and accountability mechanisms for negligence gradually go unnoticed by the public. Thus, the requirement for space utilisation cannot be determined by technical functions alone; it is also affected by governance structures that regulate access, risk allocation and benefit distribution in the world community [10].

The legitimacy of space utilization as a public investment depends on the extent to which it operates within sustainable and equitable governance frameworks. When satellite data, climate monitoring, and communications infrastructure provide conveniences for production and daily life, space utilization fulfils the criteria of public good production. However, when orbital resources are monopolized by a handful of countries and corporations, space debris risks lack corresponding accountability mechanisms, and the benefits of space data flow disproportionately to specific regions, the necessity of space activities becomes difficult to justify. The distinction between legitimate space utilization and less defensible forms of space activity, therefore, hinges not on the technology itself but on the governance arrangements that shape its deployment and distribution. It must be subject to democratic deliberation and international oversight if space is to serve the public interest.

3. Space exploration: conditional justification

Space exploration does not bring immediate dividends; instead, the benefits will only be realised several generations from now. Therefore, exploration does not have the self-evident legitimacy that

DOI: 10.54254/2753-7064/2026.HT36217

development and exploitation possess from the start of a project. The Legitimacy of Space Exploration is Contingent. It should be shown that it serves the public interest, not to boost national pride, to pursue commercial profits or to satisfy the wishes of a few privileged people.

The view that exploration lacks immediate practical value and is thus a waste of public funds is based on a narrow concept of utility that only considers visible, short-term returns. Knight's first division of risk and uncertainty is that risk is a situation in which the probability distribution of future outcomes is known, whereas uncertainty refers to conditions in which the future state of the world cannot be envisioned in advance [11]. Climate tipping points and trajectories of resource depletion are all deep uncertainties for which no probabilistic forecast exists. Thus, the construction of a powerful technological and knowledge base for space exploration serves as a kind of option value; it is an investment in capabilities that may be needed to face unforeseen circumstances in the future. Romer's endogenous growth theory shows that knowledge is non-rivalrous and partially excludable; that is, an increase in one area can spread to boost the productivity and innovation of the whole economy [12]. Space exploration has produced many such spillover effects, including materials science developed for spacecraft R&D that offers new ways to manufacture on Earth; life support systems designed for extraterrestrial environments that are benefiting medicine and environmental engineering; and the computational power required by mission planning that is advancing artificial intelligence and data processing. The above spillover effects will help promote the long-term development of the economy and extend the public's knowledge base. However, the spillover effect is not automatic; rather, institutional mechanisms need to be established to promote it, such as open-access publication, technology transfer programs and public-private cooperation. These mechanisms will extend the application of space knowledge to other areas [13].

From the perspective of STS, visions of a technological future often contain broad social ideas about the aims of people, the future of society, and the nation [14]. Space exploration is appealing because it can show people what life will be like in the future. Sociotechnical imaginaries can serve the public interest in the long run by motivating people and promoting international cooperation. It is not appropriate to omit the distribution of benefits and replace the expression of aspiration with unaccountable governance. Space exploration has conditional legitimacy if and only if the three conditions are met. First, it needs to create real public goods and promote the scientific exploration of fundamental problems in life [15]. Secondly, it should be able to boost the long-term competitiveness and resilience of society tangibly [16]. Third, it should be in a good government that guarantees the long-term sustainability of the plan and fair distribution of benefits. If the purpose of exploration is solely to achieve symbolic or grandiose ends, if its benefits are limited to a particular group of people, or if there is no transparent and inclusive governance system, then it will no longer be regarded as a legitimate public investment.

4. Space spectacle

Space spectacle encompasses activities whose primary purpose is symbolic, commercial, or elite-consumption-driven and media events that commodify the cosmos for entertainment and distraction [1]. These activities do not merely fail the test of public legitimacy; they actively undermine it by diverting scarce collective resources toward purposes that benefit narrow constituencies while externalizing costs onto the broader public and future generations.

DOI: 10.54254/2753-7064/2026.HT36217

4.1. Opportunity costs and the diversion of collective resources

Space activities at the national level are extraordinarily capital-intensive, high-risk, and characterized by extended payback periods. Given the persistence of global poverty, pandemic preparedness deficits, and educational inequality, the allocation of public funds to projects whose primary output is symbolic status or elite entertainment raises a profound question of allocative justice. The claim is when produced at the expense of material improvements in the welfare of the broader population, fails to satisfy the criterion that public investment must generate benefits with widespread and equitable distribution. When exploration serves identifiable public purposes, the opportunity cost may be justifiable. Where spectacle serves only to inflate national ego or corporate profit, it constitutes a misallocation of resources that democratic publics have good reason to reject [17].

4.2. Inequitable distribution

The benefits of space spectacles are concentrated in the hands of a privileged few, while the costs are borne by society as a whole. As status goods, the value of space tourism, luxury flight experiences, and high-end commercial development projects in orbit derives precisely from their scarcity and exclusivity [18]. Technology is by no means a purely technical product. It is always embedded within structures of inclusion and exclusion that determine who benefits and who bears the consequences [9]. Space spectacles are designed from the outset to restrict benefits to a narrow elite while relying on collective infrastructure subsidized by society as a whole—including launch facilities, orbital slots, and regulatory frameworks. It is an act of transferring public resources to private consumption, masked by ambitious rhetoric such as "the destiny of humanity" and "pioneering spirit."

4.3. Environmental externalities

Space spectacle imposes environmental costs that are borne collectively and disproportionately by future generations. Unrestrained launches, proliferating satellite deployments, and commercial competition for orbital access have rendered near-Earth space increasingly congested and hazardous. Each actor (nation-state or corporation) has an individual incentive to maximize its presence in orbit, while the risks of collision and debris accumulation are shared by all users [19, 20]. Collisions render certain orbital regions unusable for decades or even centuries. This represents not only a technical risk but also an intergenerational injustice. Current actors reap short-term benefits from visually driven expansion, yet pass on the long-term costs to those who will inherit a degraded orbital environment [10]. If space exploration damages the very orbital infrastructure upon which future exploration and utilization depend, it ceases to be a long-term investment and becomes, instead, a short-sighted depletion of shared environmental capital.

4.4. The STS critique

Opportunity cost, distributive injustice, and environmental externality demand not merely that individual projects be rejected but that governance frameworks be established to prevent the systemic drift toward spectacle. The social consequences of a new technology are difficult to predict when it is still novel and malleable, but by the time its harmful effects become apparent, the technology has become so deeply embedded in social and economic structures that it is extremely

DOI: 10.54254/2753-7064/2026.HT36217

difficult to control [21]. Space tourism, commercial space stations, and prestige-driven human spaceflight programs are currently at a stage where their trajectories can still be shaped by deliberate policy choices. Yet the political economy of space (private corporations and nation-states) makes such governance exceedingly difficult to achieve [13]. The question of who has the authority to determine which space activities are legitimate and which are indulgent is thus not merely an academic one; it is a pressing matter of democratic governance.

5. Three tests of necessity

5.1. Public goods test

A space activity needs to show that it creates public goods. Specifically, it should offer benefits that are non-excludable and non-rivalrous during consumption, or at least broadly benefit groups other than those who fund and operate the mission directly. Space-utilisation activities meet the above requirements. GPS signals, weather information and climate monitoring are all available to people of different incomes around the world at a very low marginal cost. A deep-space science mission that produces open-access knowledge on planetary geology or astrobiology creates a public good in the form of extended human understanding, even if no immediate commercial applications follow [6, 15]. On the other hand, a suborbital tourism flight whose main product is a short-term experience for a few rich people does not create any public goods in a substantial way. Therefore, the public good test focuses on whether the activity benefits the general public; whether it expands the pool of shared knowledge, protects the environment and develops culture; and whether it is only for the profit of private enterprises or brings prestige to the nation.

5.2. The options value test

The second criterion is long-term options value, which primarily assesses whether an initiative can maintain or enhance capabilities that may prove indispensable under uncertain future conditions. Society cannot evaluate all investments solely based on short-term returns; the rationale for certain expenditures lies in the options value they create. This test is passed when the technologies, scientific data, and operational experience developed through space exploration enable humanity to prepare for unforeseen contingencies that cannot yet be clearly defined. However, the option value test requires a strict condition: the capabilities retained must be universal and open to society, rather than serving only narrow national strategic or commercial interests.

5.3. Sustainability and equity test

Sustainability and equity refer to whether an activity takes place in an institutional system that ensures environmental sustainability and the fair distribution of benefits and burdens; otherwise, the externalities produced by the activity will be borne by those who are least advantaged in that activity. An activity will only pass the sustainability and equity tests if it includes binding mechanisms for debris mitigation, orbital slot allocation that respects the interests of all spacefaring and non-spacefaring nations, and benefit-sharing arrangements to prevent the monopolisation of space resources by wealthy actors. Therefore, the essential conditions of this test are that there are effective safeguards against environmental damage; that the governance structure is inclusive, transparent and accountable to the global community; whether it expands people's lives; and whether the right to participate and the benefits of participation are concentrated among a few.

DOI: 10.54254/2753-7064/2026.HT36217

6. Conclusion

This paper has argued that space exploration is closer to being a social need than a wish but only under specific and stringent conditions. From a STS perspective, this study proposes a three-part analytical framework to distinguish among current types of space activities, including space utilization, space exploration, and space spectacles. This study finds that the legitimacy of any space activity does not depend on its inherent grandeur or appeal, but rather on whether it meets three cumulative normative criteria: producing tangible public goods, upholding long-term social choice values, and sustainable and equitable governance framework.

Therefore, space exploration does not need to be about "humans entering space." It should meet stricter conditions, such as extending the public's sense of capability, offering more choices for future generations, and avoiding the transfer of risks to vulnerable groups and future societies. If space exploration can create broad, long-lasting, and widely shared benefits for humanity, then it will meet this requirement. If these conditions are not met, space exploration will no longer be meaningful or possess real value.

References

[1] Shammas, V. L., & Holen, T. B. (2019). One giant leap for capitalistkind: Private enterprise in outer space. *Palgrave Communications, 5*(10). https://doi.org/10.1057/s41599-019-0218-9

[2] Yada, A. (2025). Space exploration for earthly benefits: Satellite technology - industry, innovation and infrastructure. In P. Whig, P. Sharma, & N. Yathiraju (Eds.), *Cutting-edge solutions for advancing sustainable development: Exploring technological horizons for sustainability - Part 2* (pp. 59-72). Bentham Science Publishers. https://doi.org/10.2174/9789815322408125010 1

[3] Klimburg-Witjes, N. (2024). STS and outer space: Extending the gaze. In U. Felt & A. Irwin (Eds.), *Elgar Encyclopedia of Science and Technology Studies* (pp. 562–568). Edward Elgar.

[4] Jin, S., Meng, X., Dardanelli, G., & Zhu, Y. (2024). Multi-global navigation satellite system for earth observation: Recent developments and new progress. *Remote Sensing, 16*(24), 4800. https://doi.org/10.3390/rs16244800

[5] Nahtigal, M. (2022). Outer space treaty reform and the long-term sustainability of space exploration. *Teorija in Praksa, 59*(1), 42–59. https://doi.org/10.51936/tip.59.1.42-59

[6] Payson, D. (2026). Public goods and the evaluation of complex outcomes in space economy. *Space Policy*, Article 101762. https://doi.org/10.1016/j.spacepol.2026.101762

[7] OECD. (2023). The space economy in figures: Responding to global challenges. *OECD Publishing*. https://doi.org/10.1787/fa5494aa-en

[8] Valente, M., Caviggioli, F., & Agostini, L. (2025). Space economy and sustainability: A systematic review. *Sustainable Development, 33*(4), 4922–4959. https://doi.org/10.1002/sd.3383

[9] Winner, L. (1980). Do artifacts have politics? *Daedalus, 109*(1), 121–136. https://www.jstor.org/stable/20024652

[10] Greenstone, A. F. (2022). Government ethics and sustainable space exploration. *Northern Illinois University Law Review, 42*(3), 313–329. https://huskiecommons.lib.niu.edu/niulr/vol42/iss3/2/

[11] Knight, F. H. (1921). *Risk, uncertainty and profit*. Houghton Mifflin.

[12] Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5, Part 2), S71–S102. https://doi.org/10.1086/261725

[13] Peeters, W., & Ehrenfreund, P. (2025). Charting the future of space: A collaborative vision for innovative commercial partnerships and sustainable space exploration. *New Space, 13*(1), 7–21. https://doi.org/10.1089/space.2024.0041

[14] Jasanoff, S., & Kim, S.-H. (Eds.). (2015). *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power*. University of Chicago Press. https://doi.org/10.7208/chicago/9780226276663.001.0001

[15] Crawford, I. A. (2004). Towards an integrated scientific and social case for human space exploration. *Earth, Moon, and Planets, 94*(3–4), 245–266. https://doi.org/10.1007/s11038-005-9005-2

[16] Corrado, L., Cropper, M., & Rao, A. (2023). Space exploration and economic growth: New issues and horizons. *Proceedings of the National Academy of Sciences, 120*(43), e2221341120. https://doi.org/10.1073/pnas.2221341120

DOI: 10.54254/2753-7064/2026.HT36217

[17] Vedda, J. A. (2008). Challenges to the sustainability of space exploration. *Astropolitics, 6*(1), 22–49. https://doi.org/10.1080/14777620801907921
[18] Sen, A. (1999). *Development as freedom*. Alfred A. Knopf.
[19] Hardin, G. (1968). The tragedy of the commons. *Science, 162*(3859), 1243–1248. https://doi.org/10.1126/science.162.3859.1243
[20] Kessler, D. J., & Cour-Palais, B. G. (1978). Collision frequency of artificial satellites: The creation of a debris belt. *Journal of Geophysical Research, 83*(A6), 2637–2646. https://doi.org/10.1029/JA083iA06p02637
[21] Collingridge, D. (1980). *The social control of technology*. Frances Pinter.