COMMERCIAL SPACE MINING: LEGAL STRUCTURES, STRATEGIC INTERESTS, AND POLICY DIRECTIONS

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ABSTRACT

Commercial space mining is rapidly shifting from speculative concept to emerging industry, driven by advances in technology, private investment, and strategic competition. This paper examines its technological and economic drivers, the expanding constellation of state and corporate actors, and the fragmented legal frameworks that leave questions of ownership and benefit-sharing unresolved. It analyses the geopolitical implications of space resource extraction, particularly its role in shaping future power hierarchies. Within this global context, Pakistan's prospects are evaluated, highlighting gaps in capacity and governance alongside strategic opportunities. The paper argues that Pakistan's effective entry lies in targeted legal engagement, small-scale satellite missions through partnerships, research capacity building, and investment in human capital. By linking national preparedness to broader governance debates, it advocates for inclusive, multilateral approaches that prevent space mining from deepening existing global inequalities.

Keywords: Commercial space mining, space resource governance, geopolitical competition, Pakistan space policy, technological capacity building

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full Form
NEAs	Near-Earth Asteroids
ISRU	In-Situ Resource Utilisation
PGMs	Platinum-group metals
USD	United States Dollar
NASA	National Aeronautics and Space Administration
CLPS	Commercial Lunar Payload Services
JAXA	Japan Aerospace Exploration Agency
ESA	European Space Agency
E3P	European Exploration Envelope Programme
OST	Outer Space Treaty
ILRS	International Lunar Research Station
SUPARCO	Space and Upper Atmosphere Research Commission
PRSS-01	Pakistan Remote Sensing Satellite-01
ICUBE-Q	Institute of Space Technology Cube Satellite-Q
BRSIC	Belt and Road Space Information Corridor
APSCO	Asia-Pacific Space Cooperation Organization
NASTP	National Aerospace Science & Technology Park
IST	Institute of Space Technology
NICAT	National Incubation Centre for Aerospace Technologies
CNSA	China National Space Administration
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space

1. INTRODUCTION

In the last several years, the idea of commercial space mining has transformed from the margins of speculation to the centre of serious economic and strategic debate.[1] While space mining is still in nascent stages in terms of actual extraction, the logic driving interest in this sector is becoming harder to ignore. Earth's reserves of certain key minerals, including rare earth elements, platinum-group metals, and helium-3, are under pressure due to both geopolitical rivalries and the limits of environmental sustainability.[2] In this context, outer space is no longer seen merely as a scientific or symbolic frontier, but increasingly as a material one. The Moon, Mars, and Near-Earth Asteroids (NEAs) are now being discussed not just in terms of exploration, but exploitation.

The renewed interest in space resource extraction is not merely a consequence of scientific advancement, but a strategic response to intensifying resource nationalism, climate-induced supply chain vulnerabilities, and the global shift toward a high-tech economy dependent on materials that are often geographically concentrated and politically sensitive.[3] Space mining, thus, represents a convergence of commercial opportunity and strategic necessity, as leading spacefaring nations seek to secure early-mover advantages in this emerging domain.

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[1] José Garcia del-Real, George Barakos, and Helmut Mischo, "Space Mining Is the Industry of the Future … or Maybe the Present?," *Mining Engineering* 72, no. 2 (February 2020), https://www.researchgate.net/publication/339627406_Space_mining_is_the_industry_of_the_future_or_maybe_the_present.

[2] Mira Maulida, "The Material Paradox: Renewable Energy's Sustainability Challenges and Geopolitical Consequences Executive Summary," preprint, July 2025, https://www.researchgate.net/publication/393922780_The_Material_Paradox_Renewable_Energy's_Sustainability_Challenges_and_Geopolitical_Consequences_Executive_Summary.

[3] International Renewable Energy Agency (IRENA), *Geopolitics of the Energy Transition: Critical Materials*, International Renewable Energy Agency, Abu Dhabi, July 29, 2023, https://www.irena.org/Digital-Report/Geopolitics-of-the-Energy-Transition-Critical-Materials.

Naturally, however, this rapid acceleration brings with it a host of unresolved questions. Many of the legal instruments that currently govern space activity, most notably the 1967 Outer Space Treaty, were conceived in an entirely different geopolitical and technological context. As such, they offer limited clarity on core issues like ownership, extraction rights, and environmental responsibility, particularly where commercial actors are involved. In the absence of a revised and enforceable legal framework, the risk is that space governance will become increasingly fragmented, driven less by multilateral consensus and more by shifting power dynamics and selective interpretation of outdated norms.[4]

So far, space mining discourse has mostly been the domain of technologically advanced actors, primarily the US, China, and ESA states. Nevertheless, developing countries are also entering the discussion, though generally from less secure footing. Pakistan offers an instructive example here. While it does not currently have the technological base or institutional structure to participate meaningfully in off-world resource extraction, it is not without potential. The launch of the ICUBE-Q CubeSat with Chinese collaboration in 2023, along with earlier efforts like the PRSS-01 satellite, are small but symbolically important milestones. More recently, Pakistan's National Space Policy (2023) has indicated a clearer recognition of space as a strategic domain, highlighting, at least rhetorically, the role of commercialisation and international partnerships.

This paper argues that it would be premature to suggest that Pakistan is on the brink of joining the space mining race. Yet, its growing ties, especially through the

[4] "Space Mining: Intellectual Property and Legal Challenges," *Lawyer Role*, October 19, 2024, https://lawyerrole.us/intellectual-property-in-space-legal-implications-of-space-mining/.

China-led Belt and Road Initiative Space Information Corridor, could offer avenues for technological transfer and regional cooperation, which, over time, might enable greater participation in the broader space economy.

This paper critically examines the emerging architecture of commercial space mining, with particular focus on its global drivers, legal gaps, and geopolitical implications. It argues that without the development of inclusive and enforceable governance frameworks, the risk is not only of legal uncertainty, but of reproducing in space the same extractive inequalities and strategic tensions that have long defined Earth's own resource regimes.

2. TECHNOLOGICAL AND ECONOMIC CATALYSTS

The fact that space mining is no longer confined to speculative papers or theoretical feasibility studies owes much to two fundamental shifts: a clear leap forward in spacefaring technologies, and a growing economic argument for pursuing resources beyond Earth. These are not entirely new developments, of course, but their convergence has changed the tone of the conversation. What once seemed prohibitively expensive and technically out of reach is now, for a number of actors, moving into the realm of serious possibility, if not immediately, then within a definable planning horizon.

Perhaps the most notable development has come in the form of reusable launch systems; this single shift has reshaped the cost model for getting to orbit, and more importantly, for staying there.[5] For decades, the reliance on single-use rockets

[5] Emma Gatti and Andrea D'Ottavio, "The Missing Rocket: An Economic and Engineering Analysis of the Reusability Dilemma in the European Space Sector," *Intereconomics: Review of European Economic Policy* 60, no. 2 (March 2025), https://doi.org/10.2478/ie-2025-0018.

was a structural barrier that kept large-scale extra-terrestrial operations in the background. However, with repeated demonstrations from vehicles like SpaceX's Falcon 9, Blue Origin's New Shepard and the upcoming New Glenn, launch economics have changed dramatically. SpaceX's Falcon 9, for instance, has consistently driven down the cost per kilogram to below USD 2,000 in some cases, a price point that would have been almost inconceivable just fifteen years ago.[6] This kind of structural drop in launch costs does not just reduce the price tag; it recalibrates what kinds of missions are now worth considering.

In parallel, advances in In-Situ Resource Utilisation (ISRU) are helping to loosen another constraint, namely, the need to transport everything from Earth. If ISRU systems can be made to work reliably in space, they could enable missions to use local materials, such as ice, regolith, metals, not only for construction, but for life support and fuel.[7] Early-stage technologies like optical mining for asteroid volatiles[8], microwave sintering of lunar soil, or autonomous mining platforms designed for low-gravity environments are all being explored.[9] These tools would not eliminate Earth-based supply chains entirely, but they could radically reduce dependence on them, especially for long-duration missions or operations aiming for sustainability rather than just footprint.

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[6] "Space Technology: Rocket Reusability and the Collapse of Launch Costs," *Acquinox Capital*, blog post, July 8, 2025, https://acquinox.capital/blog/space-technology-rocket-reusability-and-the-collapse-of-launch-costs.
[7] "In Situ Resource Utilization: The Future of Human Settlements in Space," *Space Resource Tech*, blog post, accessed August 8, 2025, https://spaceresourcetech.com/blogs/articles/in-situ-resource-utilization-the-future-of-human-settlements-in-space.
[8] Joel Sercel, Christopher B. Dreyer, and Angel Abbud-Madrid, "Exploration and Utilization of Extra-Terrestrial Bodies," in *Proceedings of the 15th Biennial ASCE Conference on Engineering, Science, Construction, and Operations in Challenging Environments*, Earth & Space 2016, (Reston, VA: American Society of Civil Engineers, 2016), doi:10.1061/9780784479971.048.
[9] Charun Bao, Daobo Zhang, Qinyu Wang, Yifei Cui, and Peng Feng, "Lunar In Situ Large-Scale Construction: Quantitative Evaluation of Regolith Solidification Techniques," *Engineering* 39, no. 8 (August 2024): 204–221, https://doi.org/10.1016/j.eng.2024.03.004.

Beyond the technological dimension, the economic rationale for space mining is gaining credibility. Celestial bodies, particularly NEAs and the Moon, are known to contain abundant quantities of high-value resources.[10] Platinum-group metals (PGMs), integral to electronics, catalytic converters, and advanced batteries, exist in concentrations on some asteroids that surpass terrestrial reserves. Similarly, helium-3, a rare isotope with potential applications in future nuclear fusion technologies, is believed to be available in substantial quantities on the lunar surface.[11] The Moon's permanently shadowed polar craters are also suspected to contain large deposits of water ice, which can be electrolysed into hydrogen and oxygen for use as propellant, effectively transforming the Moon into a refuelling station for deeper space missions.

These economic opportunities are not purely speculative. According to industry estimates, a single metallic asteroid of approximately 500 meters in diameter could contain resources worth trillions of dollars.[12] This prospect has spurred both governmental space agencies and private firms to invest in exploratory and preparatory technologies. Companies, such as TransAstra are already developing small-scale mining demonstrators, while national agencies are funding precursor missions to identify viable extraction sites. The global commercial space economy,

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[10] J. A. Dallas, Simit Raval, S. Saydam, and A. G. Dempster, "Investigating Extraterrestrial Bodies as a Source of Critical Minerals for Renewable Energy Technology," *Acta Astronautica* 186 (2021): 74–86, https://doi.org/10.1016/j.actaastro.2021.05.021.

[11] Aaron D. S. Olson, "Lunar Helium-3: Mining Concepts, Extraction Research, and Potential ISRU Synergies," paper presented at AIAA ASCEND 2021, Las Vegas, Nevada, November 8–17, 2021 (accessed via NASA Technical Reports Server), https://ntrs.nasa.gov/api/citations/20210022801/downloads/AIAA%20ASCEND%202021%20Paper_211018.pdf.

[12] Mario De Leo-Winkler, "Trillion Dollar Space Industry Started, and You Missed Out," *HuffPost*, July 28, 2015, updated December 6, 2017, https://www.huffpost.com/entry/trillion-dollar-space-ind_b_7875510.

projected to surpass USD 1.8 trillion by 2035, is increasingly incorporating space mining as a strategic sub-sector within long-term planning frameworks.[13]

Therefore, the interplay between technological readiness and economic incentive structures is reshaping the discourse around space mining. What was once a distant vision limited to theoretical feasibility studies is now materialising into pilot programmes, legal reforms, and industrial roadmaps.

3. KEY ACTORS AND THE EXPANDING ECOSYSTEM

The present landscape of space mining reflects a complex and evolving interplay between state-led space programmes, private sector initiatives, and increasingly hybrid public-private partnerships. What is emerging is not a single model, but a loosely configured architecture shaped by the global diffusion of spacefaring capabilities and the steadily growing sense that resource extraction beyond Earth may soon become economically viable.

The United States remains at the forefront of these developments, primarily through National Aeronautics and Space Administration (NASA) Artemis programme, which aims to establish a sustained human and robotic presence on the Moon.[14] Alongside Artemis, the Commercial Lunar Payload Services (CLPS) initiative has been instrumental in shifting certain operational responsibilities to the private sector.[15] Companies such as Astrobotic, Intuitive Machines, and Firefly Aerospace have been

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[13] World Economic Forum and McKinsey & Company, *Space: The $1.8 Trillion Opportunity for Global Economic Growth*, insight report (Geneva: World Economic Forum, April 2024), https://www3.weforum.org/docs/WEF_Space_2024.pdf.

[14] Paul Kessler, Tracie Prater, Tiffany Nickens, and Danny Harris, “Artemis Deep Space Habitation: Enabling a Sustained Human Presence on the Moon and Beyond,” *2022 IEEE Aerospace Conference (AERO)*, March 2022, https://doi.org/10.1109/AERO53065.2022.9843393.

[15] National Aeronautics and Space Administration (NASA), “Commercial Lunar Payload Services,” updated June 15, 2023, https://www.nasa.gov/commercial-lunar-payload-services/

contracted to deliver scientific instruments, technology demonstrators, and eventually, early-stage resource extraction units to the lunar surface.[16] This reflects a broader recalibration of US space policy, one that places greater emphasis on commercialisation, cost-efficiency, and the cultivation of a more decentralised operational model.

China, for its part, has emerged as a serious strategic competitor. Through a sequence of high-impact missions, it has substantially narrowed the technological gap with established space powers. The 2018 Chang'e 4 mission achieved the first-ever landing on the far side of the Moon, while Chang'e 5 returned nearly two kilograms of lunar material to Earth in 2020, an achievement matched previously only by the US and the former Soviet Union.[17] In collaboration with Russia, China is pursuing plans for the International Lunar Research Station (ILRS), envisaged as a multifunctional platform for scientific research, habitation, and eventually, resource exploitation.[18] Its anticipated launch in the 2030s underscores Beijing's long-term commitment to space infrastructure development.

Other nations are contributing in targeted but significant ways. Japan's space agency, Japan Aerospace exploration Agency (JAXA), has led some of the most advanced asteroid exploration efforts to date. The Hayabusa2 mission, which returned samples from the asteroid Ryugu in 2020, has offered critical insights into the composition of carbonaceous asteroids data that will prove essential in future

[16] The Earth Observation Portal, "Commercial Lunar Payload Services (CLPS)," accessed August 8, 2025, https://www.eoportal.org/ftp/satellite-missions/c/CLPS_181121/CLPS.html.
[17] Bojun Jia, Wenzhe Fa, Minggang Xie, Yushan Tai, and Xiaofeng Liu, "Regolith Properties in the Chang'E-5 Landing Region of the Moon: Results from Multi-Source Remote Sensing Observations," *Journal of Geophysical Research: Planets* 126 (2021), https://doi.org/10.1029/2021JE006934.
[18] Guancha.cn, "China–Russia Lunar Cooperation: Is Nuclear Power on the Moon Feasible Soon?" *China Academy*, May 16, 2025, accessed August 8, 2025, https://thechinaacademy.org/is-the-china-russia-lunar-nuclear-power-plant-another-sputnik-moment/.

feasibility assessments for off-Earth mining.[19] In Europe, the European Space Agency (ESA), through its European Exploration Envelope Programme (E3P), has begun supporting lunar commercialisation efforts, working with companies like iSpace Europe and OHB Systems to design robotic landers and payload technologies.

While actual mining operations remain, for now, largely aspirational, the private sector has already played a central role in shaping both the technical trajectory and the strategic narrative around space resource extraction. Firms such as iSpace (Japan), Planetary Resources and Deep Space Industries (US), and the Asteroid Mining Corporation (UK) have taken on early-stage development of technologies like asteroid spectrometry, low-thrust propulsion systems, and robotic prospecting platforms.[20]

Crucially, these private endeavours have not emerged in a vacuum. In several jurisdictions, legislative support has provided a legal foundation for commercial activity in space. The US Commercial Space Launch Competitiveness Act (2015) and Luxembourg's Space Resources Law (2017) are particularly notable in this regard, granting private actors the right to own extracted resources, while stopping short of recognising territorial sovereignty over celestial bodies.[21] These legal instruments have offered clarity for investors and innovators, but they also raise unresolved normative questions. Specifically, they challenge the spirit, if not always the letter, of

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[19] Astromaterials Research & Exploration Science Division (ARES), "Hayabusa2 Mission to Asteroid 162173 Ryugu," accessed August 8, 2025, NASA, https://ares.jsc.nasa.gov/missions/hayabusa2/.

[20] K-MINE, "Mining Beyond Earth – Transforming Space Exploration," K-MINE, November 24, 2024, accessed August 8, 2025, https://k-mine.com/articles/mining-beyond-earth-transforming-space-exploration/.

[21] Philip De Man, *Luxembourg Law on Space Resources Rests on Contentious Relationship with International Framework*, Working Paper no. 189 (Leuven: Leuven Centre for Global Governance Studies, July 2017), accessed via KU Leuven, https://ghum.kuleuven.be/ggs/publications/working_papers/2017/189deman.

the 1967 Outer Space Treaty, and they risk encouraging unilateral action in what has traditionally been treated as a multilateral domain.

What is becoming increasingly clear is that the global space mining landscape is no longer the preserve of major state powers alone. A more pluralistic ecosystem is taking shape, one characterised by overlapping strategies, diverse institutional models, and sometimes competing legal and economic interests.

4. LEGAL AND REGULATORY FRAGMENTATION

As commercial interest in space mining accelerates, the existing legal framework governing outer space is increasingly outdated. Originally crafted during an era when resource extraction beyond Earth was deemed science fiction, international space law focused on exploration and geopolitical symbolism rather than economic activity. However, with private companies investing heavily in off-Earth mining technologies and states enacting supportive legislation, legal ambiguities have become pressing, posing concrete challenges for governance, jurisdiction, and equitable access.

The 1967 Outer Space Treaty (OST) remains the cornerstone of space law, codifying principles such as the non-appropriation of outer space, the peaceful use of celestial bodies, state responsibility for space activities, and international cooperation in exploration.[22] However, it offers little clarity on resource ownership. Attempts to clarify the issue at the multilateral level have not fared particularly well. The Moon Agreement, introduced in 1979, tried to establish space resources as the "common

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[22] Diplomacy and Law, "International Law and the Regulation of Outer Space," last modified July 2025, *Diplomacy and Law*, accessed August 8, 2025, https://www.diplomacyandlaw.com/post/international-law-and-the-regulation-of-outer-space.

heritage of mankind" and proposed an international regime to govern their exploitation.[23] Nonetheless, the major space powers, including the US, Russia, China, among others, never ratified it. The language of the treaty was seen as vague, and many worried it might create more constraints than solutions.

In the absence of global consensus, bilateral arrangements like the Artemis Accords have begun to fill the vacuum. These agreements, led by the US and joined by several allies, promote shared principles transparency, peaceful use, and so forth, but also allow for "safety zones" around activities, which some argue could amount to de facto territorial claims.[24]

Overall, what is emerging is a fragmented and uneven legal landscape, with competing interpretations and no single authority to mediate disputes. As more actors enter this domain, particularly from the private sector, the lack of enforceable rules and shared norms could well become a source of friction in what is already a strategically sensitive environment.

5. GEOPOLITICAL AND STRATEGIC DIMENSIONS

Commercial space mining represents more than technological advancement or economic gain; it signals a fundamental strategic transition. As the extraction of extra-terrestrials resources becomes increasingly viable, outer space is rapidly evolving into a contested domain of geopolitical rivalry and legal ambiguity.

[23] Diplomacy and Law, "International Law and the Regulation of Outer Space."
[24] Guoyu Wang, "NASA's Artemis Accords: The Path to a United Space Law or a Divided One?," *The Space Review*, August 24, 2020, accessed August 8, 2025, https://www.thespacereview.com/article/4009/1.

These fault lines are taking shape around two competing models. On one side is the Artemis Accords, spearheaded by the US and backed by dozens of other countries. They emphasise transparency and peaceful conduct around operations, ostensibly to reduce conflict. However, critics interpret these zones as a form of informal territorial control. Meanwhile, China and Russia have rejected the Artemis framework altogether. They are advancing their own agenda, most notably through the proposed International Lunar Research Station, which they claim is a more cooperative alternative. In reality, international system is witnessing is the slow formation of parallel legal regimes, each aligned with broader geopolitical blocs. It feels eerily familiar, not unlike Cold War alignments, just relocated beyond Earth's atmosphere.

Furthermore, there is also a strategic race for access to lunar regions rich in ice or rare-earth minerals.[25] Without a binding and enforceable mechanism for equitable resource allocation, it is likely that the most technologically advanced states will carve up these zones in ways that reproduce, or even exacerbate, the global inequalities that persists.

There is also the question of dual-use technologies. The same robotic infrastructure designed to mine lunar surfaces could, in the wrong context, be used to disable a satellite.[26] This could pose a real strategic risk in an environment with almost no arms control and a growing trust deficit between major powers.

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[25] Nayef Al-Rodhan, "To the far side of the Moon: the battle for lunar resources," *Engelsberg Ideas*, October 1, 2024, accessed August 8, 2025, https://engelsbergideas.com/essays/lunar-resources/.
[26] Marco Marsili, "Emerging and Disruptive Technologies: Strategic Implications and Ethical Challenges of Dual-Use Innovations," *Strategic Leadership Journal* (April 29, 2025): 57–71, https://doi.org/10.5281/zenodo.15305895.

Equally significant is the exclusionary character of current governance trajectories. As legal norms increasingly emerge through unilateral or selective multilateral processes, many states, particularly in the Global South, remain outside the decision-making structures shaping the future space economy. With limited space capabilities, these countries are largely unable to influence outcomes that may determine long-term access to extra-terrestrials resources. The absence of serious commitments to technology transfer, capacity-building, or inclusive negotiation frameworks raises the risk of replicating historical patterns of resource exploitation, only this time, on a planetary scale.

6. PAKISTAN'S PROSPECTS AND PREPAREDNESS

Pakistan is, by most measures, absent from the core developments in commercial space mining. There's no commercial space industry in the country, and state-led space activity has historically been underfunded and narrowly focused. That said, dismissing Pakistan entirely from the picture risks overriding steps it has taken to remain involved in space more broadly.

While Pakistan is not in a position to independently explore or mine celestial bodies, it has continued to maintain a presence, however modest, in space-related activities. SUPARCO, the national space agency, has historically prioritised satellite technology and Earth observation, areas more immediately relevant to domestic development and strategic surveillance.[27] Although institutional progress has been uneven, certain initiatives indicate that space remains on the national agenda, albeit in a limited capacity. The launch of the PRSS-01 remote sensing satellite in 2018,

[27] Space and Upper Atmosphere Research Commission (SUPARCO), "Major Programmes – Satellite Programs," accessed August 8, 2025, https://suparco.gov.pk/major-programmes/projects/.

developed in collaboration with China, marked a milestone in enhancing Pakistan's geospatial capabilities.[28]

More recently, the 2024 Chang'e 6 lunar mission included a Pakistani contribution in the form of the ICUBE-Q CubeSat, a joint project between the Institute of Space Technology and Shanghai University.[29] While this does not place Pakistan in the commercial space mining arena, it nonetheless suggests an interest in staying engaged with broader space developments, primarily through bilateral cooperation. These steps are tentative, but they reflect a strategic awareness of space as a domain worth cultivating, even if only through partnerships and symbolic participation at this stage.

Nevertheless, substantial challenges remain. Pakistan's domestic space agenda has long been underfunded and politically neglected, with research concentrated in a few institutions[30]. The legal and regulatory frameworks necessary for commercial participation, whether by state or private actors, are non-existent or outdated. Beyond China, Pakistan has few international partners in this field. Moreover, Pakistan currently lacks a space policy that addresses the specific demands of resource extraction beyond Earth. The absence of deep-space mission infrastructure, indigenous launch capability, and a robust industrial base for space innovation severely limits direct engagement in commercial space mining.

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[28] Space and Upper Atmosphere Research Commission (SUPARCO), "Pakistan Remote Sensing Satellite (PRSS-1)," accessed August 8, 2025, https://suparco.gov.pk/major-programmes/projects/prss-1/.

[29] Institute of Space Technology (Pakistan), "ICUBE-Q: Pakistan's Lunar CubeSat Onboard Chinese Chang'e 6 Mission," accessed August 8, 2025, https://www.ist.edu.pk/icube-q.

[30] Zohaib Altaf and Nimra Javed, "Pakistan's New Space Policy: Overcoming Historical Challenges and Embracing a New Era," *The Diplomat*, December 16, 2023, accessed August 8, 2025, https://www.thediplomat.com/2023/12/pakistans-new-space-policy-overcoming-historical-challenges-and-embracing-a-new-era/.

SUPARCO continues to operate with limited financial resources, and the broader ecosystem required to support high-end research and private-sector involvement in this field is still in its infancy.[31] Equally significant is the lack of domestic legislation to govern the commercial and legal aspects of space resource utilisation, a gap that deters foreign investment and hinders international collaboration.

Yet, strategic opportunities are emerging. Ongoing space cooperation with China, particularly through the Belt and Road Space Information Corridor (BRSIC) and the Asia-Pacific Space Cooperation Organization (APSCO), offers a platform for knowledge exchange, capacity-building, and access to critical infrastructure.[32] These relationships could enable Pakistan to support various segments of the space mining value chain, including remote sensing, resource mapping, data analytics, and telemetry.

Institutionally, efforts are being made to lay a foundation for future growth. The creation of the National Aerospace Science & Technology Park (NASTP) and the involvement of academic institutions such as Institute of Space Technology (IST) and National Incubation Centre for Aerospace Technologies (NICAT) reflect initial steps toward cultivating a domestic space ecosystem. These platforms have the potential to serve as incubators for innovation, skill development, and public-private collaboration, elements vital to sustaining long-term engagement with the global space economy.

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[31] Altaf and Javed, "Pakistan's New Space Policy: Overcoming Historical Challenges and Embracing a New Era."

[32] John M. Logsdon et al., "Asia in Space: The Race to the Final Frontier," *Asia Policy* 15, no. 2 (April 2020): 1–56, National Bureau of Asian Research, https://www.nbr.org/publication/asia-in-space-the-race-to-the-final-frontier/.

7. POLICY RECOMMENDATIONS

While commercial space mining remains a distant prospect for Pakistan, complete disengagement from this emerging domain would limit its ability to benefit from or influence future developments. Recognising the structural constraints Pakistan faces, the following recommendations offer realistic and attainable steps that align with its current capacities while keeping space mining as a long-term horizon.

7.1. Position Pakistan as a stakeholder in global space resource governance

Even without the technical means to extract resources from celestial bodies, Pakistan can play a role in shaping the evolving legal and normative frameworks governing space mining. Active participation in multilateral forums, such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), would allow Pakistan to advocate for equitable access to space resources and ensure that the interests of developing countries are not sidelined.

7.2. Focus on small-scale, resource-relevant satellite missions through partnerships

Rather than attempting expensive and technologically demanding space mining projects, Pakistan should pursue targeted collaborative missions that are relevant to space resource exploration. For instance, micro- or nanosatellite missions aimed at studying mineral-rich asteroids, lunar topography, or in-situ resource indicators could be developed in partnership with countries like China.

7.3. Build research capacity in space science with resource-focused applications

Within academic and technical institutions such as the Institute of Space Technology (IST), Pakistan can promote research clusters focused on planetary geology, in-situ resource utilisation (ISRU), and orbital mechanics, all foundational areas in space mining. Even if these remain theoretical or simulation-based in the short term, they offer a cost-effective way to start building indigenous expertise.

7.4. Invest in human capital through training, scholarships, and international academic partnerships

One of the most feasible and impactful steps Pakistan can take is to support the training of a specialised workforce. This includes creating scholarships and fellowships for postgraduate studies in space resource-related fields, such as space engineering, astrobiology, and planetary sciences, at leading international universities. Furthermore, short-term training programmes and internships with partner space agencies (e.g. CNSA or ESA) could expose Pakistani students and early-career professionals to practical knowledge in mission planning, orbital mechanics, and space instrumentation. These individuals can later serve as a nucleus for domestic capacity in space mining-related domains.

8. CONCLUSION

Commercial space mining has moved, in policy and scientific discussions, from being a distant technological aspiration to a subject of tangible strategic interest. While technical feasibility remains uneven across different aspects of extraction, processing, and transport, the pace of experimentation suggests that commercial operations could emerge within the next few decades rather than the next century. Proponents argue that the exploitation of extra-terrestrials resources could help to ease pressures on terrestrial supply chains and open new economic frontiers. Yet such claims are contested, not least because the governance architecture for space activities was designed in an era that neither anticipated nor accommodated large-scale commercial extraction.

The absence of a dedicated regulatory framework raises difficult questions about access, equity, and the risk of monopolisation by a small number of technologically advanced states and corporations. If unaddressed, these dynamics could deepen existing inequalities in the global order and introduce new forms of competition into an already fragile geopolitical environment. Scholars and policymakers have therefore called for governance mechanisms that are not only legally coherent but also inclusive and oriented towards sustainability, although there is no consensus on what form such mechanisms should take.

For countries such as Pakistan, whose space sector remains in an emergent phase, the priority cannot be to match the capabilities of established spacefaring powers in the short term. A more viable pathway lies in strengthening domestic research capacity, cultivating technical expertise through targeted training and international academic exchange, and developing legal and institutional readiness to participate meaningfully in any future multilateral arrangements on space resource utilisation.

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