EMERGING SPACE POWERS: A COMPARATIVE ANALYSIS WITH PAKISTAN

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ABSTRACT

Space has become more significant in the past few decades due to the numerous advantages it offers in the domain of development and security. Through a qualitative research approach, using the comparative case studies method, this paper delves into the space programmes of South Africa, Türkiye, and Iran, and compares them with Pakistan's space programme. In particular, the civilian and Air Force-led initiatives of the chosen case studies are explored. Through an extensive review of extant literature available from each country's official websites, scholarly articles, and newspaper reports, the study finds that South Africa has integrated its satellites' data into decision-making. Also, Türkiye's state-led institutions are involved in developing military satellites for its Air Force, whilst Iranian Space Agency and its Revolutionary Guards Corps are cooperating with one another in the space domain. A key finding is the prosperous private sector in all three case studies, a domain nearly absent in the Pakistani context. These findings underscore the need for public-private partnerships, a consolidated space data repository, and civil-military nexus to further enhance the space programme of Pakistan.

Keywords: Air Force, defence, development, satellites, space programme, SUPARCO

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full Form
SUPARCO	Space and Upper Atmosphere Research Commission
CPEC	China Pakistan Corridor
PRSS	Pakistan Remote Sensing System
NDMA	National Disaster Management Authority
PTCL	Pakistan Telecommunication Company Limited
PDMA	Provincial Disaster Management Authority
LDA	Lahore Development Authority
KDA	Karachi Development Authority
IRSA	Indus River System Authority
WAPDA	Water and Power Development Authority
MCL	Metropolitan Corporation Lahore
OGDCL	Oil and Gas Development Company Limited
PAKSAT	Pakistan Satellite
PAKTES	Pakistan Technology Evaluation Satellite
PAF	Pakistan Air Force
C4ISR	Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance
UAV	Unmanned Aerial Vehicle
NASTP	National Aerospace Science & Technology Park
SANSA	South African National Space Agency
SAAF	South African Air Force
ISA	Iranian Space Agency

IRGC	Islamic Revolutionary Guard Corps
IRGC-AF	Islamic Revolutionary Guard Corps Aerospace Force
TUA	Türkiye Uzay Ajansı (Turkish Space Agency)
TurAF	Turkish Air Force
SANDF	South African National Defence Force
EEZ	Exclusive Economic Zone
EO	Electro-optical
TAI	Turkish Aerospace Industries
PPP	Public-Private Partnership

1. INTRODUCTION

Space has transpired as an important avenue for military and civilian activities. The turn of the century witnessed an increase in the number of state-sponsored space programmes primarily due to its increased accessibility because of lower barriers to entry and cost reduction.[1]

The quotidian use of space-based services in addition to its indispensability to modern warfare has led to a 10 per cent increase in global government space investments in 2024 as compared to 2023.[2] This reveals outer space's central place in debates pertinent to national and international security.[3] This has spurred middle powers like Türkiye and South Africa to also secure their strategic interests by deploying space strategies as per their national priorities.

Pakistan's Space and Upper Atmosphere Research Commission (SUPARCO) was Asia's earliest space agency. It has made modest yet inconsistent progress in achieving its objectives for utilising space science for peaceful ends and socioeconomic benefit of the country.[4]

This paper conducts a comparative analysis of Pakistan with three similarly situated states – South Africa, Türkiye, and Iran – to produce insights and extract lessons that may steer the evolution of Pakistan's space trajectory.

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[1] Avishai Melamed, Ray Jayawardhana, and Sarah Kreps, "The Promise and Perils of the New Space Boom," *Brookings*, November 2, 2022.
[2] Olivia Garnier, "Defense Spending Drives Government Space Budgets to Historic High," *Novaspace*, January 21, 2025.
[3] Cassandra Steer, "Why Outer Space Matters for National and International Security," *Center for Ethics and the Rule of Law* (University of Pennsylvania, January 8, 2020), https://www.law.upenn.edu/live/files/10053-why-outer-space-matters-for-national-and.
[4] Fouzia Nasir Ahmad, "Reawaken Pakistan's Spirit of Discovery," *The Express Tribune*, October 22, 2023, https://tribune.com.pk/story/2442382/reawaken-pakistans-spirit-of-discovery; "About Us, SUPARCO," n.d., https://suparco.gov.pk/about-us/.

1.1. Defining Emerging Space Countries

Based on differing criteria, authors have classified countries as spacefaring, emerging space, and non-spacefaring based on their ability to possess, operate, and develop specific set of space technologies.[5]

Oniosun's definition of emerging space countries is utilised in this paper. He defines them as countries that have begun the development of their space programmes and have attained differing level of success.[6]

1.2. Hypothesis

Pakistan can strengthen its space programme by learning from South Africa, Türkiye, and Iran to develop a civil-military nexus, a vibrant private space sector, and integrating its satellite data into decision-making.

1.3. Research Questions

This paper is predicated on answering three questions:

1) What is the space use appetite in Pakistan?
2) What are the national space capabilities of South Africa, Türkiye, and Iran, and how do they compare with Pakistan?
3) What lessons can Pakistan learn from the space programmes of South Africa, Türkiye, and Iran to strengthen its own space programme?

[5] E.g., Mark Waters, "Small States in Space: Space Club Relevancy and National Interest Influence," *Journal of Indo-Pacific Affairs* 6, no. 4 (2023): 13–47; Marco Aliberti et al., "Emerging Spacefaring Nations: Review of selected countries and considerations for Europe," *European Space Policy Institute* (European Space Policy Institute, June 2021).
[6] Temidayo Isaiah Oniosun, "A holistic framework for classifying countries in the space sector," *Space Policy*, May 2025.

1.4. Methodology

Qualitative method was employed to conduct this secondary source based comparative analysis. This exploratory natured paper drew on peer-reviewed journal articles, books, and policy reports among other available published data to provide a nuanced approach and perspective.

As per Oniosun, 79 out of 192 countries are emerging space countries.[7] To draw a fair comparison with Pakistan, for this research South Africa, Türkiye, and Iran are taken as case studies. These countries are chosen as their space programmes are closely tied to national security imperatives whilst also working in the civilian domain for their socioeconomic uplift.

2. LITERATURE REVIEW

Literature produced, hitherto, on emerging space middle powers has delineated geopolitical necessity for the pursuit of space-based assets to achieve national security needs, military and socioeconomic benefits, and prestige.[8] In an academic discourse saturated by great power competition, the space efforts of middle powers are also seen through the lens of great power rivalry in space.[9]

Nevertheless, emerging space players have been discussed in the literature. They are said to be focused on collaborating with other experienced countries and

[7] Oniosun, "A Holistic Framework for Classifying Countries in the Space Sector."
[8] Harding, *Space Policy in Developing Countries*; Annette Froehlich, Diego Alonso Amante Soria, and Ewerton De Marchi, *Space Supporting Latin America, Studies in Space Policy*, (Springer Nature, 2020).
[9] Laura Neacsu and Hendrik A. Pasligh, "Middle-Power Space Strategies: A Comparison of Canada and South Korea," *The Security Distillery*, March 3, 2021, https://thesecuritydistillery.org/all-articles/middle-power-space-strategies-a-comparison-of-canada-and-south-korea.

are deemed as leaders of tomorrow.[10] Authors have explored the South African space programme through a historical overview and emphasise the importance of space to the country's economic growth.[11] Similarly, Türkiye's space programme highlights the country's strategic autonomy to augment its space capabilities driven by national security parameters.[12] The Iranian space programme has been looked at suspiciously in the literature because of its intercontinental ballistic missiles programme that can putatively threaten NATO and other players in the international arena.[13]

Specific to the case of Pakistan – an emerging spacefaring country[14], a rich tapestry of research focuses exclusively on comparing the space programmes of India and Pakistan. The aim of the aforementioned research is to delineate regional strategical stability especially in the backdrop of India's militarisation of space seen through its Ballistic Missile Defence system and anti-satellite weapons[15] because India's space programme has always been developed as an offensive towards its neighbours – Pakistan and China.[16]

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[10] Caleb Henry, "Emerging Space Powers: The Leaders of Tomorrow," ViaSatellite, n.d., https://www.satellitetoday.com/long-form-stories/emerging-space-powers-the-leaders-of-tomorrow/.
[11] Keith Gottschalk, "South Africa's Space Program," *Astropolitics* 8, no. 1 (July 15, 2010): 35–48; Chris Alden, "South Africa's Space Programme: Past and Present," *The Strategic Review for Southern Africa* 29, no. 1 (May 1, 2007): 38, https://repository.up.ac.za/handle/2263/5674.
[12] Asena Boztas and N. Ceren Turkmen, "An Interdisciplinary Analysis of Turkiye's Space Policy: An Economic and Political Perspective," *Space Policy*, November 1, 2024, 101664.
[13] Oleksandr Cheban, "The Iranian Way to the Stars: Why Iran's Space Programme Can Be Dangerous For International Security," *Ukraine Analytica* 3, no 21 (June 2020): 76-84.
[14]Waseem-Ud-Din, "National Space Legislation: A Necessity for Pakistan," *Second to None*," July 23, 2023, https://secondtonone.com.pk/2023/07/23/national-space-legislation-a-necessity-for-pakistan/.; Oniosun, "A Holistic Framework for Classifying Countries in the Space Sector."
[15]Abu Hurrairah Abbasi and Saher Liaqat, "India's Evolving Space Militarization and the Security Implications for Pakistan," Strategic Perspectives, 2025.; Mian Zahid Hussain and Raja Qaiser Ahmed, "Space Programs of India and Pakistan: Military and Strategic Installations in Outer Space and Precarious Regional Strategic Stability," *Space Policy* 47 (June 22, 2018): 63–75.
[16] Fazal Abbas Awan, Umbreen Javaid, and Rabia Munir, "Pakistan India Space Program and the Satellite System," *Journal of Indian Studies* 4, no. 1 (2018): 129–39.

1.5. Gap in Existing Literature

Extant literature has put forth case studies, at times comparative in nature, of middle space powers that pertain to developing countries to postulate the significance of their respective programmes, ranging from prestige to socioeconomic development and military applications. Moreover, in prior literature, in the context of Pakistan, comparisons are drawn with India. Therefore, a lacuna is observed as Pakistan's space developments have not been compared with other emerging space nations. Therefore, this research aims to fill the identified gap.

3. PAKISTAN'S PLACE IN THE SPACE DOMAIN

Under the auspices of Dr Abdus Salam, Pakistan became the first country in South Asia and the third country in Asia to devise its space programme. He envisioned an organisation that could accommodate the modern strategic and scientific needs of the Pakistani state.[17]

To help Pakistan in its space endeavours, China proved to be a critical ally due to its willingness to help Pakistan when it was sanctioned by the West because of its nuclear weapons programme. Thus, international cooperation brought with it a multitude of benefits in the form of financing and technical skills transfer.[18]

Badr-I, henceforth, in 1990 was sent into space via Chinese Long March 2E rocket. It was a store and transmit communications satellite that was launched in low Earth Orbit that had a one-month mission life. This was followed in 2001 by a more

[17] Noor-Ul-Huda Atif, "SWOT Analysis of Pakistan's Space Program," NUST Journal of International Peace and Stability, July 23, 2020, 48–59.
[18] Miqdad Mehdi and Jinyuan Su, "Pakistan Space Programme and International Cooperation: History and Prospects," Space Policy 47 (January 4, 2019): 175–80.

advanced Badr-II equipped with imagery and mapping instruments launched via Russian Zenit-2 rocket.

Pakistan's further cooperation with China through the China Pakistan Corridor (CPEC) led to the inking of agreements for the development and subsequent launch of Pakistan Remote Sensing System (PRSS) to monitor CPEC projects as part of Sino-Pakistan space cooperation.

Name of Satellite	Payloads	Purpose	Target stakeholders/end users
PakSAT-MM1	C, Ku, Ka and L Bands	Communication satellite providing communication services e.g., mobile banking, broadband internet, VSAT connectivity	General public; Education sector for virtual classrooms and online universities (e.g., Virtual University of Pakistan); healthcare sector's telemedicine and e-health programs; NDMA; telecommunication companies (e.g., PTCL, Jazz); multinational corporations and banks; Pakistan Armed Forces (Army, Navy, Air Force)
PRSC-EO1	High-resolution optical payload for taking multi-band images with potential resolution of up to 1 metre	Remoting sensing satellite for monitoring and resource management, disaster response, urban planning, and agricultural development	Ministry of National Food Security & Research; Provincial Agricultural Departments; NDMA; PDMA; Pakistan Environmental Protection Agency; city development authorities (e.g., LDA, KDA), IRSA, WAPDA; universities and research centres working on geospatial sciences and remote sensing applications
PRSS-II	Electro-Optical (EO) Payload	Land use monitoring, environmental quality, agriculture, urban development, supporting disaster prevention	Urban planners and municipal authorities (e.g., LDA, MCL); mining and energy companies; infrastructure and construction sector (e.g., monitoring mega-projects like CPEC)
PakTES-1A	EO Payload	Weather and environmental monitoring, agriculture, climate change	Mining companies (e.g., OGDCL); climate change institutions (e.g., Ministry of Climate Change and Environmental Coordination); urban planning and municipal authorities (e.g., LDA, WAPDA)

Table 1: List of Pakistan's satellites currently in orbit[19]

For Pakistan, remote sensing satellites are important because of the country's vulnerability to climate change. These remote sensing satellites can play a significant role in limiting intra-state conflict by adequately providing up-to-date data to combat

[19] Compiled by the author from SUPARCO's website

non-traditional security threats like climate change, food shortage and water scarcity. Land surveillance and scientific study of disaster assistance and navigation expedites response and rebuilding efforts by humanitarian departments.[20] In that regard, significant leaps have been made as seen by the launch of Pakistan's first communication satellite, PAKSAT-IR in 2011, and PRSS-1 and PAKTES-1A in 2018 as the country's first Remote Sensing Satellites.[21]

PakSat-MM1, the multi-mission communication satellite was placed by SUPARCO in the geostationary orbit in collaboration with China in June 2024.[22] Accordingly, this multi-mission satellite will play a pivotal role in uplifting the country socioeconomically and prove to be a springboard for the country's digital transformation.[23]

Though an optimism exists pertinent to space helping Pakistan combat non-traditional threats, specific examples are mostly missing.[24] In one instance, the importance of space technology in offering solutions to the issues faced by the country was mentioned. Accordingly, SUPARCO and the federal government run National Disaster and Risk Management Fund use geo-referenced data to evaluate disaster risks from hydro-meteorological threats. This provides detailed risk assessments and financial impact forecasting to assist in risk-informed investment decisions to enhance national resilience. Additionally, SUPARCO is aiding relevant

[20] Ahmad Khan, Tanzeela Khalil, and Irteza Imam, "Pakistan's Space Activities," in *Handbook of Space Security,* eds. Kai-Uwe Schrogl (Springer Nature, 2020), 1455–69.
[21] Ali Ahsan and Ahmad Khan, "Pakistan's Journey Into Space," *Astropolitics 17*, no. 1 (January 2, 2019): 38–50.
[22] PakSAT-MM1 | SUPARCO," 2024, https://suparco.gov.pk/major-programmes/projects/paksat-mm1/.
[23] Jamal Shahid, "Suparco to Launch PAKSAT Satellite on 30th," *Dawn*, May 22, 2024, https://www.dawn.com/news/1834950.
[24] Mahvish Malik and Misbah Arif, "Managing Non-Traditional Threats by Using Space Technology: A Case of Pakistan," *NUST Journal of International Peace and Stability* 2 (July 25, 2019): 32–44.

stakeholders by providing satellite monitoring data for smog's source identification for instant corrective actions.[25]

Nevertheless, Pakistan's space technology remains underutilised because of the relevant institutions and decision-makers showing disinterest in its usage. The 2022 floods are an example where poor timely decision-making in spite of free access to satellites was visible. This was primarily caused by the absence of the integration of accessible land data with satellite and ground data creating a knowing-doing gap. Resultantly, related institutions such as Ministry of Climate Change are incapable of turning knowledge into performance as during the government's decision-making, the data produced by academic institutions is frequently ignored.[26] A similar situation is observed during the subsequent floods and natural disasters that have made clear the absence of practical application of information collected by Pakistani satellites.

On the other hand, the Pakistan Air Force (PAF) understood the importance of space in contemporary warfare, and therefore started to develop its space capability in parallel, rather than relying on imported solutions. This was a crucial part of Air Chief Marshal Zaheer Ahmed Baber Sidhu's integrated multi-domain operations philosophy, which he pursued since assuming the role of PAF Commander in March 2021. PAF's Space Command was established in 2021 and has since then redefined the battlespace. Launching indigenous satellites has delivered uninterrupted ISR support, provided real-time information to PAF aircraft, and allowed pilots to gain unmatched situational awareness and offensive capabilities such as electronic

[25] UN Committee on the Peaceful Uses of Outer Space, Statement of the Pakistan Delegation, Agenda Item No. 11 – Space & Climate Change, 2025.
[26] "'Pakistan Recent Floods from Space: Technology Perspective,'" Institute of Policy Studies, 2021.

attacks owing to secure SATCOM connectivity.[27] Additional threefold rationale has also driven PAF's space indigenisation. Firstly, precision-guided munitions, that have transformed the way battles are fought, require coordinates to accurately locate and strike targets.[28] Secondly, gathering intelligence on adversaries' order of battle and capabilities through a mapping of their electromagnetic spectrum is significant for enhancing situational awareness and winning wars.[29] Thirdly, air forces are provided with secure connectivity and flexible means of communications considered to be critical to fulfilling their missions through satellites – the backbone of contemporary military communication.[30] For unmanned aerial vehicles (UAVs), satellites are necessary to transmit communications, especially when the Ground Control Systems and the UAVs are separated by long distances.[31] By having its own satellite in the orbit, PAF can ensure invulnerability to electronic warfare and jamming while trusting the provided data.

It is the synthesis of space along with other capabilities such as electronic warfare, cyber, and kinetic power that has made the PAF evolve into a full-spectrum, truly multi-domain combat air force, transitioning out of a fighter-centric air force.[32] This revolutionary transformation, under the incumbent Air Chief, made the PAF prevail over the IAF during the May 2025 war, successfully shooting down seven Indian planes: four Rafales, one Mirage-2000, one Sukhoi-30, and one MiG-29.

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[27] Asim Suleiman, "A Force Transformed," *The Nation*, July 18, 2025, https://www.nation.com.pk/18-Jul-2025/a-force-transformed.
[28] "Advancements in Precision-Guided Munitions (PGMs) and Smart Bombs: Shaping the Future of Modern Warfare," Defence Industries, 2024, https://www.defence-industries.com/articles/advancements-in-precision-guided-munitions-pgms.;
[29] Thomas D. Taverney, "The Evolution of Space-Based ISR," Air & Space Forces Magazine, September 2, 2022, https://www.airandspaceforces.com/article/the-evolution-of-space-based-isr/.
[30] "Military Space," Airbus, June 13, 2024, https://www.airbus.com/en/products-services/defence/military-space.
[31] Elena Basan, Olga Peskova, and Maria Lapina, *Analysis of Communication Channels for the Organization of Control and Interaction of UAVs from the Security Viewpoint*, ed. Anna V. Korobko et al., *Short Paper Proceedings of the 2nd Siberian Scientific Workshop on Data Analysis Technologies with Applications 2021*, vol. 3047, 2021.
[32] Alan Warnes, "Understanding the Rafale Kills," *AirForces Monthly*, October 2025, 43-57.

Materialised as the present Air Chief's vision for strategic autonomy, the National Aerospace and Technology Parks (NASTP) have been established with centres in Karachi, Kharian, Rawalpindi, Kamra, and Lahore. A project of national strategic importance, following the triple helix model of connecting government, academia, and industry, NASTP aims for innovation, development, and research as part of PAF's indigenisation and modernisation efforts. It has also emerged as a pioneer in Pakistan's space technology landscape by working on various projects. Among them is the development of Pakistan's first indigenously produced space equipment, the Flyaway antenna, in record time that is exported for both commercial and military use.[33] Henceforth, in the case of Pakistan, advancements in space are spearheaded by both the civilian sector and the air force.

4. EMERGING SPACE POWERS AND PAKISTAN

Similar to Pakistan, as understood from Table 2, for Türkiye, South Africa, and Iran space is significant for socioeconomic development and national security purposes. Furthermore, developments in space are spearheaded by both the civilian and air force sectors.

[33] S. Khalil, "Revolutionary Arena in Space AI & Cyber Security – Second to None," April 25, 2024, https://secondtonone.com.pk/2024/04/25/revolutionary-arena-in-space-ai-cyber-security/.

Country	Start of Space Programme	Space Appetite	Space Budget (USD)	Use of Space for National Security/Defence Purposes	Institutional Lead	Number of Satellites in Orbit
Pakistan	1961 with the establishment of SUPARCO	Comes from national security imperatives and socioeconomic development	84 million	PAF building NASTP and cyber-space commands linking as a way for using space for defence	Mixed (SUPARCO as a civilian organisation and PAF's active involvement in space through NASTP)	4
South Africa	2010 with the launch of SANSA	Socioeconomic and military purposes	56 million	Partnership of SANSA with the SAAF; SAAF's commitment to positioning itself at the forefront of space capabilities; Establishment of Space Command Section	Mixed (SANSA as a civilian organisation and SAAF for military space engagement)	1
Türkiye	Space Technologies Research Institute established by TÜBİTAK in 1985; TUA established in 2018	Reduce dependence on foreign technologies & enhance national capabilities for achieving economic goals	161 million	Satellite systems used for surveillance and reconnaissance as GÖKTÜRK-I EO and GÖKTÜRK-III SAR	Mixed (TÜBİTAK UZAY & TUA: Civilian); Turkish Air Force)	23
Iran	1998 by inking agreements with China and Russia to collaborate designing, building, and launching satellites	Enhancing military capabilities through communication and geo-positioning technology	200 million	Launched military reconnaissance satellites e.g., Nour)	Mixed (civilian (ISA) and military (IRGC))	~12

Table 2: Comparative Table[34]

[34] Compiled by the author from various sources such as newspaper articles and each country's official Space Agency's website.

4.1. South African Space Environment: An Air Force and Civilian Nexus

An integrated civilian-military structure is prominent in the South African Space Programme. The South African National Space Agency (SANSA) is the key body charged with the implementation of the national space policy. It works in coordination with the South African National Defence Force (SANDF) on space-related defence and security objectives.[35] SANDF has declared space power as essential for its achievement of greatness.

Primarily, in 2024, the South African Space Command was officially recognised as the primary organ for defence-related space activities, collaborating with SANSA and other government agencies. This endeavour was hailed as the fruit of the hard work of the South African Air Force (SAAF).[36] For SAAF, space engagement goes beyond the C4ISR, rather it is considered integral to the advancement of multi-domain warfare. In a collaborative effort with various industry partners and organisations such as National Earth Observation and Space Secretariat and Council for Scientific and Industrial Research, SAAF believes its future of space-based defence capabilities is getting shaped.[37]

Strong indigenisation is seen in the country wherein almost every satellite sponsored by the country was designed and manufactured locally. At the forefront of research, designing, development, and subsequent integration and testing of satellites, the South African spinoff companies, academic and research institutes are

[35] "South Africa - Space Security Portal," 2023, https://spacesecurityportal.org/states/south-africa.
[36] "It's official – the SANDF has a Space Command Section," DefenceWeb, September 17, 2024, https://www.defenceweb.co.za/sa-defence/sa-defence-sa-defence/its-official-the-sandf-has-a-space-command/.
[37] Dean Wingrin, "SA Air Force progresses with establishment of Space Command Section," SAAF, July 2023, https://www.saairforce.co.za/news-and-events/1812/sa-air-force-progresses-with-establishment-of-space-command-section.

involved. The South African capability to produce its own satellites was demonstrated at least eleven times between 1990s and 2023.[38]

The thriving South African space industry is also exemplified by its export of space products that have already been integrated into various international satellites such as the Chinese Queqiao lunar satellite.[39] There are 20 space engineering companies undertaking international export of space competent apparatuses, subsystems, and complete satellite systems for international market worth 1 billion USD.[40]

[38] Samuel Oyewole, “The Development of Space Capacities and Capabilities in South Africa,” in *Utilitarianism in Outer Space* (Springer, 2024).
[39] Munyaradzi Makoni and Munyaradzi Makoni, “Satellites Help Cement South Africa’s Space Industry,” Eos, July 2, 2025, https://eos.org/articles/satellites-help-cement-south-africas-space-industry.
[40] SANSA, “South Africa’s Ambitions for a Thriving African Space Industry”, February 28, 2025, https://www.sansa.org.za/2025/02/south-africas-ambitions-for-a-thriving-african-space-industry/.

Satellite names	Mass of satellites (kg)	Manufacturer	Purposes	Launch & operational dates	Launch facility & locations	Cost (US$ million)
SunSat	64	University of Stellenbosch	EO/ Education	23/2/ 1999–19/ 1/2001	VAFB, California, USA	2
Sumbandila	82	SunSpace & University of Stellenbosch	EO/ Technology demonstration	23/9/ 2009–8/ 2012	Baikonur Cosmodrome	3
ZaCube-1 (TshepisoSAT)	1.2	CPUT	EO/ Technology Development/ Educational	21/11/ 2013-	DAB, Russia	–
Condor-E2	–	NPO Mashinostroyeniya	EO/ Military	19/12/ 2014-	Baikonur Cosmodrome	108
Nsight-1	3	SCS Space	EO/ Commercial	26/5/2017-	ISS	–
Za-AeroSat	4	Stellenbosch University	EO/ Educational	18/5/2017-	ISS	–
Za-Cube-2	4	CPUT	EO/ Educational	27/11/ 2018-	Vostochny Cosmodrome	–
XinaBox ThinSat	<1	High Schools	Educational	17/4/ 2019–4/ 2019	Mid-Atlantic Regional Spaceport, Wallops	–
MDASat-1A (Maritime Domain Awareness)	2/3	CPUT	EO/ Maritime Domain Awareness	13/1/2022	Cape Canaveral SFS, Florida, USA	1.7
MDASat-1B	2/3	CPUT	EO/ Maritime Domain Awareness	13/1/2022	Cape Canaveral SFS, Florida, USA	
MDASat-1C	2/3	CPUT	EO/ Maritime Domain Awareness	13/1/2022	Cape Canaveral SFS, Florida, USA	
EOS-SAT 1 (AgriSat 1)	178	Dragonfly Aerospace	EO/ Agricultural monitoring and analysis	3/1/2023	Cape Canaveral SFS, Florida, USA	–

Table 3: South African Satellite Inventories and Capabilities[41]

A reinvigorated South African focus on space technology holds immense potential across multiple sectors such as agriculture, environmental monitoring, and telecommunications.[42]

[41] Oyewole, "The Development of Space Capacities and Capabilities in South Africa," 180.
[42] Guy Leitch, "SAAF Soldiering on," Times Aerospace, August 14, 2024, https://www.timesaerospace.aero/features/defence/saaf-soldiering-on.

Most of the satellites sent by South Africa are designed for EO and educational purposes. The EOS-SAT 1, for example, has delivered images of Cape Town to help farmers in developing sustainable agricultural methods for yield improvement and harvest monitoring.[43]

The SumbandilaSat, though now de-orbited, played an important role in Earth's observation wherein its dual use was evident as it helped the South African Defence Intelligence to observe the coastal waters for piracy and illicit operations, whilst also helping in local research by capturing and downloading imagery.[44] It also aided in providing data for disaster management such as fire campaigns in the Kruger National Park as well at the regional level through flood monitoring in Namibia.[45]

Moreover, the MDASat-1, an EO nano-satellite's data collected through its improved automatic identification system has helped in observing foreign vessels within South African Exclusive Economic Zone (EEZ), identifying oil spills, monitoring ocean conditions, and creating awareness of algal blooms to protect the abalone and crayfish stocks.[46] Additionally, SANSA is continuously involved in playing a significant role in maritime environmental protection by sharing relevant EO data with pertinent stakeholders involved in South African economic growth, sustainable development, and decision-making. To this effect, on a weekly basis it is obtaining pictures from the

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[43] "Dragonfly Aerospace Unveils Spectacular First Images From EOS SAT-1," Dragonfly Aerospace, May 23, 2023, https://dragonflyaerospace.com/dragonfly-aerospace-unveils-spectacular-first-images-from-eos-sat-1/.

[44] Bella Malcolm, "Military Innovation: Africa's Growing Satellite Network," African Leadership Magazine, December 23, 2024, https://www.africanleadershipmagazine.co.uk/military-innovation-africas-growing-satellite-network/.; "Sumbandila: Investing in Our Future | South African Government," September 15, 2010, https://www.gov.za/sumbandila-investing-our-future.

[45] Daleen Fouche, "Farewell to SumbandilaSat, a Proudly South African Satellite," South African National Space Agency, February 7, 2022, https://www.sansa.org.za/2022/02/farewell-to-sumbandilasat-a-proudly-south-african-satellite/.

[46] Makoni and Makoni, "Satellites Help Cement South Africa's Space Industry."

Canadian RADARSAT 2 over South Africa's EEZ which are then made part of the National Oceans and Coastal Information Management System to advance decision support tools for the Department of Forestry, Fisheries, and Environment and to enhance South African Maritime Domain Awareness.[47]

The importance of satellite imagery in South African urban morphology and classification is also underscored wherein it has been utilised for classification of various urban structures to assist in planning and implementation of sustainable urban design.[48]

SANSA is engaged in monitoring the sun for space weather forecasts. The South African 24/7 Space Weather Centre has further augmented this area by offering a vital service to the regional aerospace community. This is because space weather impacts satellites in orbit.[49]

4.2. Türkiye: Dual-Use Ambitions

In Türkiye, state-owned and state-funded organisations and institutions are involved in space-related developments. The most prominent are the TÜBİTAK UZAY, the Turkish Aerospace Inc. (TAI), and the Turkish Space Agency (TUA). Aselsan as a major Turkish defence contractor is also involved in manufacturing of satellites.

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[47] Khumbulani Mkhize, "SANSA Strengthens Earth Observation Capabilities With RADARSAT-2 Imagery Acquisition - SANSA," South African National Space Agency, April 14, 2025, https://www.sansa.org.za/2025/04/sansa-strengthens-earth-observation-capabilities-with-radarsat-2-imagery-acquisition/.

[48] "Space-technology: Catalyst for Socio-economic Development in Africa," RIIS, October 26, 2023, https://enablinginnovation.africa/space-technology-catalyst-for-socio-economic-development-in-africa/.

[49] Scott Firsing, "South Africa Is Expanding Its Space Portfolio and Has a Growing List of Partners," *Africa at LSE - LSE's Engagement with Africa*, August 28, 2024.

TÜBİTAK UZAY is the leading institution working towards the realisation of space exploration targets within the ambit of the National Space Programme. It is ambitiously working towards the Lunar Exploration Programme for Ankara to have a presence on the moon.[50] It is the organisation that contributed to a great deal to the designing of observation satellites such as GÖKTÜRK-2 and 3 in collaboration with TAI and Aselsan to serve the targeting and tactical requirements of the Turkish Air Force (TurAF) coupled with reconnaissance and surveillance.[51]

Developed by TÜBİTAK UZAY the İMECE satellite, Türkiye's first sub-metre resolution earth observation satellite, launched in 2023, became a testament to the country's indigenous and national space capabilities. It helped bridge Ankara's need for high-definition satellite imagery for farming and disaster response.[52] In May 2025, it became part of the Turkish Air Force Command and was renamed GÖKTÜRK-2B. This was part of buttressing Türkiye's defence as it was acknowledged that space has emerged as a direct defence domain requiring effective and independent presence of EO satellites against all types of threats.[53]

In line with its space programme, termed as too ambitious elsewhere[54], the TUA is working towards exporting national space technology, products and services, observing and tracking spatial objects, and increasing Türkiye's visibility in the space

[50] "Exploration of Space - TUBITAK SPACE," Tübitak Uzay, June 13, 2025, https://uzay.tubitak.gov.tr/en/exploration-of-space/.
[51] "TAI Accelerates National Satellite Projects With Ambitious 5-year Vision," *Türkiye Today*, May 9, 2025, https://www.turkiyetoday.com/nation/tai-accelerates-national-satellite-projects-with-ambitious-5-year-vision-3201206.
[52] "Türkiye Launches First Domestic High-resolution Earth Observation Satellite Into Space | UN-SPIDER Knowledge Portal," 2023, https://www.un-spider.org/es/node/13134.
[53] Tübitak Uzay. "İMECE Satellite Was Taken Into the Air Forces Command Inventory as GÖKTÜRK-2B - TÜBİTAK UZAY," May 27, 2025. https://uzay.tubitak.gov.tr/en/imece-satellite-named-gokturk-2b-taken-into-the-inventory-of-the-air-force-command/.
[54] "Turkey's Space Programme May Prove Too Ambitious," *Emerald Expert Briefings*, July 10, 2024, https://doi.org/10.1108/oxan-db288205.

domain.[55] For the latter, January 2024 saw Ankara's first four-person crewed mission to the International Space Station where they undertook scientific experiments.[56]

Turkish achievement of self-reliance in space technologies is evidenced in the recent past by the launch of its first indigenous geostationary communications satellite, the Türksat 6A. Its development was led by TAI and TÜBITAK UZAY.[57] As part of an export agreement inked at the CABSAT 2025 conference in Dubai, Türksat 6A is providing services to 4.5 billion people to countries like Indonesia and India in TV and emergency communications sectors.[58]

FGN-100-d, another indigenous satellite launched into the orbit in January 2025, was developed by a private Turkish firm, Fergani Space for the purposes of communication and positioning.[59] Similarly, Plan-S, another space technology firm launched four new satellites into space in June 2025 to support Anakara's role in strengthening communication and advancing geo-positioning technologies.[60]

4.3. Iran: Civil-Military Convergence

Iran's space activities are primarily split into two: its state space programme and a parallel programme run by the Islamic Revolutionary Guards Corps' Aerospace Force (IRGC-AF).

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[55] "National Space Program - Turkish Space Agency," n.d., https://tua.gov.tr/en/national-space-program.
[56] "Türkiye Enters 2025 After Pivotal Year for Defense, Space Progress," Daily Sabah, January 2, 2025.
[57] "Electric Thrust Engine of Türksat 6A Satellite Successfully Ignited," Daily Sabah, August 26, 2024, https://www.dailysabah.com/business/tech/electric-thrust-engine-of-turksat-6a-satellite-successfully-ignited.
[58] Ayse Bocuoglu Bodur and Emir Yildirim, "Turkish Communications Satellite Turksat 6A Completes 1st Year in Space," 2025, https://www.aa.com.tr/en/turkiye/turkish-communications-satellite-turksat-6a-completes-1st-year-in-space/3625486#.
[59] BaykarTech, "TÜRKİYE'S INDIGENOUS SATELLITE FGN-100-D1 IN SPACE," 2025, https://baykartech.com/en/press/turkiyes-indigenous-satellite-fgn-100-d1-in-space/.
[60] Goksel Yildirim and Emir Yildirim, "Turkish Space Tech Firm Launches New Satellites Into Space," 2025, https://www.aa.com.tr/en/science-technology/turkish-space-tech-firm-launches-new-satellites-into-space/3611712.

Satellite Name and Launch Year	Purpose	Manufacturer
Sina-1 (2005)	Remote sensing & telecom (store-and-forward)	Russia (NPK VNIIEM) & Iran (joint)
Omid (2009)	Technology demo, data relay (store-and-forward)	ISA / Iran Electronics Industries
Rasad-1 (2011)	Earth imaging (150 m resolution)	Malek-Ashtar University (Iran)
Navid-e-Elmo-o Sanat (2012)	Imaging (multi-spectral), weather data	Iran University of Science and Technology
Fajr (2015)	Imaging (500 m resolution); carried a cold-gas thruster for orbit raising	Iran Electronics Industries (Ministry of Defence)
Dousti (2019)	Remote sensing (test satellite)	Sharif University of Technology (Iran)
Noor-1 (2020)	Military reconnaissance (Imaging)	IRGC-AF
Noor-2 (2022)	Military reconnaissance	IRGC-AF
Khayyam (2022)	Earth observation (1 m resolution)	VNIIEM (Russia) for ISA
Noor-3 (2023)	Military ISR (imaging, improved camera)	IRGC-AF
Mahda (2024)	Research Satellite	Iran's Defence Ministry
Keyhan-2 (2024)	Narrowband communication and geo-positioning	Iran Electronics Industries (state-owned subsidiary of Ministry of Defence)
Hatef-1 (2024)	Narrowband communication and geo-positioning	Iran Electronics Industries
Sorayya (2024)	Scientific research (space weather, Earth observation)	IRGC-AF & ISA
Chamran-1 (2024)	Tech demo (orbital manoeuvring, cold-gas propulsion, altitude control)	Iran Electronics Industries and Aerospace Research Institute
Kowsar (2024)	High-resolution imaging for agriculture and environment	SpaceOMID (Iranian private company)
Hodhod (2024)	Communications (IoT connectivity in remote areas)	SpaceOMID

Table 4: Major Iranian Satellites[61]

The state space programme is under the Iranian president who chairs the Supreme Space Council that oversees the Iranian Space Agency (ISA). The ISA, in turn, develops contracts with entities working under ministries such as science, defence, and communications, as well as the private sector. The IRGC-AF's space

[61] Marcin Frąckiewicz, "Iranian Satellites and Space Agency: Capabilities, Missions, and Strategic Vision," Tech Space 2.0, August 25, 2025, https://ts2.tech/en/iranian-satellites-and-space-agency-capabilities-missions-and-strategic-vision/.

efforts are pronounced by the development of satellites, ground facilities, and launchers for military purposes and reports to the Iranian supreme leader.[62]

From table 4, it also becomes evident that both ISA and IRGC collaborate with one another. An example is the ISA's plan for sub-orbital launches in cooperation with IRGC.[63]

It is also important to identify that unlike the other case studies for this research, Iran has launched its satellite on indigenously developed Satellite Launch Vehicles such as Safir-1B and Qased developed by ISA and IRGC-AF respectively. The drive towards self-reliance stems from Iranian strategic calculus and international sanctions that have compelled it to turn inwards rather than accessing foreign launchers. Inevitably, Iran has emerged as an autonomous space player. Evidently, Iranian satellites for non-military use such as Sorayya for collecting scientific research and geo-positioning are also launched by the IRGC-AF indicating the potential for dual-use.

4.4. Comparative Synthesis

Space has emerged as a significant arena for national defence as evidenced from the case studies of Pakistan, South Africa, Türkiye, and Iran. Each country's geostrategic and geopolitical context has determined their space programme's trajectory.

One commonality among all three case studies is their thriving private sector. In South Africa, various firms are working in the domain of space and have reaped in

[62] Jim Lamson and Jeffrey Lewis, "Iranian President Raisi's Renewed Emphasis on Space Is Likely to Create New Tensions," War on the Rocks, December 20, 2021, https://warontherocks.com/2021/12/iranian-president-raisis-renewed-emphasis-on-space-is-likely-to-create-new-tensions/.
[63] "Iran will launch up to 7 new homegrown satellites into orbit," Iranian Students' News Agency, 2024, https://en.isna.ir/news/1403070201472/Iran-will-launch-up-to-7-new-homegrown-satellites-into-orbit.

a billion dollars, Türkiye's private sector has launched satellites successfully into the orbit, and Iranian-based company SpaceOMID has launched satellites putatively for non-military purposes. This demonstrates that the three countries have cultivated space ecosystems that are not only dependent on state-led initiatives, but also pay attention towards accelerating innovation and global competitiveness.

From the South African model, the application of data collected via South African satellites by relevant stakeholders has helped the country in its maritime environmental protection. This aspect is missing in Pakistan as despite facing numerous environmental challenges, the data collected from its EO satellites is not implemented in its decision-making process to manage natural disasters better.

Within Türkiye, the state-led organisations are working towards fulfilling the needs of TurAF by manufacturing satellites to help them achieve their requirements. The GÖKTÜRK series are an example. This aspect is also missing in Pakistan wherein the state-led space agency, SUPARCO, is not manufacturing satellites tailor-made to the requirements of the PAF.

5. RECOMMENDATIONS FOR PAKISTAN

Based on the comparison drawn, the following are the recommendations presented for Pakistan:

5.1. Strengthening Private Sector Engagement

Globally, the space sector has been largely democratised through public-private partnerships (PPPs). In the case of Pakistan, however, the country's space sector is still reliant on its public sector. As part of its National Space Policy 2024 it has been recognised that PPPs have to be encouraged in order to expand the use of

satellite services. Additionally, collaborations across academia, research institutions, and stakeholder engagement are underscored.[64]

Though the National Incubator Centre for Aerospace Technologies (NICAT) founded in 2022 backed by Ministry of IT & Telecom's Ignite and managed by a consortium composed of NASTP, Pakistan Aeronautical Complex Kamra, and Air University exists as a testament to public-private collaboration, more needs to be done.[65] Pakistan needs to maintain its global competitiveness by creating an enabling environment for PPPs to prosper.[66] The establishment of space-based commercial activities and PPPs will help Islamabad achieve self-reliance whilst reducing dependence on the nation's public treasury.[67]

5.2. Utilisation of Space Data

Launching a satellite into orbit requires millions of dollars. To get its return on investment, it is important for Pakistan to utilise the data collected by the various satellites to better managing its climate change driven natural disasters – a phenomenon that will accelerate in the coming years. The appetite for this has to be built within the various ministries and agencies.

Moreover, it is recommended that an institutionalised systematic infrastructure is created for archiving and cataloguing the satellite data collected by Pakistan to be accessible and discoverable for diverse Pakistani users, particularly researchers, private-sector innovators, and universities. Such a consolidated repository of satellite

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[64] SUPARCO and Government of Pakistan, "National Space Policy Pakistan," SUPARCO, 2024, https://suparco.gov.pk/wp-content/uploads/2024/01/National-Space-Policy.pdf., 14.
[65] "NICAT Announces Hi-tech Programme for Startups," *The News International*, February 8, 2025, https://www.thenews.com.pk/print/1280515-nicat-announces-hi-tech-programme-for-startups.
[66] Ezba Walayat Khan, "Launching New Frontiers: Why Pakistan Needs Public-Private Partnerships in Space Exploration," *The Friday Times*, May 20, 2025; "Pakistan's Space Policy," n.d., https://mofa.gov.pk/vienna-pakistans-space-policy.
[67] SUPARCO and Government of Pakistan, "National Space Policy Pakistan."

imagery and geospatial data acquired would help the relevant stakeholders to access the data easily as opposed to the current fragmentation across agencies and ministries. Spearheaded by SUPARCO in collaboration with the Higher Education Commission, such a framework can help Pakistan provide free or low-cost access to data for developmental and academic purposes allowing space data to be leveraged for innovation and national development.

5.3. Space's Dual-use

From the three case studies, the blurring of civil-military divide is apparent wherein a distinct dichotomy between the two is not visible. Prominently, the collaborations between the civilian space agency and their respective air forces are a demonstration of such harmonious effort. The case of Türkiye is the most interesting. It is recommended that rather than SUPARCO and PAF working in silos, they should have a handshake for synergistic coordination and intellectual pooling. This would further help Islamabad in maximising its dual-use technology that can further ensure the country can meet its defence imperatives in conjunction with its developmental goals.

6. CONCLUSION

Space has emerged as an important frontier for countries to defend themselves against adversaries and develop policies for benefitting the public through the collected spatial data. In Pakistan, satellites have been launched by SUPARCO and the PAF to fulfil their respective goals in space – remote sensing, EO, and surveillance. Countries in a similar position to Pakistan, South Africa, Türkiye, and Iran, have both convergences and divergences in their space programmes. In its

civilian sector, Pakistan has had notable achievements lately as the progress towards indigenisation is progressing through the launch of PRSC-EO1. Meanwhile, it is ruefully noted that despite having four satellites in orbit, Pakistan's use of its collected spatial data is virtually absent. On the PAF front, military satellites are launched into orbit for establishing secure communication, mapping the adversaries' electromagnetic spectrum and order of battle, and providing precise coordinates for targeting.

Through the cases undertaken in this research, it is understood that South Africa is effectively utilising its satellite data for policy and decision-making, Türkiye's state-funded sector is custom-making satellites for its Air Force, and Iran's military and IRGC are highly involved in its space programme. Nevertheless, a commonality binding all three countries together is the functioning of the private sector, creating an exuberance missing in Pakistan.

Resultantly, lessons for Pakistan are plentiful. The establishment of PPPs will help bolster the private space sector of Pakistan, particularly through the creation of a conducive environment by putting forth regulatory framework, enabling policies, and low barriers to entry. Moreover, the efficacious utilisation of space data by relevant stakeholders is the need of the hour, particularly in the wake of disastrous floods, inundating the country every year. This can be done through the establishment of a consolidated data repository to aid researchers within academia and industry alike to leverage the collated data in their research and development. Additionally, a move towards civil-military cooperation will prove advantageous in combining capital and human resources to develop dual-use satellite technology.

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