



DATA CENTRES IN SPACE

ORBITAL BACKBONE
OF THE SECOND
DIGITAL ERA?

WITH CONTRIBUTIONS BY:

Technische
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Future applications and new technologies, while carrying economic risk and technological uncertainty, need to be part of discussions on Europe's space policy, as they hold immense power to positively disrupt the sector and unlock further growth. This self-funded study on Data Centres in Space aims to give way to such discussions. Since the study's inception in late 2023 significant and sometimes unforeseen developments have picked up speed, further accelerating in the final months of the report finalisation with Google, xAI/SpaceX, and Amazon all announcing interest, and in some cases investment, in this application.

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KEY TAKEAWAYS

1 A second digital paradigm shift is upon us. Space Based Data Centres (SBDCs) have matured from a speculative idea into an emerging field of industrial development, garnering **attention from digital giant executives** such as Amazon (Jeff Bezos), Google (Sundar Pichai), xAI (Elon Musk), and the Alibaba Group (through Zhejiang Lab).

2 The global data centre market is expected to reach €535 Billion in 2030. Driven by unprecedented demand for data centre processing and computing power on Earth for AI, an increased strain on terrestrial energy and environmental resources, and increased data generation of operational and future satellites in orbit. These developments drove Jeff Bezos to assert “We will be able to beat the cost of terrestrial data centres in space in the next couple of decades.”

3 A dynamic ecosystem of **startups targeting the market** has emerged over the past years across Europe, North America, and Asia. Close to €70 million in private investment was tracked targeting the application itself, or directly relevant enabling components.

- ADA Space and Zhejiang Lab (China) have launched the initial 12 satellites from the planned 2,800 satellite-strong Three-Body Computing Constellation.
- In November 2025, Starcloud (USA) launched its initial demo satellite featuring the first Nvidia H100 GPU in space.
- European startups and scaleups are also active in this segment either directly targeting the market or enabling infrastructure, including D-Orbit, KP Labs, Edge Aerospace, and Loft Orbital.

4 Several **institutional programmes**, including the EU-funded ASCEND study led by Thales Alenia Space, and ESA missions such as Φ-sat, have developed building blocks that can enable a future on-orbit data processing infrastructure.

5 **Formidable challenges remain** to reach gigawatt-scale infrastructure.

- Launch costs, while falling thanks to reusable rockets like SpaceX’s Falcon 9 and soon, Starship, remain a significant barrier.
- Thermal management itself, dissipating gigawatts of waste heat in orbit is a daunting engineering task.
- In-orbit assembly is still underdeveloped to reach integrated gigawatt-scale infrastructure in the short term



OUR RECOMMENDATION

Europe cannot afford to miss a new potential golden age with high multiplier effects across the economy. While developments are in their infancy, Europe should capture the opportunity using ESA’s GSTP and the EC’s IOD/IOV programmes as a public-private testbed for enabling technologies, critical components, and operational practices in pursuit of SBDCs. Near-term opportunities already exist in improved in-orbit edge computing and satellite-to-cloud integration, which could act as stepping stones toward larger ambitions.

Building on the findings of the ASCEND study and in view of the proposed Horizon Europe Moonshot Projects under the 2028-2034 MFF, an ambitious European Space Based Data Centre initiative should be proposed. Going beyond R&D and demonstration, it should include a phased roadmap towards potential commercial deployment, supported by ESA’s ARTES programme.

While the technical and economic challenges remain a barrier, it is exactly disruptive concepts such as SBDCs that can, if successful, massively boost Europe’s competitiveness and, in turn, autonomy, repositioning Europe as a global leader.

Executive Summary

Over the last decade, the concept of **space-based data centres (SBDCs)** has progressed from speculative discussions to an **area of tangible R&D, industrial, and programmatic development**. Approximately €70 million of private capital has been invested in SBDC ventures since 2020, spread across close to 30 companies in Europe, North America, and Asia. These ventures, ranging from purpose-built start-ups such as Starcloud and Lonestar Data Holdings to larger players like Axiom Space, are testing concepts in orbital cloud computing, secure remote storage, and in-space edge processing. At the same time, public programmes are continually funding in-space edge computing initiatives: the EU-funded ASCEND study explores the environmental benefits of orbital data centres; ESA has launched Φ-Sat-2, demonstrating AI-enabled onboard processing; NASA has deployed its Spaceborne Computer-2 on the ISS; and China's "Three-Body Computing Constellation" aims to field a satellite compute mesh.

This expansion of activities must be understood against the tremendous rise in global data generation and growing demand for data processing. By 2028, total data production is forecast to exceed 400 zettabytes, further accelerated by AI, IoT, and

When space journalist Eric Berger speculated whether Eric Schmidt bought Relativity Space for the purpose of building data centres in-orbit, Schmidt himself replied with a simple "Yes."

Eric Schmidt, X, 28 April 2025

EO applications. The terrestrial data centre sector, valued at over €324 billion in 2024, is straining to keep pace. Projections suggest as much as **€5.7 trillion in investment** may be needed by 2030 to adequately keep pace with growth. Terrestrial data centres are becoming **increasingly costly, and land, energy, and cooling requirements are stretching grids and ecosystems to their limits**.

In this context, space offers enticing advantages. The continuous availability of solar energy coupled with the ability to process and filter data at source, presents a pathway to **economically advantageous, sustainable, and resilient infrastructure**. As former Google CEO Eric Schmidt warned in testimony before the U.S. Congress, an additional 67 gigawatts of new power generation will be needed for terrestrial data centres by 2030 - equivalent to 67 nuclear plants. His subsequent investment in launch provider Relativity Space underscores the view that orbital deployment could form part of the solution.

"We will be able to beat the cost of terrestrial data centres in space in the next couple of decades."

Jeff Bezos, Italian Tech Week, Turin (IT), October 2025

Beyond economics, **data sovereignty** is emerging as a decisive driver. The conflict between GDPR requirements and extraterritorial laws such as the U.S. CLOUD Act highlights the risks of dependency on non-EU providers. For organisations handling sensitive information, true compliance and security depend not just on where data is stored, but who controls the infrastructure. By that token, sovereign European SBDC capacity is not optional; it is essential.

This report examines the **economic, environmental, and strategic** drivers behind the emergence of SBDCs and evaluates their viability through a cost model benchmarked against terrestrial data centres (TBDCs) developed by researchers at the Technical University of Munich (TUM). The report also situates SBDCs within broader industrial and regulatory contexts. Interviews with industry experts and stakeholders reveal both **optimism and caution**:

"Simply scaling up Starlink V3 satellites, which have high speed laser links would work. SpaceX will be doing this."

Elon Musk, X, October 2025

advances in commercial off-the-shelf computing for space, combined with developments in reusable heavy-lift launch systems, strengthen the business case, while challenges in radiation protection, thermal management, latency, and data governance remain unresolved and demand increased investment.

Based on informed assumptions, two architectures were modelled for a gigawatt-scale SBDC in Sun-synchronous orbit: I) a monolithic configuration comprising 96 10 MW units, and II) a constellation of 6,700 smaller 150 kW units. Results show that monolithic architectures achieve cost competitiveness with high-end terrestrial Tier III data centres, with comparable capital expenditure and potentially lower lifetime operating costs if IT hardware can endure three or more years in orbit and launch costs fall considerably. By contrast, the constellation architecture remains prohibitively expensive, with capital costs double and operating costs more than triple those of TBDCs if a 1GW scale architecture is pursued. The analysis highlights hardware longevity, launch affordability, and the feasibility of robotic in-orbit maintenance as critical enablers for economic viability.

This study highlights an industrial opportunity; while large-scale SBDCs remain a **long-term prospect**, near-term applications such as in-orbit edge processing of Earth observation data, secure orbital storage, and sovereign satellite-to-cloud integration can act as valuable stepping stones.

For Europe, this window of opportunity is open now. By embedding an outlook for SBDC development within the future frameworks of IRIS², the EU Green Deal, and ongoing efforts to create a **sovereign cloud-edge continuum**, Europe allows itself the opportunity to:

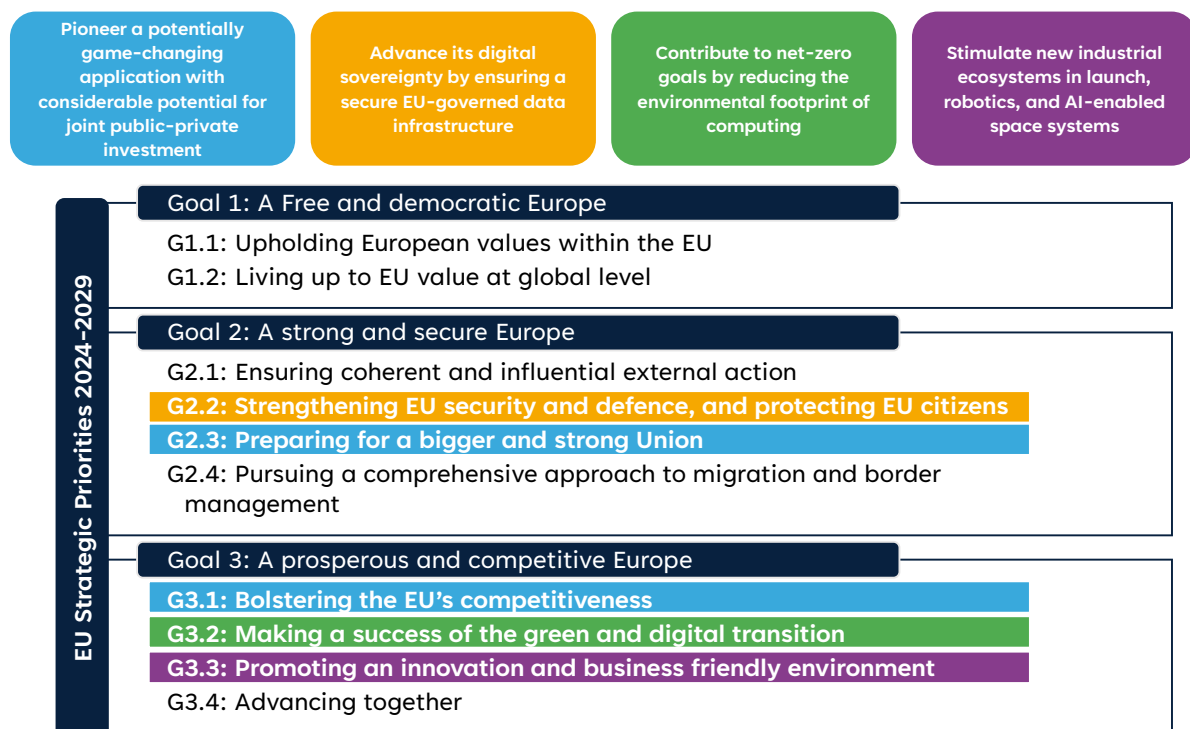


Figure 1: Benefits of SBDC developments and their convergence with EU strategic priorities.

If Europe acts decisively while the technological, financial, and political momentum converges, SBDCs offer an opportunity to secure leadership in a critical domain of the perpetually growing digital economy. While gigawatt-scale SBDCs remain a long-term prospect, they could evolve from niche applications to a viable complement to terrestrial data centres in the decades ahead. These developments clearly fall in line **with EU strategic priorities**, and thus, an argument is to be made that this opportunity for a European flagship mission should not be squandered.



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Report Overview

In Chapter 1 we lay the groundwork with a primer on computing in space. We introduce the **advancements in space-based data centres (SBDCs)** before heading into Chapter 2. Chapter 2, **the in-space computing and storage ecosystem** provides an industry landscape review of today's growing investment into the sector, and profiling both privately funded initiatives in orbital cloud computing, remote storage, and supporting infrastructure, as well as publicly funded projects.

Chapter 3 then zooms in on the **drivers of SBDC development**, focusing on economic imperatives, environmental pressures, and sovereignty concerns tied to data centre development and its push towards space. To balance, Chapter 4, **an industry perspective** provided by industry experts, highlights the commercial opportunity, while also benchmarking the costs of space-based versus terrestrial Tier IV data centres, identifying enabling technologies and acknowledging technical barriers.

Developed by TUM, within **Annex A** we offer a **cost model for SBDCs**, setting out assumptions and architectural considerations, before benchmarking monolithic and constellation-based SBDC designs to terrestrial data centres.

Upon request the reader may gain access to the **technical derivation of the complete cost model**, detailing assumptions, methodologies, and comparative results for terrestrial and space-based data centres under different scenarios.



Figure 2: Render of ASCEND Data Centre in orbit. (Source: Thales Alenia Space)

1 Advancements in Space-Based Data Centres (SBDCs)

The compounding rise of data generation in orbit, with increasing energy and environmental resource scarcity on Earth for compute-demanding applications, is driving interest towards the development of SBDC concepts and first real-world demonstrations. While significant technical, economic, and operational challenges remain, accelerated efforts towards some of them are clearly visible. SBDCs are considered a relevant candidate for investment in the unfolding AI revolution, whereby the data centre market is expected to reach a CAGR of 11.2% between 2025 and 2030, and annual investments in data centre and cloud infrastructures to reach €247 billion by 2028.¹

This opening chapter provides an overview of the perimeter addressed by the report, and provides a simple explanation of applications covered herein, targeting non-expert readers.

1.1 A brief introduction on computing in space

The term SBDCs in this report is used as a catch-all phrase for a number of operational concepts addressing in-space cloud computing, edge computing, and data storage applications. The report does not address data relay systems or communications networks.



Figure 3: Applications within the scope (blue) and outside (grey) the scope of the report.

In-space cloud computing is categorised by the positioning of server infrastructure in orbit, which then handle data processing for third parties. Constellations are being developed to build a network of satellites forming a distributed computing infrastructure that can match services as offered on Earth. Equally, monolithic architectures are being proposed resembling space stations that host server racks to the benefit of paying users in orbit.

Relatedly, today in space, latency is reduced by bringing processing power closer to the data source in a process called **edge computing**. Typically involving smaller computing units integrated within the satellites, edge computing in space is especially suited for applications requiring rapid decision-making and allows circumventing typical SWAP (size, weight and power) constraints. AI is increasingly being integrated into edge computing

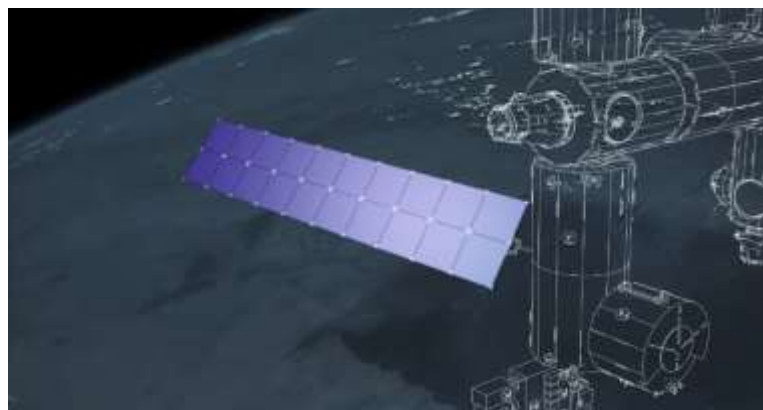


Figure 4: A concept for an edge computing device attached to an orbital space station as envisioned by Sophia Space. (Source: Sophia Space)

¹ Arizton. Data Center Market – Global Outlook & Forecast 2023-2028, June 2023. (Link)



architectures in orbit, enabling greater autonomy and efficiency in space operations. By embedding AI capabilities directly within satellites and spacecraft, data can be processed and interpreted in situ, reducing reliance on ground-based analysis and alleviating pressures on limited downlink capacity. Initiatives highlight the breadth of applications: NASA's rovers employ AI-driven navigation and target recognition systems; the European Space Agency's Φ -Sat missions demonstrate the ability to filter out cloud-obscured imagery and detect critical events such as wildfires; and commercial actors such as Spire Global are incorporating AI to deliver near-real-time insights from Earth observation data.²

This is particularly relevant in view of significant **downlink bottlenecks** caused by both the limited bandwidth available and ground segment capacities. Earth Observation (EO) satellites send data to ground stations for processing, of which they are in view for only a few minutes per orbital pass. Radio frequency (RF) link technology used to downlink data only enables a transmission of around 60Mbps, while SAR platforms gather between 1-2Gb for each orbital pass.³ Although systems like the European Data Relay System (EDRS) can provide data relay services to LEO satellites for up to 1.8Gbit/s,⁴ when scaled up to constellations and considering technological progresses being made in sensors, data collection grows exponentially and only a very limited amount can therefore be effectively downlinked and used.⁵ Analysis regarding the 10K, hyperspectral frames captured by Landsat 8 estimates the ground segment to be only able to capture 2% of the total image data collected.⁶ While downlink is optimised via data prioritisation, platforms operating without in-orbit edge processing capabilities still transmit both high-value and low-value data. Figures for Landsat 8 reveal about a third of high-value data, with the rest being typically characterised by low-value data.⁷ Similarly, for Sentinel-2, only 28% of potentially observable flood events are indeed observed with the low percentage being attributed to cloud cover.⁸ In-orbit edge computing capabilities are thus used to reduce the pressure on downlink capacities through refined processing and selection of high-value data.

Remote storage in space refers to the creation of physically remote data storage solutions, such as on the Moon or in-orbit for added security or redundancy. Terrestrial storage solutions are quickly showing signs of struggle in keeping pace with the accelerated growth in global data creation. Estimates of global data creation are set to reach more than 400 zettabytes by 2028 (400 billion terabytes), and a recent Raconteur infographic asserts that 463 exabytes of data (463 million terabytes) will be generated every day over the next two years.^{9,10} Terrestrial storage infrastructure is struggling to keep up, as the demand for physical space and energy grows for companies managing petabytes of data daily. This shift to in-space remote storage not only offers a resilient, high-capacity solution capable of operating in extreme conditions but also

² Max Polyakov, AI in Space: Projects Currently under Development, August 2025. (Link)

³ Avalanche Technology. The Fluidity of Data in Space – Chapter 2: “Data Storage Needs Grow Astronomically in Orbit – Now what? You are going to use the power of the sun to Store the data?” (Link)

⁴ Calzolaio, F. Currelli, J. Duncan, A. Moorhouse, G. Perez, S. Voegt. EDRS-C – The second node of the European Data Relay System is in orbit. Acta Astronautica, December 2020. (Link)

⁵ Bradley Denby et al. “Kodan: Addressing the Computational Bottleneck in Space”. In Proceedings of the 28th ACM International Conference on Architectural Support for Programming Languages and Operating Systems, Volume 3 (ASPLOS '23), March 25–29, 2023, Vancouver, BC, Canada. ACM, New York, NY, USA. (Link)

⁶ Ibid.

⁷ Ibid.

⁸ A., Mondini, A. C., and Camici, S.: Effectiveness of Sentinel-1 and Sentinel-2 for flood detection assessment in Europe, Nat. Hazards Earth Syst. August 2022. (Link)

⁹ Statista. Data growth worldwide 2010-2028 (Link)

¹⁰ Recountour. A Day in Data (Link)

alleviates pressures tied to electricity use and real estate on Earth. With several initiatives underway, both established players and start-ups are actively exploring this opportunity.

Satellite network relay systems and telecommunication satellite constellations are considered out of scope for this report as they primarily address data transmission challenges rather than in-orbit processing or storage. Relay systems, such as EDRS, extend connectivity between satellites and ground stations, while large-scale telecommunication constellations focus on global internet coverage and bandwidth provision. Although both play an important role in mitigating downlink bottlenecks, their core function lies in enhancing communication pathways rather than enabling on-board computing, in-orbit processing, or data storage capabilities. Since the focus of this report is on in-space cloud computing and remote storage, i.e., where computational tasks and data management occur directly in orbit to reduce latency, optimise bandwidth usage, and expand capacity, transmission-focused infrastructures fall outside the defined scope of analysis.

1.1.1 Technical building blocks of SBDCs

To achieve viable SBDC, a reduction in costs and a number of technological developments of several key technical building blocks need to materialise, with the key technical building blocks presented below:

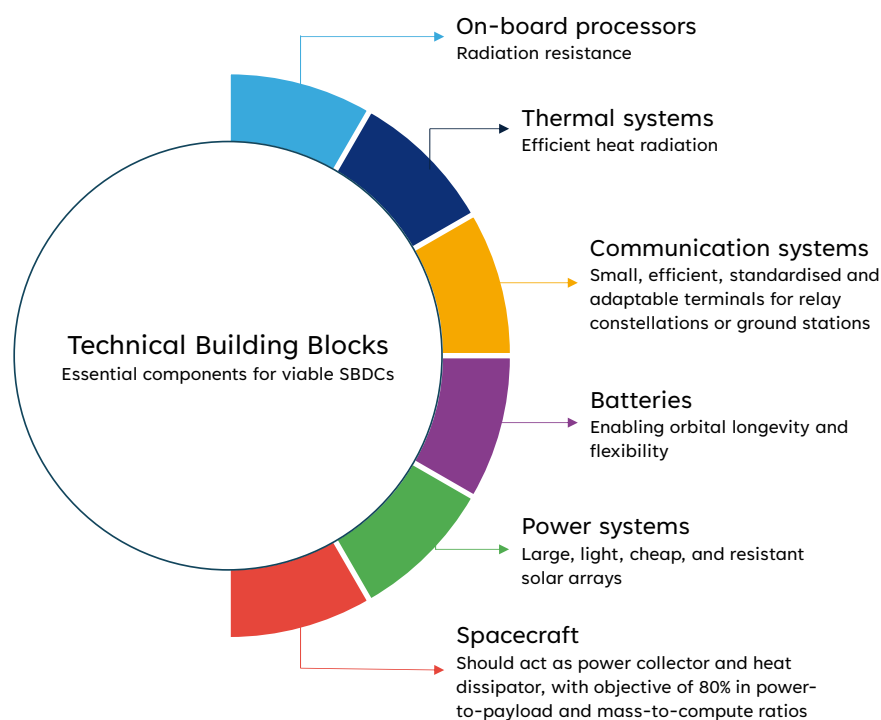


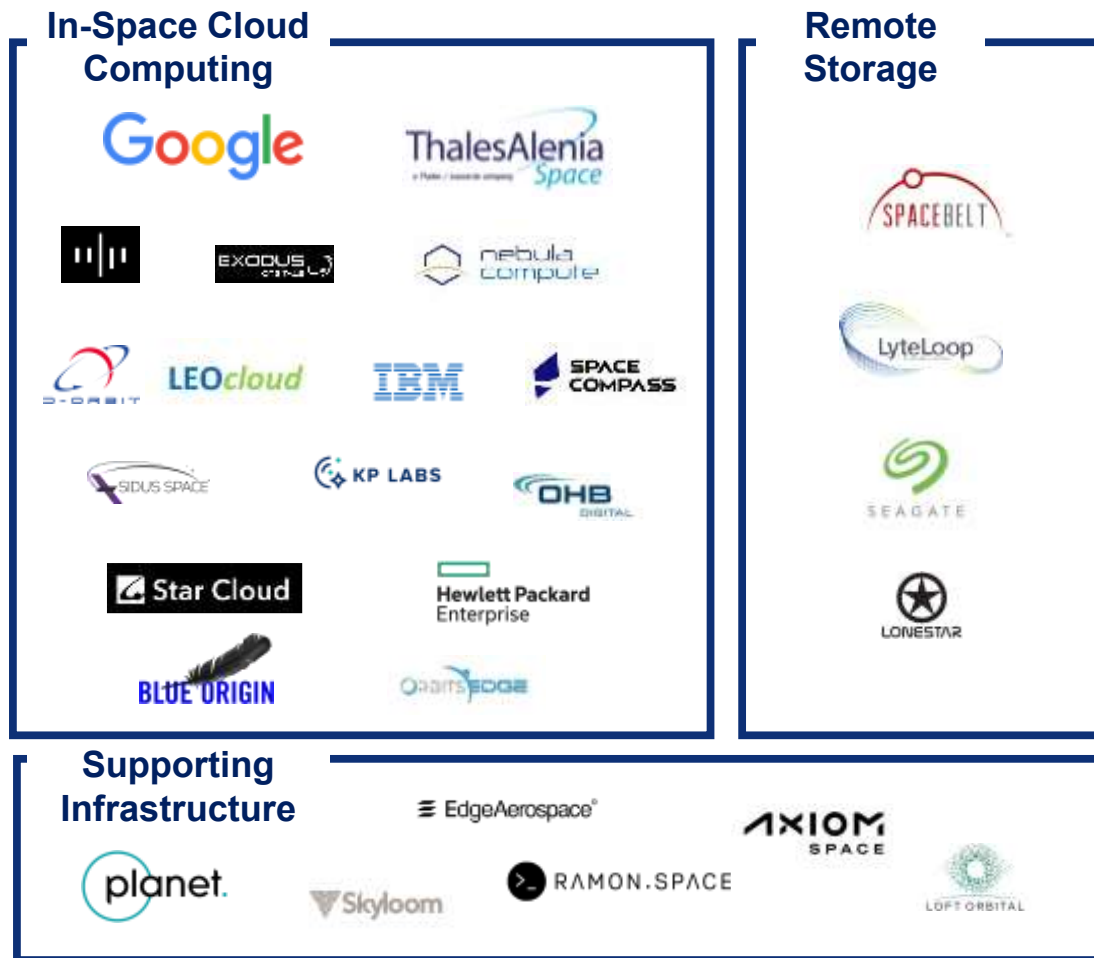
Figure 5: Technical building blocks necessary to the development of viable space-based data centres (Credit: Edge Aerospace)

Communication systems represent a significant hidden cost. As launch and infrastructure costs fall and considering the broader ecosystem SBDCs are to be embedded within, space-to-ground communications are to become more dominant in the equation.

Besides the necessary funding and technological developments, efforts towards SBDCs will have to grapple against the continued development of terrestrial data centre infrastructure in its own attempt to rein in costs. Nonetheless, capturing a mere 1% of the estimated €650 billion terrestrial data centre market would represent an attractive opportunity for the space sector.

2 The In-Space Computing & Storage Ecosystem

Recent years have witnessed the transition of SBDCs into an area of tangible industrial and programmatic development. This transformation is evidenced by a growing cohort of private companies supported by venture capital, partnerships with and among established aerospace and technology companies, and the initiation of state-backed programmes across North America, Europe, and Asia. This chapter attempts to provide a comprehensive review of the current SBDC landscape.



In-Space Cloud Computing includes satellite-as-a-service application hosting. Only companies in lead of projects are depicted. Non-exhaustive.

Figure 6: Private SBDC and cloud computing venture ecosystem map.

2.1 Publicly funded initiatives

Publicly funded developments form important testbeds for lower technology readiness level (TRL) technologies in the space while also linking to broader strategic policy considerations. In Europe for example, the ASCEND project is linked directly to the EU's Green Deal and digital sovereignty objectives. Across Europe, North America, and Asia, governments are funding missions that demonstrate the operational potential of high-performance edge processing in orbit or go as far as funding the development for precursors of large-scale orbital supercomputing capacity. Beyond AI applications in space (edge computing), this section highlights publicly funded space-based computing architecture that may one day form the backbone of national SBDC projects.

2.1.1 Europe

ASCEND or **Advanced Space Cloud for European Net zero emissions and Data sovereignty**, was a research project launched in 2023 funded by the European Union to the tune of €2 million under Horizon Europe. The consortium was led by **Thales Alenia Space** and comprised of major players in relevant domains: Carbone 4 and Vito for environmental analysis, Orange, CloudFerro, and HPE for data centres architecture and cloud computing, Airbus Defence and Space and DLR for space systems development, and ArianeGroup for launchers.

The goal of the proposed study is to demonstrate that placing future data centre capacity in orbit, using solar energy outside the Earth's atmosphere, will substantially lower the carbon footprint of digitalisation. Space data centres could therefore become an active contributor to the European Commission's (EC) Green Deal objective of carbon neutrality by 2050, which would justify the investment required to develop and install such a large space infrastructure system. Curbing the energy and environment impacts of data centres could kick-start major investments within the framework of the EU Green Deal, potentially justifying the development of a high-capacity, eco-designed and reusable launcher.

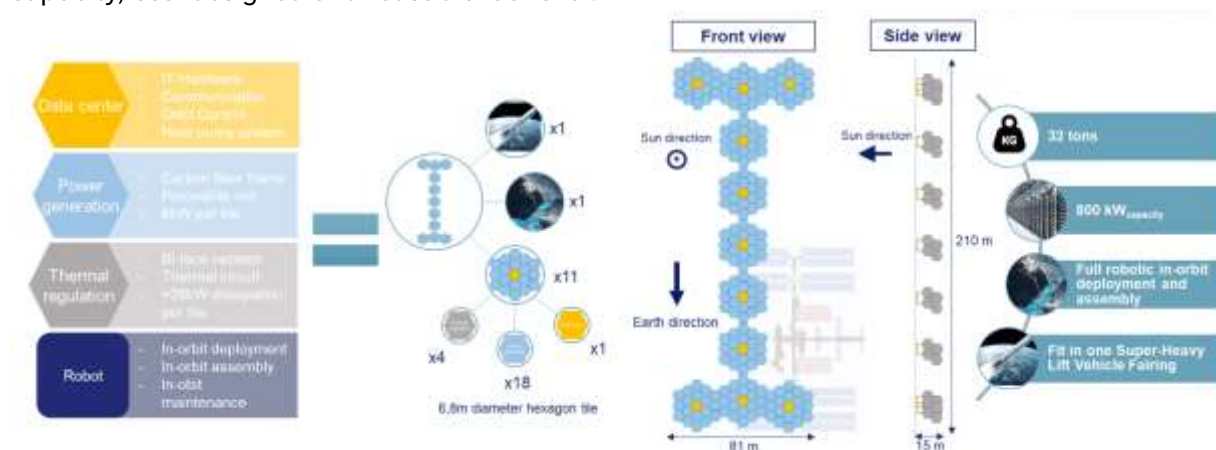


Figure 7: ASCEND Data Centre in Space architecture. (Source: ASCEND Cloud in Space)

The results of the study offer several insights: **The flagship endeavour**, apart from generating jobs and critical expertise in data centre domains, **could strengthen European digital sovereignty**, ensuring data security for European citizens and businesses. Contingent upon the development of a launch vehicle ten times less emissive over its entire lifecycle, deploying the infrastructure in space would also reduce the carbon footprint of the continent's data processing efforts. When considering the target of a 1GW deployment before 2050, ASCEND validates the project's economic viability and advances a return on investment of several billion euros by 2050. From a technical perspective, synergies have been found regarding the assembly of the infrastructure with the European Commission EROSS IOD (European Robotic Orbital Support Services In Orbit Demonstrator - also led by Thales Alenia Space), which will seek to demonstrate in-space servicing operations such as rendezvous, capture, or docking, and is planned for a first mission in 2026.¹¹

¹¹ ASCEND. Advance Space Cloud for European Net zero Emission and Data sovereignty. Horizon Europe, January 2023. (Link)

2.1.2 China

China is fielding a purpose-built, in-space computing network through **ADA Space's Star Compute programme**, whose first tranche of 12 AI computing satellites launched on May 14, 2025, aboard a Long March-2D from Jiuquan. The batch inaugurates the Three-Body Computing Constellation, a planned 2,800-satellite mesh that **shifts heavy processing from ground to orbit to cut downlink bottlenecks and latency**. Early specs published by the programme cite ~744 TOPS per satellite, ~5 POPs combined for the first cluster, optical inter-satellite laser links up to 100 Gbps, and ~30TB networked storage in this initial node.^{12,13} The architecture is explicitly framed as in-orbit “edge” supercomputing. Roadmap materials target ~1,000 POPs at full build-out.¹⁴



Figure 8: Logo of the launch mission (Source: Zhejiang Lab)

ADA Space (also known as Chengdu Guoxing Aerospace Technology Co., Ltd.) leads spacecraft design and integration and publicly unveiled Star Compute in late 2024; the May 2025 mission is designated “021” (“zero-to-one”), marking the programme’s operational start. Zhejiang Lab co-leads the constellation concept and in-orbit AI stack, describing the system as a thousand-satellite-scale space computing infrastructure. The latter is a research institute established jointly by the Zhejiang Provincial Government, Zhejiang University, and the Alibaba Group.

CASC provided the launch capability. Programme communications also reference support from regional innovation zones (e.g., Neijiang High-tech Zone) for industrialisation.

China’s approach emphasises on-board inference, filtering, compression, and cross-link aggregation so that only refined products are downlinked. The first satellites demonstrate laser cross-links to form an orbital compute mesh and carry a CAS National Astronomical Observatories/Guangxi University X-ray polarisation detector for rapid transient detection (e.g., GRBs), showcasing multi-mission, AI-assisted processing on orbit.¹⁵

2.1.3 United States of America

When it comes to high performance computing in space, the International Space Station in 2017 saw the arrival of the Spaceborne Computer-1 (SC-1). Designed by Hewlett Packard Enterprise (HPE) as an experiment with NASA, the edge computer’s hardware was unmodified and therefore publicly expected to run for about four days. It however performed for a year and a half, returning to Earth in June 2019, after having executed benchmark tasks, nominally recovered from anomalies, and opened way for **supercomputing operations aboard the Station**. The second iteration of the machine, Spaceborne Computer-2 (SC-2), arrived at the ISS and was set up in May 2021, boasting double the computing power, equipped with HPE’s Edgeline ruggedised system, and was successfully connected to Microsoft’s Azure cloud.¹⁶

¹² TOPS – Tera Operations Per Second i.e. trillions of operations of a system performed in one second. POPs – Point of Presence, refers to a physical location, or node, where two or more different networks or communication devices share a connection.

¹³ Wes Davis. China begins assembling its supercomputer in space. The Verge, May 2025. (Link)

¹⁴ Andrew Jones. China launches first of 2,800 satellites for AI space computing constellation. SpaceNews May 2025. (Link)

¹⁵ Ben Turner. China is building a constellation of AI supercomputers in space — and just launched the first pieces. Live Science, June 2025 (Link)

¹⁶ ISS National Laboratory. “New Technology Demonstration and Facility Installed on the Space Station to Enable Future Research.” (Link)

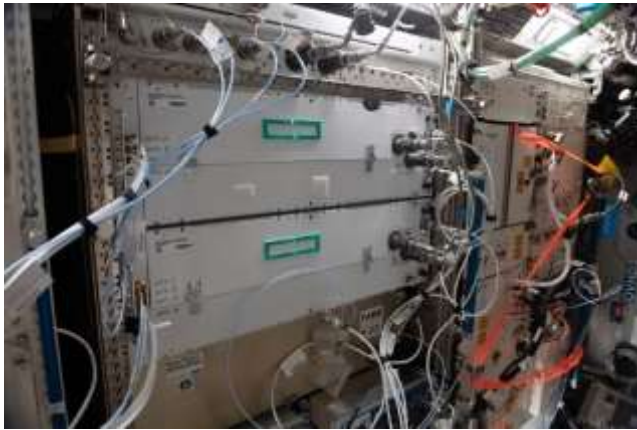


Figure 9: Hewlett Packard Enterprise's Spaceborne Computer-2 onboard the ISS. (Source: NASA)

Spaceborne Computer-2 is able to run machine learning models capable of swiftly processing images to identify, for instance, damage to astronaut equipment, or analyse experimental data, allowing to reduce the amount of information that needs to be transmitted back to Earth - a process that can take weeks or months, in the case of unprocessed gigabytes, due to limited bandwidth.¹⁷

Microsoft and NASA have conducted experiments using the HPE SC-2 and Azure cloud to sequence DNA data from astronauts' blood samples collected in the

ISS. It enables NASA to monitor the consequences of exposure to radiation on astronauts. Gene sequencing is generating a large amount of data that needs to be compared against a large database. HPE SC-2 is able to conduct in-orbit data processing of the gene sequences and only offload data containing anomalies or selected interesting bits to HPE ground station, which is then sent to Microsoft's Azure cloud.

¹⁷ Microsoft Azure. "Genomics testing on the ISS with HPE Spaceborne Computer-2 and Azure, 18 August 2021." (Link)

2.2 Private investment in SBDCs and in-space storage

In this section we examine the global investment landscape, highlighting the extent of venture capital and industrial engagement since 2020 by profiling leading privately funded initiatives. These include ambitious orbital infrastructure projects such as Starcloud's gigawatt-scale SBDC concept, lunar-based storage solutions pioneered by Lonestar Data Holdings and integrated in-space cloud services advanced by LEOcloud and OrbitsEdge. Larger industrial players, such as Axiom Space in partnership with AWS and Microsoft, and Space Compass in Japan, are also assessed for their role in bringing commercial credibility and scale to the sector. The chapter further outlines the contributions of enabling technology providers such as Skyloom, Ramon.Space, and Loft Orbital, whose innovations in optical communications, hardened computing hardware, and modular platforms can form key enablers for SBDC deployment.

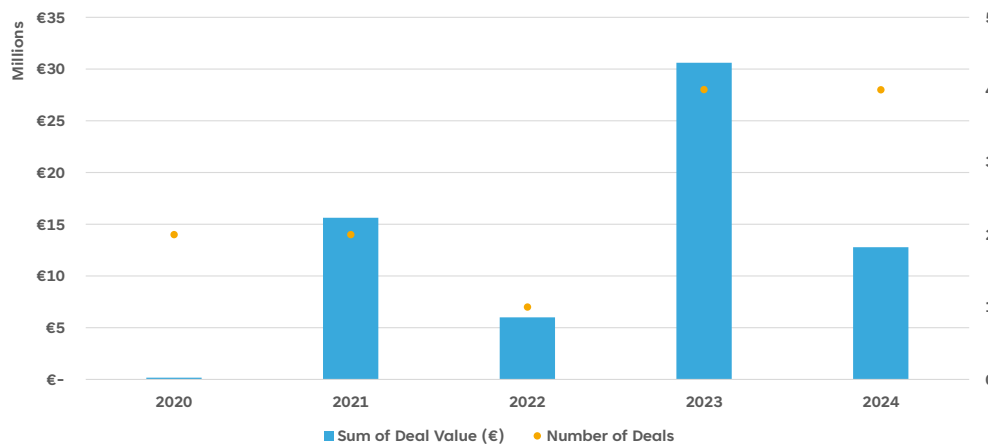


Figure 10: VC investments into pure-play SBDC ventures since 2020.

Since 2020, nearly €70 million in private capital has been invested into SBDCs across 13 deals, spiking in 2023 with €30 million raised for the year.¹⁸ Ramon.Space, StarCloud, and Lonestar constitute the top three companies that have raised capital to that purpose specifically.

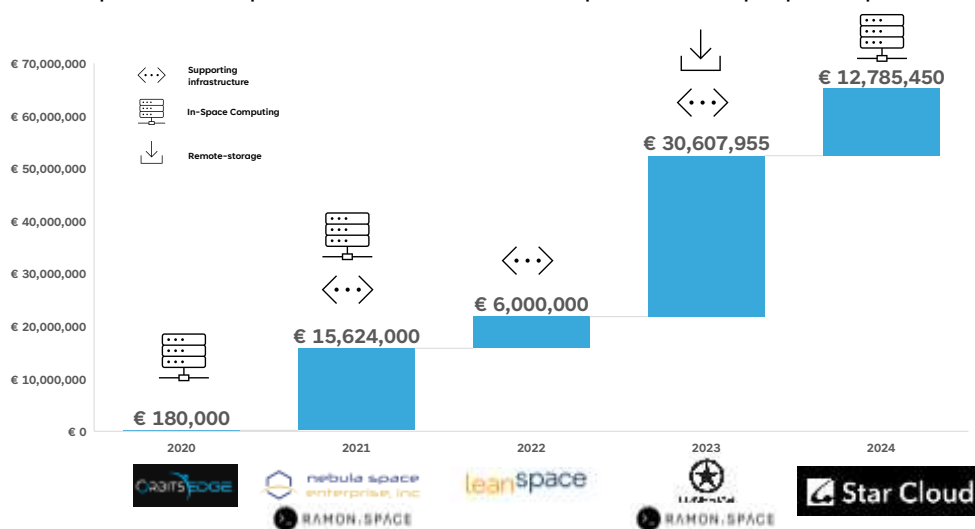


Figure 11: Top private VC deals in SBDCs since 2020

¹⁸ ESPI In-house Space Venture Database

2.2.1 Companies pursuing cloud computing in space

Almost 30 private companies are identified to pursue development into SBDCs primarily split between cloud computing services in space or ultra remote storage offerings. The U.S. invests almost 10x more private capital into SBDC initiatives than Europe. The following section highlights some private ventures looking into pure-play SBDCs or directly working with pure-SBDC ventures as a significant business line. The companies follow no particular order, and include both recent additions, as well as some companies who are by now largely inactive, but targeted the market over the past 5 years.

Starcloud

Starcloud, formerly Lumen Orbit, plans the deployment of a modular 5GW data centre to Sun-synchronous orbit (SSO), benefitting from uninterrupted solar power generation through a plane which remains perpendicular to the Sun's direction year-round and reduced material fatigue.¹⁹ The data centre would sit at the centre of a 4 × 4 km solar array made of low-cost silicon cells. A major challenge is array deployment and maintaining orientation of such a large structure. Thermal management is another significant challenge. Starcloud is designing giant deployable radiators designed to absorb heat waste away from the compute modules through cooling loops, dissipating gigawatts of thermal load. Starcloud aims at deploying a first commercial satellite, Starcloud-2, in SSO by 2027 pending on their demonstrator satellites, Lumen-1 is to be launched into LEO in 2025. Designed around a GPU cluster, it would



Company type

Startup, venture-capital backed

Funding to date

EUR 25.96 million

Challenges investigated

Deployable infrastructure, mega structures and robotic assembly, SSO thermal management, in-space maintenance

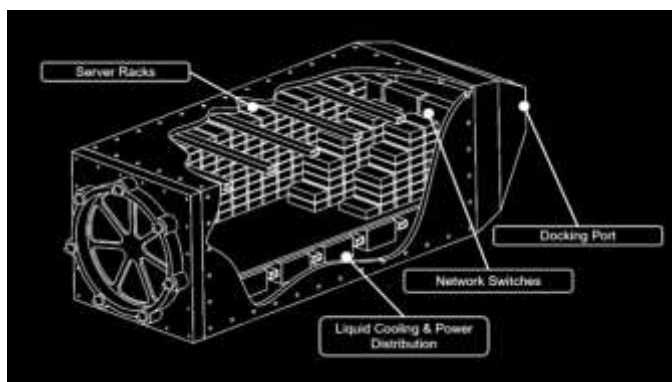


Figure 12: Starcloud compute container schematic. (Source: Starcloud)

enable heavy processing of space-based data before beaming back refined insights to Earth, therefore avoiding large, bandwidth-heavy transmissions. The startup signed a MoU in January 2025 with Archangel Lightworks, a company developing optical communication systems, to integrate their TERRA-M ground station with Starcloud's SBDC for rapid and enhanced processing and provision of EO insights.²⁰ Optical communication systems offer the

advantage of not being subject to regulation, as opposed to most traditional and restricted methods like radio spectrum. Starcloud also plans to mitigate impacts on astronomy by adhering to International Astronomical Union guidelines for Dark and Quiet Skies.

¹⁹ Starcloud. Why we should train AI in space - White Paper. September 2024 (Link)

²⁰ Archangel Lightworks. "Starcloud and Archangel Lightworks Sign MOU to Reshape Earth Observation with Space-Based Data Centres." January 2025 (Link)


Company type

Startup, venture-capital backed

Funding to date

EUR 0.18 million

Challenges investigated

Space radiation and thermal management, multi-orbit data transfer

OrbitsEdge

OrbitsEdge is exploring the deployment of a multi-orbit data centre constellation called Astraeus. The distributed architecture will see a small number of data centres in GEO store data acquired from a larger LEO constellation, which would also serve as a processing platform and low-latency relay for distribution back to Earth.²¹ OrbitsEdge's processing power relies on COTS components, HPE's EL8000 servers, with whom it signed an agreement in 2019,²² and which it encased in an in-house designed hardened satellite bus, SatFrame.²³ SatFrame also features the data centre's cooling system, built around a chassis and radiators and which enables protection against radiation.²⁴ Power is provided by

a large array of solar panels. OrbitEdge assumes however a different choice of orbit than SSO, which would see the structure pass in Earth's shadow, and therefore integrates a battery pack. The company hoped for an initial satellite in orbit by 2021, before contracting with Vaya Space in 2022 for the launch of the LEO segment by 2023.²⁵ As of May 2025 however, no launch has occurred, with the next scheduled flights aboard SpaceX Falcon 9 in early 2026.


Company type

Established, joint venture (NTT & Sky Perfect JSAT)

Funding to date

Undisclosed

Challenges investigated

Secure, high-bandwidth, low-latency transmission; line-of-sight downlink limitations

Space Compass

Space Compass was established as a joint venture between NTT and Sky Perfect JSAT to expand space-based ICT infrastructure. In April 2025, NTT and Microsoft claimed a 98% reduction in EO images transmitted were possible by leveraging AI processing to extract only the vessel information and delete unnecessary data. The space data centre business will aim to provide a high-capacity communication and computing processing infrastructure in space by steadily increasing the number of satellites equipped with advanced computing functions. The company has finalised a partnership with Skyloom to deliver a first GEO optical relay platform, SkyCompass-1, by 2025, which is to cover the Asia-Pacific region.²⁶

²¹ Ryan Morrison. "Data Centres in Space will Boost Satellite Computing Power and Storage" Techmonitor 3 July 2022 (Link)

²² OrbitsEdge. "OrbitsEdge OEM Agreement with Hewlett Packard Enterprise." 2019 (Link)

²³ OrbitsEdge. SatFrame™ 445 LE – An Overview. 2024 (Link)

²⁴ Ibid

²⁵ OrbitsEdge. "Vaya Space and Orbits Edge Enter Into Long-Term Launch Agreement." 2022 (Link)

²⁶ Space Compass. Space Compass and Skyloom Finalize Partnership to Bring Optical Data Relay Services to the Earth Observation Marke. Space Compass, January 2023. (Link)

LEOcloud

LEOcloud seeks to provide an integrated, end-to-end solution for space cloud services to private and public customers. It identifies barriers caused by the terrestrial exploitation of space-based data, which can potentially hinder technical research and the success of missions leveraging said data. Likewise, the sheer amount of unprocessed data being transmitted back to Earth limits one's ability to leverage information due to its limited shelf-life relevance. The startup provides little detail on its architecture but puts forward the use of a "scalable space-hardened micro datacentre" to offer a "seamless cloud presence between Earth and space" and allow hyperscalers to expand their services into orbit.²⁷ In 2021, LEOcloud signed several partnerships with Leaf Space, Exodus Orbital, and Ramon.Cloud, to accelerate development of the technology and look into deployment of hosted applications. In 2022, it announced cooperation with Axiom and Microsoft for installing infrastructure aboard Axiom's Station which would allow in-space deployment of the Azure Space's cloud computing platform. In May 2024, further progress provided the opportunity to install its Space Edge virtual data centre on the ISS by the end of 2025. On April 3, 2025, Voyager announced its intention to acquire the startup.²⁸



Company type

Startup, acquired

Funding to date

Acquired by Voyager in April 2025

Challenges investigated

Barriers caused by terrestrial exploitation of space data; short data shelf-life relevance; material hardening

mu Space Corp

mu Space Corp is developing its Space Internet Data Centre (Space IDC) infrastructure, made up of "modified server computers and communication systems"²⁹ targeting both Earth-orbit and surface applications. Notably, looking into material endurance, the company undertook a strength resistance test using a projectile with a speed matching that of a space debris.³⁰ The launch was meant to occur in 2022. The same year, mu Space Corp signed an MoU with Cloud Constellation Corporation to supply small satellites enabling the latter's project SpaceBelt of data storage in space.³¹



Company type

Startup, venture-capital backed

Funding to date

EUR 35.07 million

Challenges investigated

Material resistance

²⁷ LEOcloud. Our Value. (Link)

²⁸ Debra Werner. "Voyager Technologies to acquire LEOcloud". SpaceNews, 3 April 2025 (Link)

²⁹ mu Space. Space Internet Data Center (Link)

³⁰ mu Space. mu Space uncovered plan to push Thai technology into space industry. September 2020 (Link)

³¹ mu Space. Mu. "Space and SpaceBelt have signed an MoU and together developing the proof of concept and constellation system for SpaceBelt's Data Security-as-a-Service." September 2022 (Link)

	
Company type	Startup
Funding to date	EUR 1.7 million
Challenges investigated	On-orbit computing cyber security

Nebula Compute

Nebula Compute is developing space-based cloud computing platforms called ServerSats to support government, blockchain, and cyber use cases. Set to launch in 2027, the data centres will leverage the vacuum of space for cooling and use solar and nuclear for powering. AI and machine learning algorithms will be integrated to allow pre-processing and enable faster insight acquisition for customers by reducing reliance on terrestrial centres.³² In 2023, Nebula secured a Phase Two contract from the U.S. Air Force innovation arm (AFWERX) to advance security-relevant on-orbit computing for the future Space Force architecture.³³ No details on ServerSats' readiness progresses could be found.

	
Company type	Startup, venture-capital backed
Funding to date	EUR 2.71 million
Challenges investigated	Data processing latency

Sophia Space

Sophia Space recently emerged from stealth in 2025. The company's modular TILE platform (1m x1m x1cm) is designed to enable data processing, AI acceleration, and edge computing for satellites, defence systems, and commercial space stations. The solid-state, self-sustaining computing modules include a radiation tolerant integrated back panel and radiator panel exposed to space enabling cooling, as well as integrated solar power, without affecting the motherships power or thermal allocations. The offering is vendor agnostic and envisioned to be "tacked-on" to existing and upcoming satellite buses.³⁴



Figure 13: A rendering of an orbital data centre and TILE platform from Sophia Space. (Source: Sophia Space).

³² Nebula Media. Space Without Limits: Your Place in Space. September 2022 (Link)

³³ Newswire. "Nebula Compute Awarded Space Force Contract for On-Orbit Computing Capabilities in Space Force Architecture." November 2023 (Link)

³⁴ Sophia Space. (Link)

2.2.2 Companies pursuing remote storage

These ventures pursue the development of ultra-remote secure storage solutions in orbit or on the Moon.

Lonestar Data Holdings

Lonestar Data Holdings aims at establishing the first data centre on the Moon, leveraging its environment to use it as a platform for secure and critical data infrastructure. The successful demonstration of their Independence virtual data centre payload in February 2024 marked a breakthrough, showcasing operation and data retrieval from both Cislunar space and the Lunar surface. The forthcoming Freedom Payload, anticipated as the first physical data centre on the Moon, seeks to redefine disaster recovery and data processing capabilities in space. According to the company's press release, this represents the first purpose-built data centre off planet. The Freedom Payload carries 8TB worth of



Figure 14: *Odyssey lander in orbit above the moon with the Lonestar Independence payload aboard.*
(Source: Intuitive Machines)

Institute, and also material resistance tasks regarding power, temperature, and CPU management.³⁶



Company type

Startup, venture-capital backed

Funding to date

EUR 5.87 million

Challenges investigated

Space hardening, error correction, ultra remote storage and retrieval, data recovery

powered by a RISC V processor from Microchip, running a specialised version of Linux. The integrated system was thus delivered to Intuitive Machines at their Houston facility in December 2023 after having undergone and passed a series of rigorous space flight qualification tests. Following the off-site landing and subsequent tumble of IM-2 Athena on March 6, 2025, Lonestar reported that its data centre was the sole surviving payload and is therefore expected to report on progress made.³⁵ The voyage itself allowed the testing of key technologies such as file downloads and uploads, processing tasks for customers like Valkyrie AI and the Exploration

³⁵ Ryan Burkett. "Lunar data center intact despite lunar lander's botched landing, St. Pete company says" FOX 13 Tampa Bay, March 2025 (Link)

³⁶ PRNewswire. "Lunar Data Center Achieves First Success En Route To The Moon" March 2025, (Link)

	
Company type	Startup
Funding to date	EUR 4.5 million
Challenges investigated	Data vulnerability, fast data retrieval

Cloud Constellation Corporation

Cloud Constellation Corporation is developing SpaceBelt, a LEO, high-speed “global cloud storage network of 10 space-based data centres.” By storing and “isolating” data in space, the company seeks to ensure data integrity for organisations, hence achieving the “ultimate air gap security” and coining their “Data Security as a Service”.³⁷ To provide the service, SpaceBelt hopes to leverage a complete architecture to offer secure storage and global connectivity, with ground-based secure terminals, GEO spacecraft for global coverage, and the aforementioned LEO satellites for fast data retrieval. Cloud Constellation Corporation was in talks for a €72 million Series B round, led by HCH

Group from Hong Kong but ultimately cancelled.³⁸ It also tied several partnerships in the last months of 2020, including with Australia-based cybersecurity technology developer Red Piranha, Singapore Space and Technology, or Fintech-solutions provider MindCraft, but has gone silent since.

	
Company type	Startup
Funding to date	EUR 33 million
Challenges investigated	Mass to orbit, photon-based storage

LyteLoop

LyteLoop offers a model where “data storing is technically always in transit between satellites”, through ultra-high bandwidth lasers that allow data to move in an endless circulating loop, helping to increase performance and utilisation and reducing the total cost of ownership by taking up less space and using less electricity. In 2021, the team was expanded to tackle the last remaining challenges on the patented photonic method of data storage and bring it to the market within the next three years. However, as of today, three years later, the company’s website and LinkedIn profile are no longer accessible.

³⁷ Cloud Constellation. Cloud Constellation Corporation's SpaceBelt. (Link)

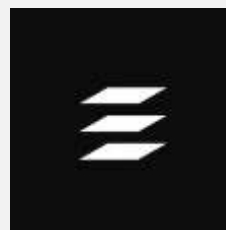
³⁸ Caleb Henry. Why Cloud Constellation turned down \$100 million. SpaceNews. November 2019 (Link)

2.2.3 Supporting infrastructure providers

Tangential to the scope of the report but no less vital, these ventures are partners in the development of SBDC and Remote storage infrastructure. They provide the more foundational aspects to ensure an SBDC future is achievable.

Edge Aerospace

Edge Aerospace is a startup currently transitioning out of stealth and developing high-performance space computers for satellites and spacecraft. The company leverages commercial-off-the-shelf CPUs and GPUs, enhanced with advanced fault-tolerance and recovery mechanisms to mitigate radiation-induced errors, eliminating the need for costly radiation-hardened hardware. Edge Aerospace's computers run edge AI directly on satellites, enabling real-time data processing and autonomy in orbit. The company has successfully tested its first models in space-like environments and is preparing to launch its inaugural flight units in 2026. Today, Edge Aerospace is focused on the first critical step on the path to SBDCs: developing affordable, on-board computers and communication systems that can be scaled while maintaining the hardware, software, and cybersecurity reliability expected in both spacecraft and Tier IV data centres.

**Company type**

Startup

Funding to date

Undisclosed

Challenges investigated

Radiation-tolerant computing

Axiom Space

As part of the development of their commercial space station, the company has partnered with AWS in April 2022 to launch and install an AWS Snowcone computer on the ISS. The objective of what Axiom calls a “first tranche of orbital data centre capability” (ODC T1) is to provide a degree of “Earth independence”, where collected data could directly be processed aboard the Station. Ultimately, the technology is envisioned to enable rapid feedback on microgravity scientific research and management applications for the company's customers. A latest partnership was announced in March 2025 with Red Hat, a provider of open-source solutions.³⁹ The collaboration saw success with Red Hat Device Edge, a platform enabling edge computing on resource-constrained devices, power Axiom's Data Centre Unit-1, launched to the ISS in spring 2025.

**Company type**

Scaleup, venture-capital backed

Funding to date

EUR 500 million

Challenges investigated

Orbital station; high-bandwidth transmission

³⁹ Axiom Space. “Red Hat Teams Up with Axiom Space to Launch, Optimize the Space Company's Data Center Unit-1 On Orbit.” March 2025 (Link)

Company type	Startup, venture-capital backed
Funding to date	EUR 27.3 million
Challenges investigated	Optical inter-satellite data links

Skyloom

Skyloom is designing an optical, laser-based network to allow data transport in space. The company's architecture is structured around four pivots and products. First, an inter-satellite link, "V'GER", will allow high-bandwidth, 1-10 Gbps LEO to LEO communications, but also LEO to ground, airborne, and maritime. Then, "SCOTTY", a user terminal, will allow third-party connections from LEO satellites to Skyloom's GEO relay satellites. The use of a GEO node permits to bypass rapid orbits of LEO satellites, which lead to reduced communication windows with Earth and prevent LEO satellites from offloading data. These GEO satellites, "UHURA", orbit at a speed matching

Earth's and therefore allow a constant connection to ground stations. Finally, another terminal, "KIRK", designed for low-cost and easy integration to existing ground stations, allows data retrieval. The integrated architecture is built on an all-optical communication chain, promising high-capacity data transfer – notably putting a stop to traditional GEO offload latency, with download speeds of 20 Gbps - and increased security over RF terminals. Skyloom entered into a joint venture with Italy-based Officina Stellare, a manufacturer of mechanical optics, to set up a factory in northern Italy and get access to the European market.

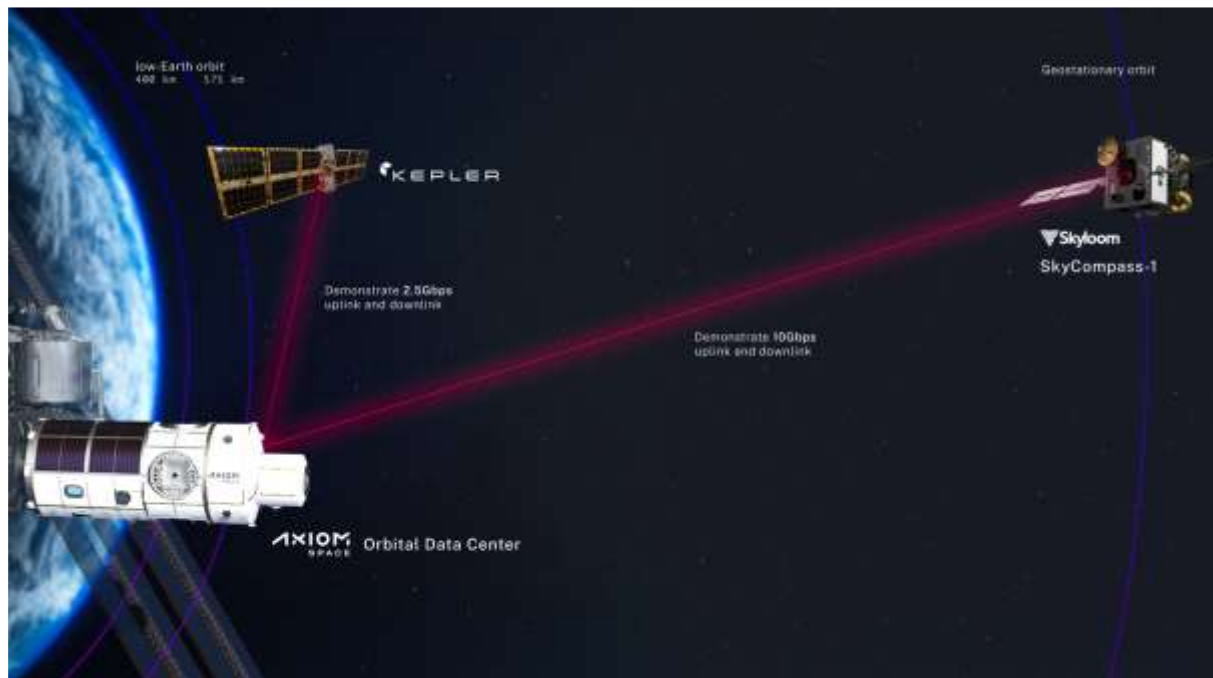


Figure 15: Axiom render of its ODC-T1 interaction with partners in orbit. (Source: Axiom Space)

Ramon.Space

Ramon.Space designs space-resilient computing hardware through three products: NuStream, a 1TB, radiation-hardened storage drive; NuPod, a hardened computing system allowing data processing; and NuComm, a hardened communications processor. These solutions integrate AI and ML algorithms and permit third-party software integration, as well as “autonomous operations and onboard analytics” for EO, IoT and remote sensing applications. The company boasts over 50 space missions and hundreds of “compute units” in orbit.⁴⁰



RAMON.SPACE

Company type

Startup, venture-capital backed

Funding to date

EUR 40 million

Challenges investigated

Hardened components; SWaP optimising

Loft Orbital

Loft Orbital develops hardware and software “abstraction layers” on COTS buses which allows for easy customers’ systems integration. The company is also expanding towards virtual missions, where a customer can deploy its software onto Loft’s platform to leverage its onboard subsystems and payloads. This was exemplified with YAM-6, a satellite launched in March 2024 which enables real-time data processing through edge computing and Microsoft’s Azure Orbital framework, therefore reducing reliance on ground stations.⁴¹ A year later, Loft Orbital deployed YAM-8, introducing its new Longbow platform of increased SWaP, offering more capacity to run AI applications and “collect and process data at scale”.⁴² The company teamed up with Little Place Labs in 2024 to advance near real-time space analytics by integrating edge computing and low-latency operations into its satellite infrastructure. It also joined forces in 2025 with Helsing to develop Europe’s first AI-driven multi-sensor satellite constellation for defence, designed to deliver real-time intelligence and situational awareness.⁴³ Set to launch in 2026, this constellation will operate in LEO, enhancing real-time data processing and transmission through cloud computing.⁴⁴



Company type

Startup, venture-capital backed

Funding to date

EUR 302.82 million

Challenges investigated

Material resistance

⁴⁰ Ramon.Space (Link)

⁴¹ Leandre Berstein. “Loft Orbital Brings Software Developers to Space with Virtual Satellite Missions”. Kratos Defence, 13 December 2023 (Link); Loft Orbital. YAM-6: The Rise of the Virtual Missions. November 2023 (Link).

⁴² Loft Orbital. YAM-8: Entering the Longbow Era. February 2025 (Link)

⁴³ Loft Orbital. Helsing and Loft Orbital Join Forces to Deploy Europe’s First AI-Powered Multi-Sensor Satellite Constellation for Governmental, Defence and Security Applications. Loft Orbital, 10 February 2025 (Link)

⁴⁴ Ibid.



2.2.4 Other notable experiments and industrial partnerships for edge computing in space

The following are industry partnerships and public-private partnerships that further demonstrate progress on computing in space developments.

ESA, KP Labs, OpenCosmos, TAS: Φ -Sat-2

ESA in cooperation with Open Cosmos as the prime contractor, supported by an industrial consortium including CGI, Simera, Ubotica, CEiiA, GEO-K and KP Labs, Thales Alenia Space and Microsoft, implemented a project under ESA's Φ -lab that seeks to enhance satellite autonomy through AI. Named **Cognitive Cloud Computing in Space (3CS)**, it focuses on enabling on-board data processing capabilities that reduce reliance on extensive downlinks of unprocessed data, thereby alleviating bandwidth constraints and shortening the latency between observation and analysis. As the next step, ESA's **Φ -sat-2 satellite**, a 6U Cubesat designed and developed by OpenCosmos, launched in August of 2024 and provided a platform for the in-flight uploading, deployment, and updating of third-party ML models.⁴⁵ The onboard AI capabilities include selecting images with clear visibility, while discarding images obscured by cloud cover.⁴⁶

NASA, various

NASA sports a diverse portfolio of edge computing initiatives, with over two dozen AI projects aimed at enhancing autonomy, efficiency, and scientific return in space missions. These range from rover-based systems such as AEGIS, which autonomously selects scientific targets, and Enhanced AutoNav, which enables the Perseverance rover to navigate using 3D terrain reconstruction. To MLNav and Terrain Relative Navigation, both of which employ on-board machine learning and computer vision for safe and efficient path planning. Mission planning and resource optimisation are supported by tools such as ASPEN and CLASP, while SensorWeb and SPOC exemplify the integration of AI into environmental monitoring and soil classification. NASA's collaborations with industry further extend its capabilities, with projects like Skyline Nav AI demonstrating GPS-independent navigation through advanced computer vision at the lunar surface.⁴⁷

Huawei: Sky Computing Constellation

As early as December 2021, Huawei announced that its first cloud-native satellite part of its "Sky Computing Constellation" initiative had been successfully placed into orbit and was operating stably. This satellite was designed to combine both edge and central cloud capabilities directly in space, enabling real-time AI inference, multitasking, and coordinated use of satellite and ground resources. According to test data, this architecture improved computational accuracy by over 50% and reduced the volume of downlinked data by about 90%, while shrinking analysis latency (for tasks like satellite imagery processing) from a typical ~1 day to ~1 hour.⁴⁸

Sidus Space

Recognising the growing demand for real-time insights from orbit, Sidus Space has developed and deployed the FeatherEdge GEN-2 on-orbit edge computer, now fully operational aboard its LizzieSat-3 satellite. Built around NVIDIA's Jetson Orin NX module, the system delivers up to 100 TOPS of AI inference in a compact, radiation-tolerant package designed specifically for low Earth orbit operations. Carol Craig, Founder and CEO of Sidus Space, noted: "By bringing high-

⁴⁵ ESA. "PhiSat-2 begins science phase for AI Earth images." July 2024. (Link)

⁴⁶ ESA. "ESA continues to explore the value of AI in space in partnership with Thales Alenia Space and Microsoft." ESA Phi-lab. (Link)

⁴⁷ Max Polyakov, AI in Space: Projects Currently under Development, August 2025. (Link)

⁴⁸ Amy Sarlar. Huawei Cloud gets world's first cloud native satellite with sky computing constellation in space. Huawei Central, December 2021 (Link).



performance AI to orbit, we reduce the need to downlink massive data sets, allowing customers to access processed, actionable information in near real time.”⁴⁹

The Edge Computing in Space Alliance

As early as 2021, several space start-ups and companies founded the “Edge Computing in Space Alliance”, which is a working group that aims at promoting edge computing in space, the Satellite-as-a-Service (SaaS) business model, as well as fostering cooperation between the IT and space sector. The Alliance gathers companies such as Exodus Orbitals, Orbital Transport, ModularitySpace, LEOcloud, Copernicus Space, EXO-Space, Orbits Edge, Skywatch, Spiral Blue, Deploy Solutions, Ramon.Space, KP Labs, Ibeos, Spacelinks, Little Place Labs, Zephyr Computing Systems, 3K SpaceTech, CySec, Pandio, Sfera Technologies, and Skudo.⁵⁰

Amazon, D-Orbit, and Unibap

In November 2022, Amazon Web Services, in partnership with Italian space logistics company D-Orbit and Swedish AI company Unibap, conducted a 10-months-long edge computing experiment in LEO.⁵¹ The experiment demonstrated how in-orbit processing can enable satellite operators to deal with high volumes of imagery and sensor data before delivering them to the cloud to customers. AWS integrated its suite of ML models and its IoT Greengrass software for imagery analysis and cloud management onto Unibap’s processing payload, which was then placed on D-Orbit’s ION spacecraft to conduct the experiment. AWS reported a 42% reduction in image size, resulting in faster processing rates and the possibility of real-time analysis.

D-Orbit and Planetek Group

On April 4, 2025, at Italy’s Ministry of Enterprises and Made in Italy, D-Orbit and Planetek Group announced a strategic business combination. While preserving their operational autonomy, the two companies will integrate their complementary strengths to develop cloud-based applications in space, AI-driven in-orbit data processing, and near-real-time data services. Planetek holds expertise in geospatial analytics and mission software. Their past collaboration includes the AI-eXpress mission, which leveraged artificial intelligence and blockchain to enhance satellite autonomy and data security, enabling low-latency analytics transmitted directly from orbit.⁵²

Palantir and Satellogic

In April 2022, U.S. data analytics company Palantir partnered with Uruguayan space company Satellogic to integrate the latter’s NewSat platform with Palantir’s Edge AI technology.⁵³ The mission sought to test in-orbit imagery processing in-orbit, and in fine “separating signal from noise in high-scale data” to avoid saturating the bandwidth and enable real-time insights acquisition. Palantir’s software was optimised for NVIDIA’s Jetson Platform, which powers Satellogic payload system, and communication was established through Satellogic’s ground station network. Novel solutions to identified challenges and proved capabilities across Edge AI’s deployment consisted of image pre-processing to improve model accuracy, fault tolerance design to achieve better data reliability, AI integration with multiple third-party models to improve adaptability, in-orbit upgrade to enhance onboard AI capabilities, and cryptographic mechanisms to augment data validation. Several AI models were eventually successfully deployed, capable of identifying vehicles, buildings, clouds, or

⁴⁹ Sidus Space. Sidus Space Announces Successful On-Orbit Operation of FeatherEdge™ Gen-2 Aboard LizzieSat@-3. Press Release May 2025 (Link)

⁵⁰ Spacequip. “Edge Computing in Space Alliance is Launched!” November 2021. (Link)

⁵¹ AWS. AWS successfully runs AWS compute and machine learning services on an orbiting satellite in a first-of-its kind space experiment, November 2022. (Link)

⁵² Emilio Cozzi. “D-Orbit and Planetek Group announce a strategic business combination.” Wired. April 2025. (Link)

⁵³ Palantir Blog. Palantir Edge AI in Space, April 2022. (Link)



terrain types, and were able to run sequentially, then processed, to generate precise outputs of the objects of interest to be downlinked.

IBM, Red Hat Technology, and EnduroSat

In May 2022, American cloud services providers IBM and Red Hat Technology integrated EO and computing payloads onto EnduroSat's NanoSat. Running on IBM's "Endurance" project, the experiment is designed to allow developers and students to host and access data from NanoSat's sensors, and, by bringing processing closer to collection, saving time and bandwidth.

Seagate and Ball Aerospace

Recognising the need for robust, space-ready storage solutions, Seagate and Ball Aerospace have signed an MoU to research the development of high-capacity data processing and storage devices suitable for space environments, with a focus on LEO satellite systems applications. Plans are underway to conduct testing of Seagate's technology aboard a Ball-engineered payload. Mike Gazarik, VP Engineering at Ball Aerospace, said in a statement: "There is a need for on-orbit, high-density storage capabilities to meet new mission requirements – in essence space-ready storage that works and acts like terrestrial storage. Therefore, we decided to collaborate on a proof-of-concept solution".⁵⁴ Devices of today are either performant but fragile, designed for terrestrial applications, or hardened, space-specific, but slow and expensive. Seagate is therefore seeking to design devices that offer both state-of-the-art performances (or close to) and whose manufacturing lay on off-the-shelf, commercially available components. The balance found consists in the use of hardened components solely "where critical or inexpensive" and turn towards "error detection and mitigation techniques" to prevent radiation damages on the other parts of the device.⁵⁵

⁵⁴ Space Foundation. "Ball Aerospace and Seagate to Collaborate on Data Storage in Space." July 2022 (Link)

⁵⁵ Seagate. Space-Ready Data Storage Requires Next-Level Innovation. (Link)



3 Three Factors Driving SBDC Development

SBDC developments are a consequence of the convergence of three major drivers: economic, environmental, and sovereign. Each dimension lays out challenges experienced by the data centre market for which SBDCs may provide added value and a suitable alternative destination.

The expansion of SBDC activities must be understood against the tremendous rise in global data generation and growing demand for data processing. By 2028, total data production is forecast to exceed 400 zettabytes, further accelerated by AI, IoT, and EO applications.

Space offers enticing advantages. The continuous availability of solar energy coupled with the ability to process and filter data at source and away from earthly troubles, presents a pathway to both sustainable and resilient infrastructure. As former Google CEO Eric Schmidt warned in testimony before the U.S. Congress, *“an additional 67 gigawatts of new power generation will be needed for terrestrial data centres by 2030 - equivalent to 67 nuclear plants.”*⁵⁶

An estimated 92 % of data produced in the Western world is currently stored in the USA and only 4 % in Europe. Meanwhile European cloud infrastructure companies make up just 15 percent of the intra-European market.

European Parliamentary Research Service, July 2020 & Synergy Research Group, July 2025

Beyond economics and sustainability, sovereignty considerations add further momentum. In Europe, the dependence on AWS, Azure, and GCP is estimated at over 70%. This discrepancy between high market dependency and the political striving for digital sovereignty represents a central area of tension. Governments and regions, particularly the European Union, increasingly regard cloud and compute capacity as strategic infrastructure subject to regulatory and geopolitical imperatives. Frameworks such as the GDPR, Data Act, and upcoming sovereign connectivity initiatives like IRIS² underscore the desire to secure sensitive data flows under domestic or regional control. Space-based infrastructure presents an extension of sovereign networks offering resilience, trusted connectivity, and sealed environments for critical workloads.

Together, these economic, environmental, and sovereignty drivers are pushing towards a reality in which orbital data centres become integral to the global digital ecosystem.

3.1 Economic: Global surge in data generation and demand

The global data economy is entering a phase of rapid expansion, with creation and processing needs growing at unprecedented rates. Terrestrial data centres and AI workloads dominate current investment, while advances in Earth observation and non-terrestrial networks are also accelerating space-based data generation, significantly increasing the operational costs of space missions.

On Earth, cost pressures tied to energy, real estate, and infrastructure are reshaping the economics of data management on Earth. At the same time, falling launch costs and breakthroughs in reusable rockets may be opening the door for space-based data centres to become a viable complement to terrestrial infrastructure in high-value markets.

⁵⁶ Full Committee: "Future of AI Technology, Human Discovery, and American Global Competitiveness" April 9, 2025 (Link)

Global data creation is expected to grow to more than 394 zettabytes between 2024 and 2028.⁵⁷ Between 2022 and 2024 alone, more data was produced than in all previous human history, with daily volumes surpassing 400 million terabytes. This relentless growth of the digital economy, increasingly driven by AI workloads, IoT proliferation, but also remote sensing data, is reshaping the economics of data infrastructure.

The global terrestrial data centre market in 2024 was valued at €323.25 billion, and expected to reach €534.70 billion in 2030, a CAGR of 8.75% across the period.⁵⁸ Investments into the sector are booming: in **2024**, Alphabet, Amazon and Microsoft have spent a combined **€154 billion in data centre infrastructure**, with the figure rising to **€397 billion** when accounting other players in the sector.⁵⁹ Despite initial reports of potential oversupply or of a “data centre bubble”, with Microsoft and Amazon cancelling or not renewing leases, others point more towards a recalibration following overcommitment, uncertainties surrounding tariffs, and the specificities of the market.⁶⁰ More recently, OpenAI reportedly plans to invest roughly **€340 billion to develop five new U.S. data centre sites**, with locations spread across Texas, New Mexico and Ohio. The expansion, in partnership with Oracle and Softbank, marks the biggest push yet to fulfil a pledge to spend half a trillion dollars on AI infrastructure in the United States. This comes after OpenAI struck a €85 billion deal with Nvidia in September 2025 to support data centres.⁶¹

Projections into 2030 shed light on the scale of investments necessary to keep up with data processing demand. Translating demand in GW capacity into capital expenditures, McKinsey expects **€5.7 trillion in investment worldwide needed by 2030**, depending on two premises holding: AI is widely adopted, leveraged, and transformed into added-values applications, and the pace of innovation cycles in the technology doesn’t slow down.⁶² The figure is mostly driven by AI workloads, which make up €4.4 trillion of the total alone.

Expert interview extract

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TBDCs means billions invested into new power sources and grid ameliorations. In addition to issues of cooling water, DC manufacturers are now worried about social impact as well. Hyperscalers have money to build what’s needed, also through solar, but will European states accept to see their grids tapped into? Prices are thus expected to rise rapidly in the next 10 years.

3.1.1 The strain on terrestrial data centres

The terrestrial data centre sector, valued at over €324 billion in 2024, is straining to keep pace. Projections suggest as much as €5.7 trillion in investment may be needed by 2030 to adequately keep up with growth.⁶³ Terrestrial data centres are becoming increasingly costly, however, with land, energy, and cooling requirements stretching grids and ecosystems to their limits. The average data centre has a size of over 9000 square meters, with China Telecom’s Inner Mongolia Information Park Data Centre being the world’s largest, at almost a million square meters. While IT hardware remains the biggest expense, real estate and energy are also major costs.

⁵⁷ Statista, & Various sources. (May 31, 2024). Volume of data/information created, captured, copied, and consumed worldwide from 2010 to 2023, with forecasts from 2024 to 2028 (in zettabytes) [Graph]. Statista, May 2024. (Link)

⁵⁸ Arizton. Investment Trends in Global Data Center Market 2025-2030 Arizton, May 2025. (Link)

⁵⁹ Kendrick Cai. Alphabet reaffirms \$75 billion spending plan in 2025 despite tariff turmoil. Reuters April 2025. (Link)

⁶⁰ Jackie Snow. AI data center race hits obstacles in power grid, land costs. Quartz, May 2028. (Link)

⁶¹ Bloomberg. OpenAI Expands Stargate With Five New Data Center Sites Across US. September 2025 (Link)

⁶² McKinsey. The cost of compute power: A \$7 trillion race. McKinsey Quarterly, April 2025. (Link)

⁶³ Ibid.

Recent years have seen delays and rising construction expenses due to low vacancy, labour shortages, and supply chain issues, reversing a two-decade trend of falling costs.⁶⁴ East Asia, Europe, and North America are the most expensive regions. Tokyo (€12.2/W) and Singapore (€11.7/W) top a 2024 cost index, constrained by limited land and power. In Europe, the FLAP (Frankfurt, London, Amsterdam, Paris) markets face competition from cities like Zurich, Helsinki, and Stockholm, offering cooler climates and renewable energy, appealing to sustainability-focused investors.⁶⁵

The increasing demand however leads to rising costs on top of local workforce issues. In North America, Northern Virginia and the Silicon Valley remain prime locations. The former hosts the world's largest concentration of data centres, including from companies like AWS or Equinix and has seen rental rates surging by almost 42% between 2023 and 2024, with power costs also rising by 21% year-on-year. Silicon Valley scores fourth in terms of cost, with €10.9 per Watt, and developable land availability being scarce, with reports indicating more than a decade waiting time.⁶⁶ Less-expensive rural areas have experienced heightened interest for relocation, although many require new fibre connectivity for AI training solutions and face workforce shortages.

3.1.2 Energy is a binding constraint

Data centres have a predicted energy consumption of 1000 TWh per year in 2026 up from the 460 TWh per year from 2022.⁶⁷ The growing consumption is fuelled by the ever-growing amount of data processed and stored. The development of new data centres is limited by grid build-out, congestion and interconnection issues resulting in fluctuating electricity costs in times of high demand. It is this **fluctuation in OPEX for which SBDCs could potentially play a strong role**, alleviating financial pain through more predictable running costs and uninterrupted power generation.

Adding to the shortage, approval processes for wind, solar, storage, and hydro-renewable projects now take more than four years on average, with project costs more than doubling since 2020. As a result, data centre pricing continues to rise. Following a projected 16% year-over-year

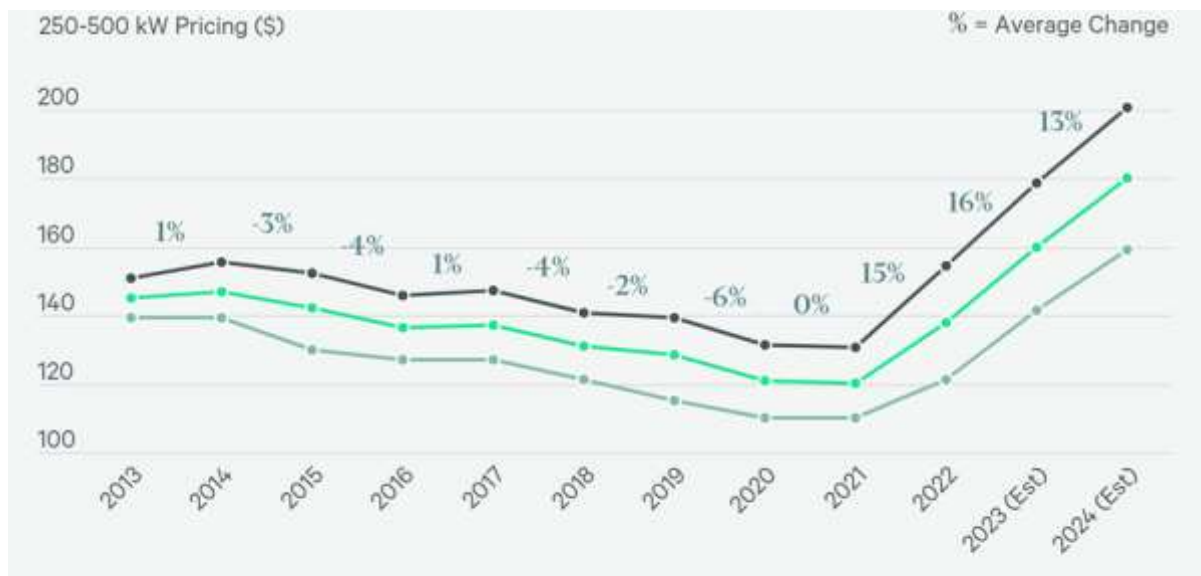


Figure 16: Average Asking Rental Rate with Y-o-Y % Change for Primary Markets. (Source: CBRE)

⁶⁴ Turner and Townsend. Data centre cost trends - Data centre cost index 2024 (Link)

⁶⁵ Enel X. Tight supply and Demand Drives New Demand Response Record in the Capacity Market. Press Release, December 2024 (Link)

⁶⁶ CBRE. Global Data Center Trends 2024 (Link)

⁶⁷ IEA. Electricity 2024 - Analysis and forecast to 2026. International Energy Agency, January 2024 (Link)



increase in pricing for 250-to-500-kW requirements in 2023, experts at CBRE reported another 10% to 15% pricing increase in 2024. According to CBRE, operators may be willing to lower pricing for legacy assets with vacancy, but this discount will not apply to AI workloads requiring high power density.

3.1.3 AI workloads are exerting immense pressure

Data centres serve as the critical infrastructure supporting the AI ecosystem. Global electricity use from data centres is projected to more than double between 2022 and 2026, with AI training and inference being far more energy-intensive than conventional cloud operations.⁶⁸ This escalation pressures energy infrastructure, leading to constrained supply (power lines, generation capacity) and even local issues like water consumption, siting conflicts, and higher electricity prices. Sam Altman, CEO at Open AI, points out that while improvements in hardware, automation, and production efficiencies will drive down many variable costs, the irreducible cost of electricity (and how clean or carbon-intensive that electricity is), will increasingly determine which companies or regions can lead in AI development. In November 2025, Google announced **Project Suncatcher**, a novel research initiative to one day scale machine learning in space using the ubiquitous power potential of the Sun.⁶⁹

Sam Altman, CEO at Open AI “

The cost of AI will converge to the cost of energy.

From an investment and policy perspective, energy infrastructure becomes as strategically critical as AI hardware or software. Energy cost volatility (fuel prices, carbon pricing, regulation) will increasingly translate into competitiveness in AI. Firms that can secure clean, reliable power at low marginal cost will have an edge. As such, the ubiquitous power generation potential offered by orbital infrastructure coupled with an AI use case provides an immense incentive for companies to pursue SBDC developments.

3.1.4 Increase of in-space data generation

About 1,000 active remote sensing satellites are currently in orbit, while Novaspace expects the launch of over 5400 new platforms between 2024 and 2033.⁷⁰ The increased abundance and accessibility of high-resolution, high-frequency data lowers entry barriers for downstream service providers and supports the development of new commercial applications across sectors. A study from the World Economic Forum and Deloitte assesses a potential €595 billion in value-added from Earth data by 2030, and €3.2 trillion in aggregated contribution to the global gross domestic product between 2023 and 2030.⁷¹

Expert interview extract

Even if no drop in launch cost is observed, there is still a reasonable size business [for in space computing]. Hundreds of millions of dollars of revenue.

The rise in commercial missions, and the growth of data generation through public programmes such as Landsat and Copernicus, in part driven by improvements in sensor technology, and an increased number of missions, however, also result in a significant increase in data-downlink,

⁶⁸ IEA. Data centres & networks. (Link)

⁶⁹ Google. “Meet Project Suncatcher, a research moonshot to scale machine learning compute in space.”. Google, November 4, 2025. (Link)

⁷⁰ Novaspace. Earth Observation satellites set to triple over the next decade. Novaspace, July 2024. (Link)

⁷¹ WEF. Amplifying the Global Value of Earth Observation. Insight Report, May 2024. (Link)

data processing, and data storage needs.⁷² A small Synthetic Aperture Radar (SAR) satellite as operated by ICEYE can collect over 1Gb per orbital pass and conduct 15 revolutions in a day.⁷³ Larger platforms, like the Sentinel-2 satellite, generate up to 2.5Tb of data every day. Onboard AI can address these bottlenecks by pre-processing data directly in space. For example, AI algorithms can filter noise from hyperspectral optical sensors, select in real time which images should be prioritised for downlinking, and enhance image resolution.⁷⁴ Finally, geospatial foundation models trained on satellite data are also being developed to analyse environmental risks in near real time, reducing the need for extensive data cleaning and labelling.⁷⁵

Looking towards the future, while the operational cost per managed data volume continues to decrease, the introduction of Copernicus expansion missions as well as the next generation missions will significantly increase the volume of data. For example, the ROSE-L mission will increase data generation 5-fold when compared to Sentinel-1. Computing a portion of this data in space offers enticing advantages.

3.1.5 A continue drop in launch costs may make hosting AI data centres competitive

The launch cost deflation over the past 50 years has significantly altered the economics of deploying large-scale infrastructure to orbit. While not yet a commodity today, access to space has historically been prohibitively expensive, limiting the deployment of large, mass-intensive systems to government programmes. From the 1960s through to the early 2000s, launch costs consistently exceeded \$10,000/kg.

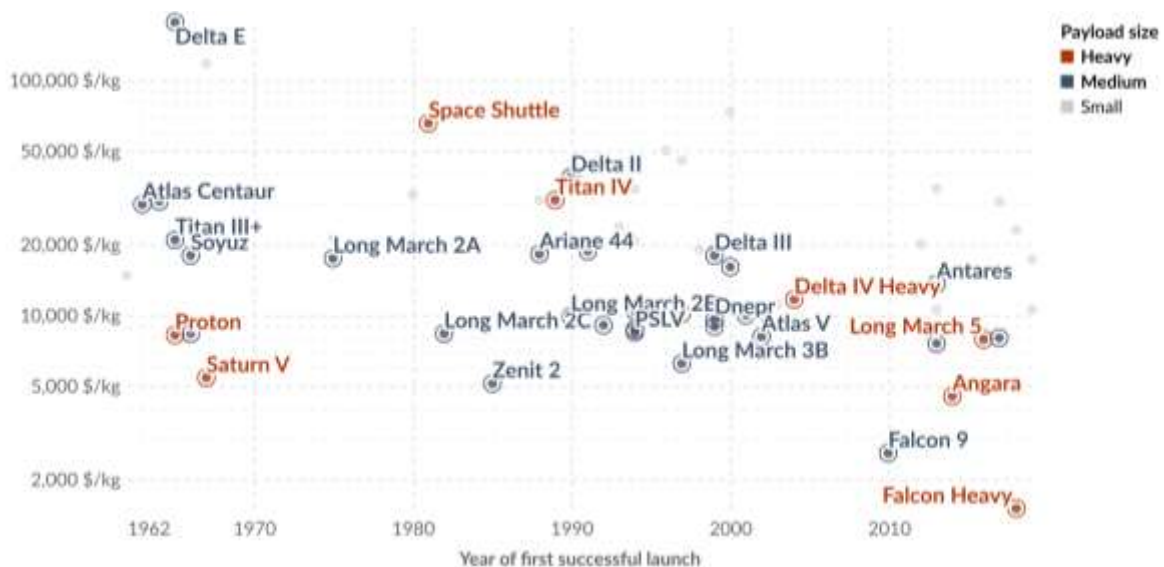


Figure 17: Launch cost per kilogram of payload (constant 2021 US\$). Note: Medium vehicles carry between 2,000-20,000kg to LEO and heavy ones >20,000kg. Small vehicles are not highlighted. (Source: CSIS Aerospace Security Project (2022))

The high costs were a consequence of low launch frequency, single-use vehicles, and a dominance of government-funding backed industry, with limited incentive to drive down costs. A

⁷² Michael A. Wulder, Jeffrey G. Masek, Warren B. Cohen, Thomas R. Loveland, Curtis E. Woodcock. *Opening the archive: How free data has enabled the science and monitoring promise of Landsat*. Remote Sensing of Environment, July 2012 (Link); Copernicus. Access to data. (Link); ESA, Copernicus Data and Information Access Services Operations, January 2017 (Link)

⁷³ ICEYE. SAR Product Guide. May 2021 (Link)

⁷⁴ See Chapter 2.2.4 for examples of AI projects in space.

⁷⁵ Sudmanns, M., Tiede, D., Lang, S., Bergstedt, H., Trost, G., Augustin, H., ... Blaschke, T. *Big Earth data: disruptive changes in Earth observation data management and analysis?* International Journal of Digital Earth, February 2019 (Link)

turning point occurred in the 2010s with the advent of commercial launch vehicles and reusable rocket technologies, led primarily by SpaceX and facilitated by NASA's procurement reform.

The Falcon 9 and Falcon Heavy reduced launch costs up to approximately \$2,500/kg and \$1,500/kg respectively. Though these priced to cost launches are primarily enjoyed by SpaceX's own Starlink payloads with average real prices currently to LEO for other customers between \$8,000/kg and \$15,000/kg and between \$30,000/kg and \$35,000/kg to GEO destinations. For

Expert interview extract

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A pivot to Starship will come, whose marginal costs is \$30/kg for 100 tons, but the question is how much of these savings goes to customers? The hope is that because they're building such gargantuan capacity, they will be incentivised to pass some of that through, driving high volume rather than having less frequent and therefore more expensive launches. Starlink is getting marginal costs, fuel, labour + upper stage = approx. \$10M, 100x times cheaper than ULA or Ariane.

European launchers, Arianespace hasn't publicly disclosed the cost for an Ariane 6 launch. However, the ESA's Acting Director of Space Transportation, Toni Tolker-Nielsen, said the Ariane 6 launch cost could fall in the range of €3,700/kg and €4700/kg, about 30-40% lower than the cost of an Ariane 5 and 50% higher than a F9 launch.⁷⁶

According to Citi Research, further declines are expected by 2040. Launch costs could fall as low as \$100/kg with projections supported by key drivers such as reusability of both rocket stages and payload fairings, as well as anticipated reductions in material and operational costs.

One of the main barriers to the deployment of SBDCs has traditionally been launch cost. A typical terrestrial data centre can weigh hundreds of tonnes once infrastructure and cooling systems are

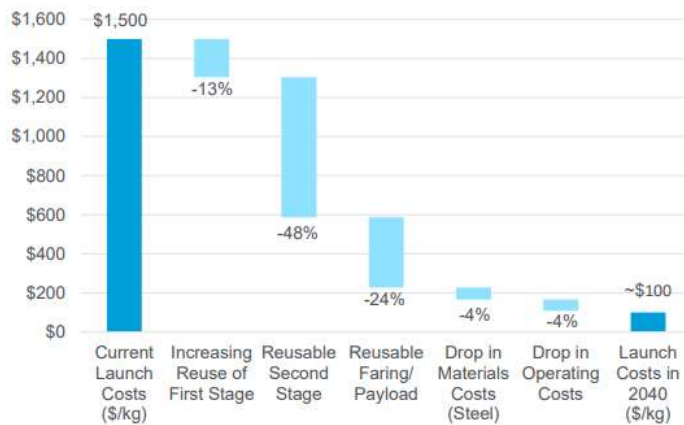


Figure 18: Drivers of forecast launch cost reduction by 2040. (Source: Citi Research)

included. At historical launch prices, even a 100-tonne orbital module would have cost over \$1 billion to launch. However, should launch costs ever fall as low as \$100/kg, the launch cost for such a module could be reduced to just \$10 million.⁷⁷ This cost shift fundamentally alters the economic equation for SBDCs, making them not only viable but competitive in certain high-value markets, such as defence, critical infrastructure, and ultra-low-latency financial services, when compared to Tier IV terrestrial data centres. See Annex A on the results of our cost

model for a comparison between SBDC and TDC costs.

⁷⁶ Speaking at the June Paris Air Show

⁷⁷ Citi GPS. Space – The Dawn of a New Age. Citi. May 2022. (Link)



3.2 Environmental: Increase scrutiny over terrestrial data centre resource use

Data centres affect environmental pollution in three dimensions: consumption of environmental resources, generation of waste and heat, and land utilisation. Locating these facilities outside Earth's biosphere would alleviate land and water consumption, as well as address the energy consumption related issues on national grids, contributing to a more sustainable digital infrastructure.

SES operations, particularly satellite ground stations and data centres, are energy intensive. Stakeholders, including customers, investors, and regulators, are increasingly scrutinising the carbon footprints of companies in the telecommunications sector. Failure to demonstrate a robust and transparent decarbonisation strategy aligned with science-based targets (“SBT”) could lead to potential reputational damage, lost contracts, and difficulty in attracting ESG-focused investors. **Emission from Operations – Extract from the SES 2024 Annual Report**

3.2.1 Energy use is increasing

Data centres and data transmission networks account for nearly 1% of energy-related greenhouse gas (GHG) emissions. To align with the Net Zero Emissions by 2050 Goals, these emissions need to be reduced by half by 2030. It is thus obvious; data centres present a significant hurdle for reducing emissions.⁷⁸

According to statistics from various sources including Cloudscene, Datacentermap and Statista, there are around 11,800 data centre locations as of March 2024.⁷⁹ In Germany for example, data centres are a significant component of the nation's energy landscape. According to the German Data centre Association (GDA), data centres in Germany account for approximately 2.7% of national electricity usage. The GDA highlights that as digitalisation and the demand for data services continue to expand, energy consumption by data centres is projected to increase, despite

Expert interview extract

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Changes in needs are too quick for the construction of TBDCs. Terrestrial power grids cannot support the growth, and some countries already limit data centre expansion.

improved efficiency. The association advocates for a dual approach: enhancing energy efficiency within data centres and increasing the use of renewable energy sources.⁸⁰

3.2.2 Cooling and byproducts

Data centres consume vast amounts of water primarily for cooling purposes. This substantial water usage intersects with broader global water issues. According to the United Nations, climate change exacerbates water scarcity and alters precipitation patterns, intensifying the hydrological cycle and leading to more frequent and severe droughts and floods.⁸¹ Reports from the Intergovernmental Panel on Climate Change (IPCC) and initiatives like the World Bank's Thirsty Energy highlight the critical need for sustainable water management in energy-intensive sectors like data centres. Despite the significant water usage, there is a notable lack of transparency in the industry regarding how much water data centres consume.

Tech giants such as Google, Amazon, and Microsoft are significant consumers of water for their expansive data centres. One example is Google's 2019 report, whereby its data centres consumed

⁷⁸Jacob Roundy. Assess the environmental impact of data centres. TechTarget, July 2023 (Link).

⁷⁹Brightlio. 255 Data Center Stats. September 2025 (Link)

⁸⁰German Datacenter Association. 2024 Data center impact report Deutschland. (Link)

⁸¹United Nations. Water – at the center of the climate crisis. Climate Action, 2025. (Link)



over 3.3 billion gallons of water.⁸² Techniques like water reuse and advanced water management can reduce consumption while building data centres in colder climates or even space could result in more efficient cooling systems. Improvements in efficiency are however on the way and might further reduce long-term water consumption. Microsoft's September 2025 development involves an advanced microfluidic cooling system that embeds liquid coolant directly into silicon chips, enhancing heat dissipation by up to three times compared to traditional cold plates.⁸³

For now, however, terrestrial data centres not only consume significant resources but also

Expert interview extract

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The digital economy has an emissions problem which is accelerated by huge amounts of data and AI. Data centres weren't thought to be a problem initially but with AI training it exploded. ADEME (French environmental agency) sees 30% of all European electricity needed for data centres.

generate various byproducts, contributing to global e-waste and environmental concerns. According to the United Nations Global E-waste Monitor, the rapid expansion of data centres is a substantial contributor to the growing volume of electronic waste which poses severe environmental and health risks.⁸⁴

3.2.3 For environmental purposes, relocation to orbit is already considered viable today

Locating computing capacity in orbit may offer a direct response to the environmental constraints of terrestrial data centres. Unlike Earth-based facilities, orbital platforms can harness uninterrupted solar radiation as a **renewable and predictable energy source**, bypassing reliance on strained terrestrial grids and reducing exposure to volatile electricity costs and carbon pricing regimes. Cooling as one of the largest resource burdens for data centres, responsible for billions of gallons of freshwater use annually, is managed through radiation into space, eliminating or reducing the sector's dependence on increasingly scarce water resources.

Christophe Valorge, Chief Technical Officer, Thales Alenia Space

“

The results of the ASCEND study confirm that deploying data centres in space could transform the European digital landscape, offering a more eco-friendly and sovereign solution for hosting and processing data. We're proud to be contributing to an initiative supporting Europe's net-zero objectives and strengthening its technological sovereignty.

Orbital deployment also alleviates land pressures, avoiding the need for massive industrial footprints that compete with housing, agriculture, and conservation priorities. Moreover, a monolithic space-based system, encourages modularity and reuse, supported by robotics and in-orbit servicing, reducing contributions to the growing global e-waste stream.

In pursuit of these advantages, in 2023, the European Union launched the **ASCEND** research project under Horizon Europe, with a €2 million budget and a consortium led by **Thales Alenia Space** alongside Airbus, ArianeGroup, Orange, CloudFerro, HPE, DLR, and others. The study demonstrates that orbital data centres powered by solar energy could significantly cut the carbon footprint of digitalisation, directly contributing to the EU Green Deal's 2050 carbon neutrality target. ASCEND also highlights potential economic returns in the billions of euros,

⁸² Water Footprint Calculator. Google Data Center Water Use in the US Revealed To Be a Lot. January 2023. (Link)

⁸³ Catherine Bolgar. AI chips are getting hotter. A microfluidics breakthrough goes straight to the silicon to cool up to three times better. Microsoft, September 2025 (Link)

⁸⁴ UNITAR. Global e-Waste Monitor 2024: Electronic Waste Rising Five Times Faster than Documented E-waste Recycling March 2024. (Link)



strengthens European digital sovereignty, and identifies synergies with in-orbit servicing programmes such as EROSS IOD, while also being in-line with future EU plans on ISOS.⁸⁵

3.3 Sovereign: Concerns around data location and control

Data sovereignty does not only refer to the idea that data is governed by the legal frameworks of the jurisdiction from which it originates; for the EU, “digital sovereignty” extends data protection laws to elements of control over data, operations, and the underlying technologies.

European policymakers increasingly frame cloud and compute as strategic infrastructure, noting both market-power risks (e.g., extraterritorial access under the U.S. CLOUD Act) and dependency on non-EU hyperscalers. This has led to calls for sovereign, cross-border infrastructure and a “cloud-edge continuum” built to European rules and operated by European players.

No European Data Sovereignty while U.S. Cloud Act exists with no U.S.-EU agreement

AWS, Microsoft Azure, and GCP at the end of 2023 and early 2025 controlled a share of around 66% to 70% of global sales in the cloud infrastructure market. In Europe, the dependence on those three cloud service providers is estimated at over 70%. This discrepancy between high market dependency and the political striving for digital sovereignty represents a central area of tension.⁸⁶

The CLOUD Act allows U.S. authorities to require disclosure of data even if the data is stored outside the U.S. That may conflict with the GDPR’s restrictions on transfer/disclosure to third countries. The EDPB stresses that the U.S. CLOUD Act “allows U.S. authorities to directly compel service providers subject to U.S. jurisdiction to disclose data, irrespective of where the data is stored,” creating a direct clash with EU rules. Under the GDPR, “any judgment of a court or tribunal and any decision of an administrative authority of a third country requiring [...] disclose personal data may only be recognised or enforceable if based on an international agreement” (Article 48). The EDPB and EDPS therefore warn that the CLOUD Act “circumvents the existing frameworks for international cooperation and **undermines the sovereignty of EU law** over personal data located within its territory.”⁸⁷

European Data Protection Board, July 2019

Initiatives exist to remedy the situation. The T-Systems-led 8ra (IPCEI) initiative envisions a multi-provider, open-standards “super cloud-edge continuum”, uniting hundreds of partners including SAP, Siemens, Bosch, Airbus, Orange, Telefónica and others, under European governance and open-source control. Targeting up to 10,000 interconnected edge-cloud nodes by 2030, potentially scaling to over 100,000 across the EU, this model delivers high performance, resilience, energy efficiency, and strong data protection while premised on European sovereignty.

Competitiveness and sovereignty need each other; one cannot be sustainable without the other. The European continent has all it takes to reposition itself as a force of innovation, develop best-in-class sovereign capabilities, as proven with Galileo, and nurture a thriving commercial base fit to win global markets in this thriving evolution of the digital economy.

⁸⁵ See chapter 2.1.1 for more details

⁸⁶ Konrad Wolfenstein. Why the US Cloud Act is a problem and risk for Europe and the rest of the world: a law with far -reaching consequences. Xpert.digital, April 2025 (Link)

⁸⁷ EDPB, Initial legal assessment of the impact of the US CLOUD Act on the EU legal framework for the protection of personal data and the negotiations of an EU-US Agreement on cross-border access to electronic evidence. EDPS, July 2019. (Link)

3.3.1 Extending the basis for EU’s sovereign cloud offering to space

Expert interview extract

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Storage is a function of sovereignty. EU nations have signed up as customers because they are interested in the solution as it is illegal to store EU data outside of EU.

Secure, sovereign connectivity is a prerequisite for any orbital compute to participate in EU data spaces. Here, the Union’s upcoming IRIS² multi-orbit constellation, part of the Secure Connectivity Programme, aims to provide EU-controlled satcom for government and commercial users. As IRIS² deploys, it can furnish the trusted backhaul that a future hybrid cloud would require to meet EU assurance

levels for public-sector and regulated workloads. **Europe could expand the 8ra Important Project of Common European Interest on Next Generation Cloud Infrastructure and Services (IPCEI-CIS) initiative to include a dedicated space layer by leveraging the IRIS² satellite constellation, transforming today’s “cloud–edge continuum” into a fully sovereign cloud–edge–space continuum.** While the current IPCEI design focuses on terrestrial infrastructure, adding a space component could dramatically enhance resilience, security, and efficient reach of each node. The framework for such an experimental expansion already exists; the Commission has carved out an option for a dedicated space for startups and SMEs through a low-LEO constellation of at least 10 satellites, (co)financed by the Commission, to serve as a testbed for new technologies from emerging players.⁸⁸

Expert interview extract

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Resilience is a focus; our [satellite] company wants to make sure customers always have access to their data and down time in case of natural disasters, power outages etc. is kept at a minimum. The goal is to keep regions connected no matter what, to build a ‘hybrid sovereign gateway’.

The design principles of distributed computation, interoperability, vendor neutrality, and governance anchored in Europe, are directly applicable to space-based data centres. Orbital compute, designed within the super-cloud framework, could act as an extension of the sovereign edge continuum: offering low-latency, high-resilience compute that remains fully under EU control. The industrial coalition supporting terrestrial deployments could logically extend to encompass orbital platforms, with the inclusion of Europe’s technically apt and market-driven satcom operators, facilitating shared infrastructure, common operating stacks, and interoperable launch-to-compute systems governed by EU law and standards.

Identified near-term, sovereignty-aligned use cases

- Preprocessing and fusing space-borne sensor data before selective downlink;
- High-throughput, latency-tolerant workloads (e.g., training runs/checkpointing staged over sovereign satcom);
- “Sealed” processing for sensitive datasets where EU control over the full stack, including launch, operations, ground stations, identity/attestation, and incident response, can be demonstrated.

⁸⁸ ESPI. IRIS² Growing Up: From Strategic Roots to Commercial Power Play. Brief, April 2025 (Link)



4 The Perceived Challenges of SBDC Deployment

The following chapter provides a short overview of some of the major challenges, based on expert interviews and research, on the technicalities constraining SBDC deployment. We also collect other constraints currently being discussed that may not constitute significant hurdles.

4.1 Cost of launch

The most obvious barrier to the development of SBDCs is the cost of launching the infrastructure to orbit. While some industry experts and billionaires believe that within ten years, all new data centres could be deployed in space, primarily due to the abundance of renewable energy in orbit, this is based on uncertain assumptions. This vision is contingent on launch costs falling below a threshold of approximately \$400 per kilogram, which is widely seen as the point at which such projects become economically viable.⁸⁹ Optimists have pointed to SpaceX's Starship and its potential marginal cost of \$30 per kilogram for payloads of up to 100 tonnes. While it remains uncertain how much of these savings would be passed on to customers, it is hoped that economies of scale will incentivise SpaceX to drive high launch volumes rather than fewer, more expensive launches.

Expert interview extract “
*Launch costs pre-Starship
are way too high.*

Current launch costs are thus prohibitively high and most feasibility assessments for SBDCs depend on the success of SpaceX's Starship specifically. The second-generation Starship design has faced significant structural challenges, but the industry continues to pin hopes on its ability to radically reduce the cost of access to space. **Without this step-change, the competitiveness of SBDCs against terrestrial data centres would be significantly diminished.**

Starship Test Flight 10 breaks streak of failures

SpaceX's Starship Flight Test 10 on August 26, 2025, broke a streak of failures, restoring momentum in Starship's development toward reuse and lunar missions, while also lifting the hopes of the SBDC community globally.

Booster 16 and Ship 37 launched from Starbase, Texas, completing hot-staging, controlled splashdowns, as well as the first payload deployment and in-space engine relight in Starship's history. Despite sustaining damage during re-entry, the spacecraft executed a landing flip and splashed down upright in the Indian Ocean, while the booster performed a simulated engine-out test before splashing into the Gulf of Mexico.

⁸⁹ See the cost model in Annex A for more detail.

4.2 Power and thermal management

Experts continuously note that cooling remains essential, with at least half of engineering teams at some SBDC ventures currently devoted to the radiator challenge, underscoring its technical complexity. On one side, it is argued that advancements have been made in radiation technology since the 1960s and thus costs cannot be expected to balloon to trillions of dollars. On the other side, the large-scale infrastructure undertaking of a monolithic data centre architecture in orbit would carry more unknowns compared to the research conducted into small-sat and cube-sat thermal management systems. Cooling under atmospheric conditions may be efficient but is highly complex and introduces significant room for critical errors.

Expert interview extract

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Energy supply is a critical bottleneck. The International Space Station operates at approximately 120 kilowatts, but a viable SBDC, capable of meaningfully reducing the global carbon footprint would need an energy capacity in the range of 500 megawatts to 1 gigawatt.

The Tiangong Space Station maintains its climate through a system of mechanically pumped fluid loops (MPFLs), offering robustness, reliability, and effective gravity-immunity since the coolant remains in a single phase and its circulation can be precisely controlled even in microgravity. However, such single-phase systems are limited in their heat transfer capacity, relying solely on sensible heat, which restricts their ability to meet the extreme heat flux demands of next-generation electronics. By contrast, two-phase convective boiling systems leverage both sensible and latent heat, enabling far higher heat transfer coefficients and heat flux dissipation (up to 10^2 – 10^3 W/cm²).⁹⁰ Microchannel-based two-phase loops face significant challenges in phase management, particularly vapour–liquid separation, flow stability, and cycling reliability under variable gravity, which remain barriers to their widespread deployment in space.

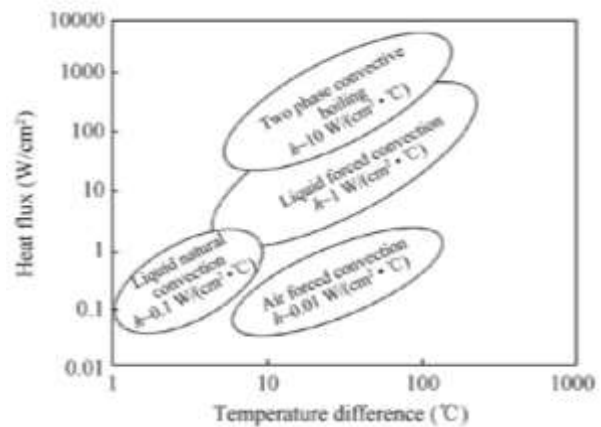


Figure 19: Performance comparison of various heat transport methods. (Source: Wang et al. 2021).

In practice, this suggests that early space-based data centres may rely on conservative liquid forced convection designs, such as ATA, while hybrid or advanced two-phase solutions could eventually unlock the density and efficiency needed to scale orbital computing to Earth-competitive levels.⁹¹

⁹⁰ Jixiang WANG, Yunze LI, Xiangdong LIU, Chaoqun SHEN, Hongsheng ZHANG, Kai XIONG. *Recent active thermal management technologies for the development of energy-optimized aerospace vehicles in China*. Chinese Journal of Aeronautics, February 2021 (Link)

⁹¹ NASA and JPL are working on a two-stage, single-phase mechanically pumped fluid loop to reject thermal power for energy dense 6U and above cubesats known as ATA.

4.3 Scale, in-orbit servicing, and robotic maintenance

A monolithic SBDC architecture demands the maintenance of terrestrial grade GPUs and server components orbit require shuttles delivering replacements. The cost of in-orbit servicing remains extremely high, to the extent that deorbiting a failed satellite and launching a replacement is generally considered more cost-effective than sending robotic or human crews for repairs akin to the STS-31 crew to the Hubble space telescope in 1993. In the absence of human servicing capabilities, robotic systems would be essential. Autonomous repair units are already under development by actors such as the European Space Agency (RISE) and DLR. With the upcoming ISOS pilot mission and the EIC Challenge Innovative in-space servicing, operations, robotics and

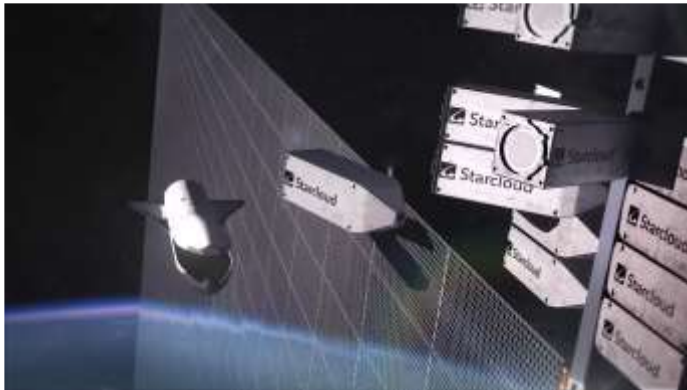


Figure 20: A render of a SBDC ‘hot-swap’ (Source: Starcloud)

technologies for resilient EU space infrastructure.⁹² Experts suggest a reasonable approach might be to replace servers on a five-year cycle through hot-swapping modular components.

Experts also raise concerns about the resilience of the infrastructure, especially with regard to data integrity in the event of satellite node failures.

Questions remain about how tolerant SBDCs will be to node failure, and how

such failures will be integrated into wider terrestrial systems. The maintenance cycle is expected to depend heavily on redundancy, which in itself increases costs.

The problem of scaling infrastructure in orbit is compounded by the current lack of robotic systems capable of large-scale assembly. At present, there are no commercially available systems able to construct monolithic data centre structures, and the assumption that humanoid robots could one day perform this work is regarded as speculative at best.

The necessary scale of a monolithic architecture derived data centre raises in-space environmental concerns as well. The accumulation of orbital debris poses a significant risk to SBDC development. To address these risks, robust end-of-life management protocols would need to be introduced alongside spacecraft shielding.

4.4 Radiation shielding

The Mars helicopter, Ingenuity, designed for just three months in a radiation-heavy environment, continued to operate five years later using a standard Snapdragon processor found in consumer Android phones. Modern microchips are designed or can be reengineered with considerable redundancy; thus, some experts suggest, radiation may no longer be the critical barrier once feared. Spaceborne Computer-1 and -2 also proved that software hardening may be enough to use computing in LEO.⁹³ Some unknowns still exist however, on the behaviour of GPUs and CPUs for long duration missions as are envisioned for SBDCs, especially if deployed in GEO or Cislunar space.

The primary risks come from two sources: Galactic Cosmic Rays (GCRs), which are high-energy

⁹² See ESPI, On-orbit Servicing, Assembly, and Manufacturing. October 2023 (Link), for more OSAM projects; European Commission, In-Space Operations and Services (Link); ESA, ESA to build first in-orbit servicing mission with D-Orbit, 14 October 2024 (Link)

⁹³ NASA. Cutting-Edge Computing Goes Spaceborne. NASA Spinoff, February 2025 (Link)



particles originating outside the solar system, and Solar Particle Events (SPEs), which are bursts of energetic particles from the Sun. These particles have enough energy to penetrate spacecraft shielding, causing single-event effects (SEEs), which lead to data errors and processor faults. Protecting the critical hardware inside space-based data centres, therefore, requires a combination of effective shielding strategies and radiation-tolerant computing systems.

NASA's RadPC provides an excellent example of how radiation-tolerant technologies are evolving to support space-based systems. Developed by Montana State University, RadPC uses redundant processors, fault recovery mechanisms, and autonomous error detection to ensure continued operations despite radiation exposure. NASA is set to test RadPC on the Moon as part of its Commercial Lunar Payload Services (CLPS) initiative, to demonstrate the ability of onboard computers to recover from radiation-induced faults during deep space missions.⁹⁴

LEO radiation levels are lower than those encountered in deep space, but some risks still exist for longer-duration missions, particularly during solar flares and geomagnetic storms or frequent passage through the South Atlantic Anomaly (SAA). Starlink satellites for example, are built with lightweight materials such as carbon fibre-reinforced polymers (CFRPs), which replace traditional aluminium structures used in older spacecraft designs while still providing modest shielding.⁹⁵

A recent study of CFRP panels for small satellites has demonstrated that these materials, while not as effective as traditional solid aluminium panels, can still provide adequate shielding in LEO environments. Using Geant4 simulations, researchers at the Space Technology and Industry Institute (STII) at Swinburne University of Technology assessed the ability of CFRP panels to protect satellites from radiation. Preliminary results indicated that CFRP panels could provide sufficient radiation shielding for missions lasting over 1000 days, based on the typical dose limits of commercially available electronics.⁹⁶

4.5 Other challenges

Bandwidth is a constraint, with satellites limited in their power allocations due to thermal management requirements. Efficient bandwidth allocation remains a complex task, particularly when seeking to accommodate high-demand services such as streaming video. Although orbital data centres, when addressing terrestrial applications, may be able to process a portion of their data in-situ, they will remain heavily dependent on ground stations for communication with Earth, creating potential bottlenecks at ground segment level. Experts observed that the bandwidth capacity, latency, and integration between ground stations and orbital infrastructure remain to be explored, making it difficult to assess the technical feasibility of transmission systems for SBDCs.

From a regulatory aspect, European Union's Digital Operational Resilience Act (DORA), which mandates stringent data storage and backup requirements for financial institutions, illustrates issues that might confront SBDCs. While the Act restricts storage of sensitive data outside the EU, the interpretation of "EU territory" as merely "jurisdiction and control" remains to be seen.

⁹⁴ Beth Ridgeway. NASA to Test Solution for Radiation-Tolerant Computing in Space. NASA, January 2025. (Link)

⁹⁵ Rajarshi Pal Chowdhury, Luke A. Stegeman, Matthew L. Lund, Dan Fry, Stojan Madzunkov, Amir A. Bahadori. *Hybrid methods of radiation shielding against deep-space radiation*. Life Sciences in Space Research, August 2023 (Link)

⁹⁶ Matthew Large. *CFRP vs Aluminium for Small Satellites: A comprehensive assessment of the radiation shielding performance of structural panels in LEO*. ESTEC June 2024 (Link)



Annex A: A Cost Model for Space-Based Data Centres

The following section is a summary of the derived total cost equation for the installation and running of data centres in space. The proposed equation estimates the capital expenses (CapEx) and operating expenses (OpEx) of a 1GW SBDC on two defined architectures: A Sun-synchronous orbit (SSO) monolithic and a SSO constellation architecture. Their cost is benchmarked against current, existing terrestrial data centres. The cost breakdown shall be granular enough to capture the influence of the major cost drivers in TBDCs and SBDCs. This may enable the firms investing in SBDCs to identify potential cost saving opportunities.

High level assumptions

A number of assumptions have been made in the development of the cost model. A full list of assumptions feeding into the cost model are documented in the complete cost model documentation, **available on request**.

The cost model assumes that the SpaceX Starship will be the most affordable launcher available in the near future for the required payload mass and orbit type. For this reason, the Starship is selected as the baseline launcher. The model assumes that the Starship can deliver approximately 87.5 tonnes into SSO, based on 70% of its estimated 125-tonne capacity to LEO. It is further assumed that the spacecraft has a cylindrical payload bay with a 9-metre diameter and 18-metre height. The cost per launch is taken to be \$10 million, assuming each vehicle is reused five times.

The benchmark terrestrial data centre is assumed to operate with an availability of 99.9%, putting it at least at Tier III. It is assumed that the benchmark terrestrial data centre has an average power usage factor of 0.95, an electricity price of \$0.010 per kilowatt-hour, and a power usage effectiveness (PUE) of 1.2.

For hardware reliability, it is assumed that non-space-hardened components deployed in space have a lifetime of two years. The cost model assumes that non-space-hardened core IT components, rather than fully space-qualified hardware, are used in the SBDC.

Current terrestrial cost conditions for both data centre components and electricity pricing are assumed.

Summary of the SBDC Cost Model

A cost equation for the CapEx and OpEx of two 1GW SBDCs is proposed. The chosen use-case of the modelled data centres is high-performance computing for training of AI models. Two system architectures were chosen for modelling:

- A SSO monolithic architecture: To reach 1GW of system power, 96 large 10MW SBDC units are proposed.
- A SSO constellation architecture: Sixty-seven hundred 150kW SBDC units are proposed.

To assess their economic viability in detail, the CapEx and OpEx of the major cost elements of both architectures are benchmarked against the major cost elements of TBDCs.

Decades of work are needed for the deployment of SBDCs at the GW-scale. Up to the point of deployment, technology would most likely make both TBDCs and SBDCs cheaper with respect to 2025 costs. Still, in this model the costs are not projected to a future point in time. The basis for all costs is the \$FY2025.



Three key economic barriers/cost-sensitive model parameters are identified: Cost of data centre (DC) core information technology (IT) hardware, lifespan of the IT hardware under space radiation, and launch affordability. Assuming equal core IT hardware costs for TBDCs and SBDCs, a 2-year lifespan of IT hardware in space and a launch cost of \$114/kg, the following study outcomes are calculated:

$$\text{Cost of the benchmark TBDC} \quad C_{TBDC} = 28.8 \cdot P + 09.0 \cdot P \cdot t \quad (1)$$

$$\text{Cost of the SSO monolithic SBDC} \quad C_{SBDC_{Monolithic}} = 30.6 \cdot P + 11.4 \cdot P \cdot t \quad (2)$$

$$\text{Cost of the SSO constellation SBDC} \quad C_{SBDC_{Constellation}} = 55.1 \cdot P + 28.3 \cdot P \cdot t \quad (3)$$

with P denoting core IT hardware power in MW and t being the operation time in years.

The models show that a SSO constellation is cost-efficient for up to the 1-MW-scale SBDCs. This is because each SSO monolithic data centre is 10.4MW to maximise the launch vehicle volume. Above 1MW, based on Equations (1) - (3), the monolithic architecture proves much more competitive than the constellation architecture. Its costs are very close to the terrestrial data centres.

Given that the three above-mentioned assumptions for the cost and lifespan of core IT hardware and launch costs are satisfied in practice, this cost model shows that SSO monolithic SBDCs will offer an economically viable alternative to terrestrial solutions while being much more environmentally friendly.⁹⁷

Architecture

Depending on the use-case and the need, different dominant architectures emerge. The architectural matrix in Table 1 structures the trade-space in architectural decisions, each exhibiting multiple alternatives. The two architectures are chosen based on the existing SBDC concepts.^{98,99,100} In Table 1, the blue line represents the SSO monolithic architecture, and the red line represents the SSO constellation architecture.

In this model, the total costs are split between IT hardware costs and infrastructure costs for both TBDCs and SBDCs. The IT hardware costs are derived from a cost model for TBDCs. The infrastructure CapEx and OpEx are then broken down into the following categories: Maintenance, Electricity, Cooling, Software, Ups, Transmission, Land and Shell, Building Fit-Out, Staff, Insurance, Launch (Data Centre, IT Hardware, Solar, Cooling, Maintenance) and Radiation. The costs that are present but not assigned to the above categories are therefore assigned to the category “Rest”. The currency used in the model is \$FY2025. The IT hardware costs are derived as a function of the TBDC infrastructure costs. The following derivations are the basis of the results of this study: Table 2 and Table 3 as seen in the Results and Discussion section.

The main use-case for this cost model on SBDCs is data processing. Data processing is an active service to process and manipulate data using programs. AI training is seen as a subset of cloud computing. The computing resources are used to train machine learning models on large-scale datasets in this case. Data storage enables users to store and manage data and objects. The

⁹⁷ E. Hutchinson and D. Yves , “Intelligent Data Centres,” 26 July 2024. (Link)

⁹⁸ E. Feilden, A. Oltean and P. Johnston, “Why we should train AI in space,” September 2024. (Link)].

⁹⁹ D. Dumestier and G. Durand , “ASCEND - SOLAR POWER FOR ON-SITE ORBITAL,” 18 April 2024. (Link)

¹⁰⁰ J. C., China in Space, ADA Space Eyes Launching 2,800 AI Satellites, 15 May 2025. (Link).



data handling is considered passive as the data is not altered. In principle, data processing is much more energy intensive than data storage.

Architectural Decision	Architectural Alternatives				
Launcher	Starship	Future Starship	Ariane 6	PROTEIN	
Main Use-Case	Data Storage	Data Processing			
Customer	Government	Private	Both		
Communication & Data Acquisition	Direct	Relay Satellite	Satellite internet provider	Physical Retrieval	
Location	GEO	LEO	SSO	Moon Orbit	Moon Surface
Satellite Configuration	Monolithic	Constellation			
Cooling	Natural	Passive	Active	Hybrid	Heat Pump
Cooling Medium	Air	Water	Hybrid		
ERD	No ERD	ERD			
Power Generation	Solar Cells	Fuel Cell	RTG	Fission Reactor	
Cooling SS	Integrated	External Distributed	External Unitary		
Energy Storage	None	Battery	Fuel Vessel		
Radiation Protection	Commercial hardware + shielding	Space-Hardened	Space hardened + Shielding	Hybrid hardware + shielding	
Servicing	In-Orbit	On-Earth	None	Hybrid	
Interconnection	None	Mechanical	Data	Energy	Combination
Assembly	In-Orbit	On-Earth			
Data Latency	ms	sec	hour	month	
Attitude and orbital control	Tug Satellite	Onboard ADCS			
End of Life	Leave orbit	Bring Earth to	Atmospheric Burn	Graveyard Orbit	
IT Hardware Type	Of-the-Shelf	Space-Hardened			

Table 1: Architectural Matrix and proposed architectures: SSO monolithic (blue), SSO constellation (red).



Results and Discussion

Table 2 compares the CapEx and OpEx costs for the TBDC and the monolithic SBDC architecture while Table 3 compares the CapEx and OpEx costs for the TBDC and the constellation SBDC architecture. From the data, the following cost equations is derived for the CapEx and the OpEx of the three systems: The benchmark TBDC in Equation (1), the SSO monolithic architecture in Equation (2) and the SSO constellation architecture in Equation (3).

$$\text{Cost of the benchmark TBDC} \quad C_{TBDC} = 28.8 \cdot P + 09.0 \cdot P \cdot t \quad (4)$$

$$\text{Cost of the SSO monolithic SBDC} \quad C_{SBDC_{Monolithic}} = 30.6 \cdot P + 11.4 \cdot P \cdot t \quad (5)$$

$$\text{Cost of the SSO constellation SBDC} \quad C_{SBDC_{Constellation}} = 55.1 \cdot P + 28.3 \cdot P \cdot t \quad (6)$$

Overall, the monolithic SBDC architecture shows comparable CapEx to the TBDC architecture. With respect to OpEx it's still 38% more expensive than the TBDC given the modelling assumptions. It is worth noting that with an IT hardware lifespan of over 3 years, the lower operating cost of the monolithic architecture makes the SBDC concept cheaper over its lifetime than the TBDC.

According to the model, the constellation architecture is not nearly as competitive as the monolithic architecture in the GW-scale. Its CapEx is double the TBDCs and its OpEx more than triple. It is worth comparing the cost of the infrastructure with the cost of the IT hardware for each SBDC architecture. Overall, for the same amount of value-generating IT hardware, the monolithic architecture is by far the most efficient solution.

This discrepancy in efficiency between the two architectures is due to two major reasons: First, for each kg of core IT hardware in space, the constellation architecture requires more mass for its support systems. The bigger the size of the data centre, the better the performance of the SBDC improves in this model.

The second major reason is the difference in the maintenance concepts between the two architectures in combination with the lifetime of IT hardware in space. If all the components of the data centre had similar lifespans, then the zero-maintenance concept of the constellation architecture makes more sense, given its scalability benefits. Having to decommission all the space infrastructure every 2 years wastes the lifespan potential of most of the components in the data centre. That is not something that the monolithic architecture avoids. This architectural comparison highlights the need for in-orbit robotic maintenance, assuming that the lifespan of core IT components does not improve substantially in the future.

Multiple representatives of companies working in SBDCs estimated life expectancies of around 5 years. This makes SBDCs much more economically viable, but no peer-reviewed material has been found validating their claims. For this reason, the value of 2 years is used in this model.¹⁰¹ Due to the high sensitivity of the model to this parameter, it is essential for more tests to be conducted with HPC hardware under radiation conditions.

In conclusion, the potential for SBDCs being economically feasible is high. SBDCs will prove a viable alternative to TBDCs given that the lifespan and cost of IT components improve, the

¹⁰¹ W. S. Slater, N. P. Tiwari, T. M. Lovelly and J. K. Mee, "Total Ionizing Dose Radiation Testing," in 2020 IEEE High Performance Extreme Computing Conference (HPEC), Massachusetts, 2020.



robotic maintenance and assembly concept is proven feasible and successful at large scale, and that for the launch vehicle a cost per kg of under \$150/kg is achieved.

The limitations of the model are discussed in the full cost model. As SBDCs are still in the early concept-exploration phase, with no fully operational systems currently in orbit, assumptions need to be made for the development of the cost model. The assumptions pose limitations to the model. The model does not consider the increased risk of an SBDC with respect to a TBDC. The cost of capital is assumed to be the same for TBDCs and SBDCs. Hence, the increased cost of loans awarded to novel high-risk ventures is not captured.

Due to GW-scale SBDCs being in the concept phase, the available data is insufficient for the creation of a statistical dataset. The expected mean value of the cost is provided instead. In conclusion, the cost equations include no measure of uncertainty.

The granular cost breakdown of TBDCs and SBDCs of this model is necessary to detect the sources of their respective cost advantages and shortcomings. This analysis will enable better informed decisions when the technology level is adequate to satisfy the presented modelling assumptions and future GW-scale SBDCs are built. Moreover, the insights of this work shed light on which components of SBDCs require the most improvement to reach viability.

The costs of GW-scale SBDCs are very sensitive to their unique architecture, and most probably their main use case. The feasibility of the SBDC concept is not a question of their cost, but rather a question of their value-to-cost proposition with respect to TBDCs. Due to their unique environment, SBDCs have multiple unique selling propositions like edge computing for satellites and cybersecurity in the kW scale. Serving these use-cases already acts as a steppingstone for larger scale architectures, eventually leading to the GW scale that this work explores.

This section forms a simplified summary of the full model breakdown with a focus on the SBDC architecture and results only. This cost model was fully developed by staff of the TUM Chair of Spacecraft Systems. **The reader may request** the full details of the cost model by email found at www.espi.eu.



Cost Category	CapEx [\$M/MW]		OpEx [\$M/MW/y]	
	TBDC	SBDC	TBDC	SBDC
Infrastructure	10.55	9.28	5.22	3.16
IT Hardware	19.18	19.18	3.78	9.59
Maintenance		0.04	2.64	0.02
Electricity	0.04	0.25	1.00	0.03
Cooling	2.64	5.70		0.57
Software			0.72	0.72
UPS	1.90			
Transmission	1.19	0.30		
Land and Shell	1.85			
Building Fit-Out	2.64	0.02		
Staff			0.96	0.01
Insurance		2.84		1.02
Launch		2.96		0.80
Radiation		0.02		
Rest	0.31		-0.10	
Total	29.73	31.30	9.00	12.75
Launch Cost Breakdown				
Data Centre		1.04		
IT Hardware				0.62
Electricity		0.20		
Cooling		1.69		0.17
Maintenance		0.03		0.02

Table 2: TBDC vs Monolithic SBDC

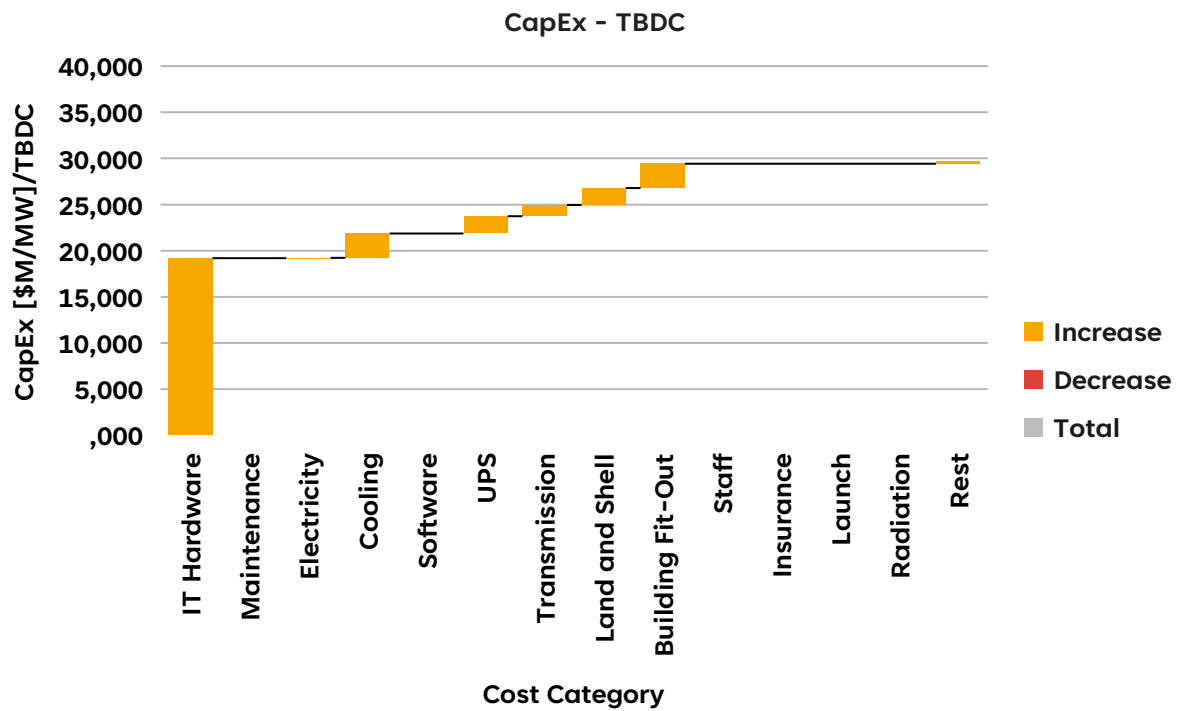


Figure 21: CapEx breakdown of the TBDC.

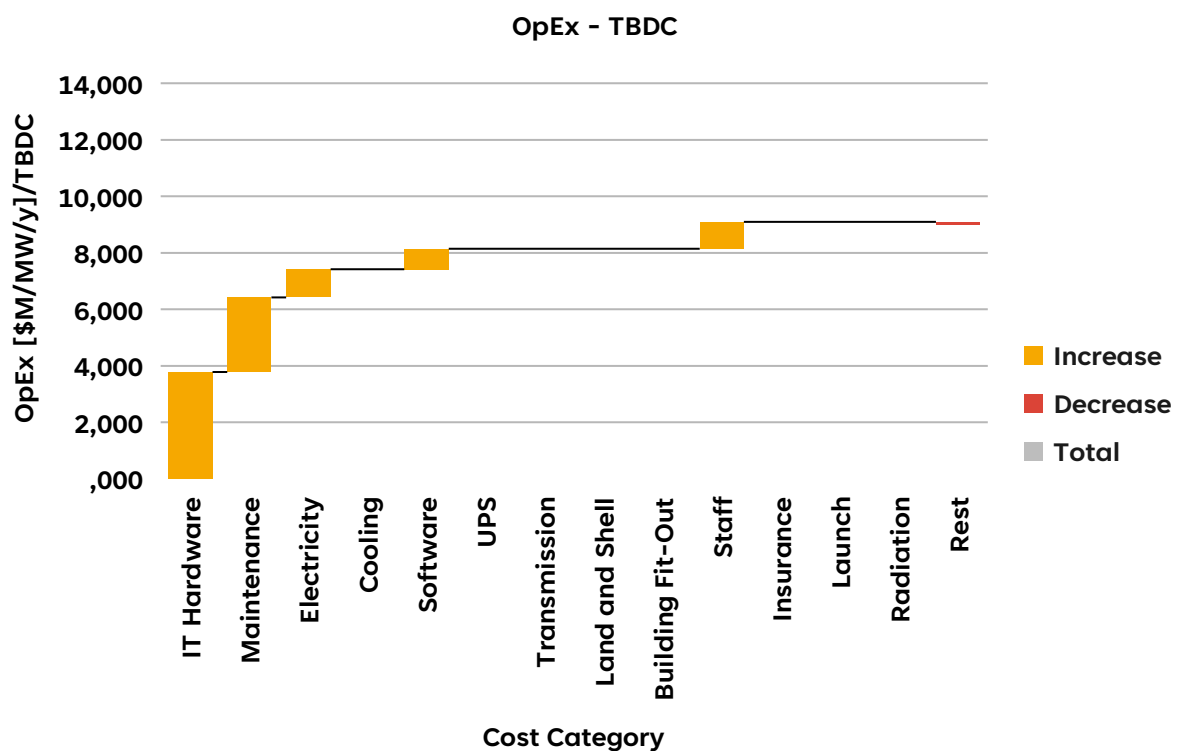


Figure 22: OpEx breakdown of the TBDC.

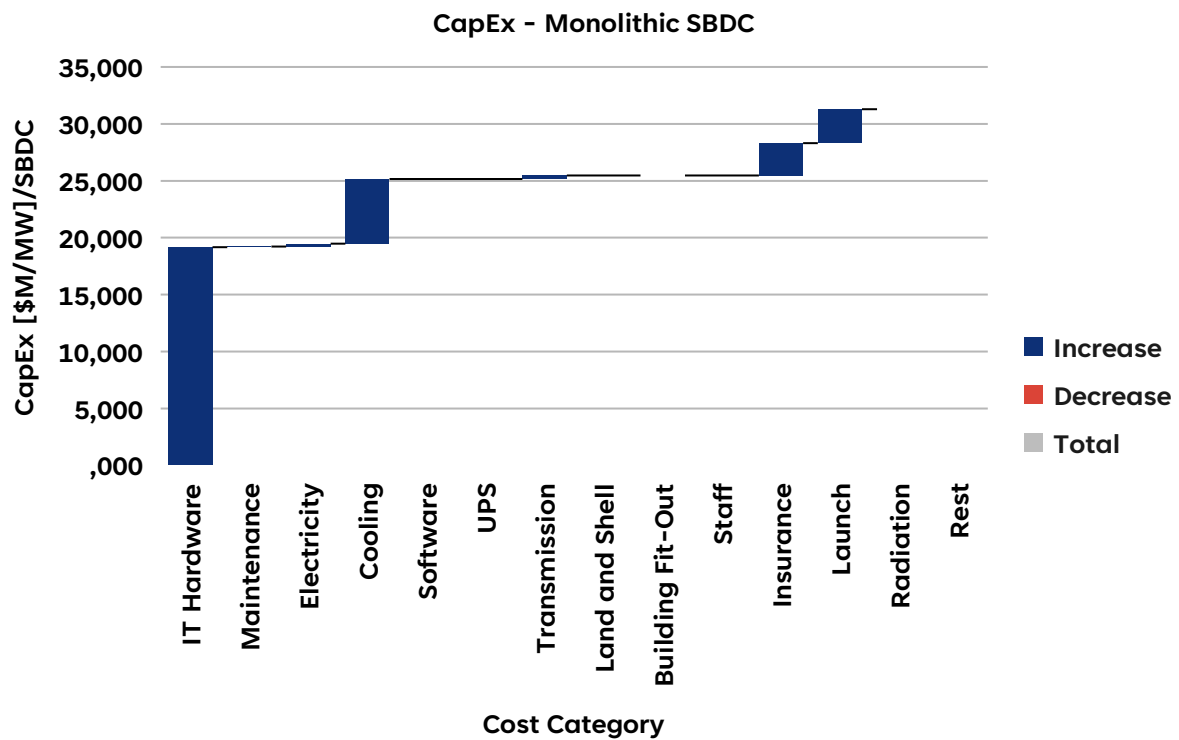


Figure 23: CapEx breakdown of the monolithic SBDC.

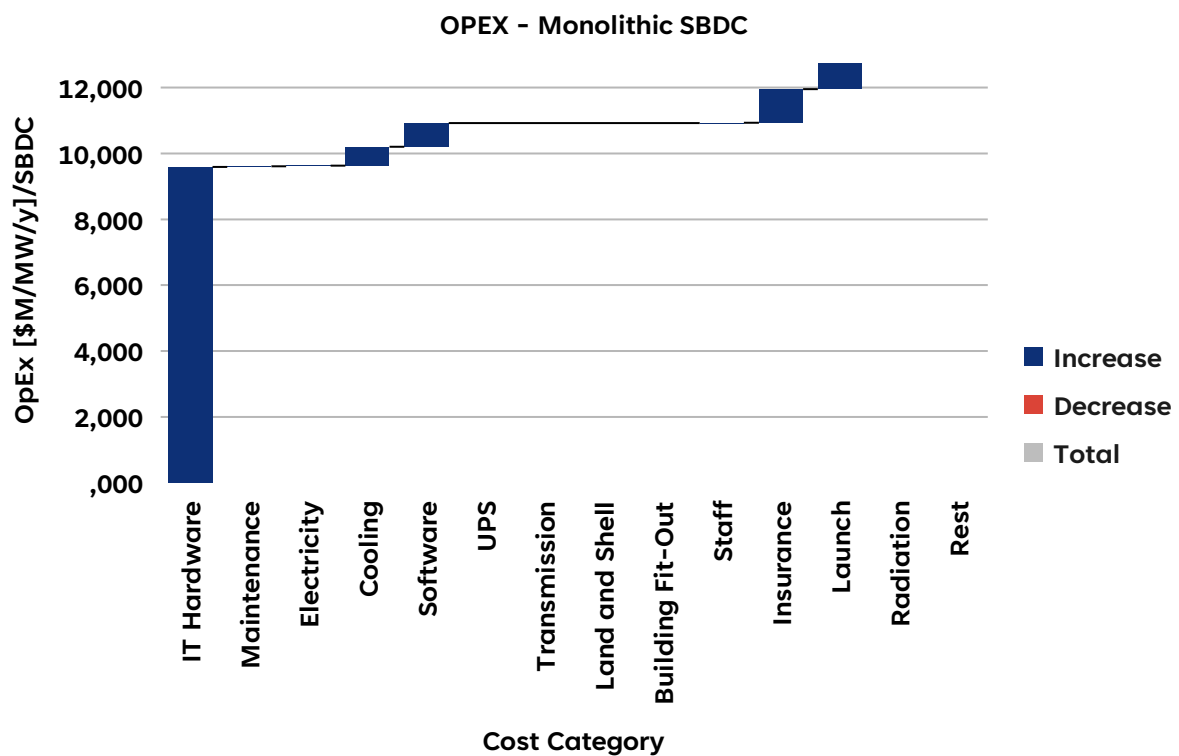


Figure 24: OpEx breakdown of the monolithic SBDC.



Cost Category	CapEx [\$M/MW]		OpEx [\$M/MW/y]	
	TBDC	SBDC	TBDC	SBDC
Infrastructure	10.55	31.53	5.22	18.99
IT Hardware	19.18	19.18	3.78	9.59
Maintenance			2.64	
Electricity	0.04	0.25	1.00	0.13
Cooling	2.64	5.70		2.85
Software			0.72	0.72
UPS	1.90			
Transmission	1.19	13.33		6.67
Land and Shell	1.85			
Building Fit-Out	2.64	0.04		
Staff			0.96	0.02
Insurance		5.07		2.53
Launch		12.16		6.08
Radiation		0.05		
Rest	0.31		-0.10	
Total	29.73	55.77	9.00	28.58
Launch Cost Breakdown				
Data Centre		10.27		5.13
IT Hardware				
Electricity		0.20		0.10
Cooling		1.69		0.85
Maintenance				

Table 3: Cost comparison: TBDC vs SSO constellation SBDC.

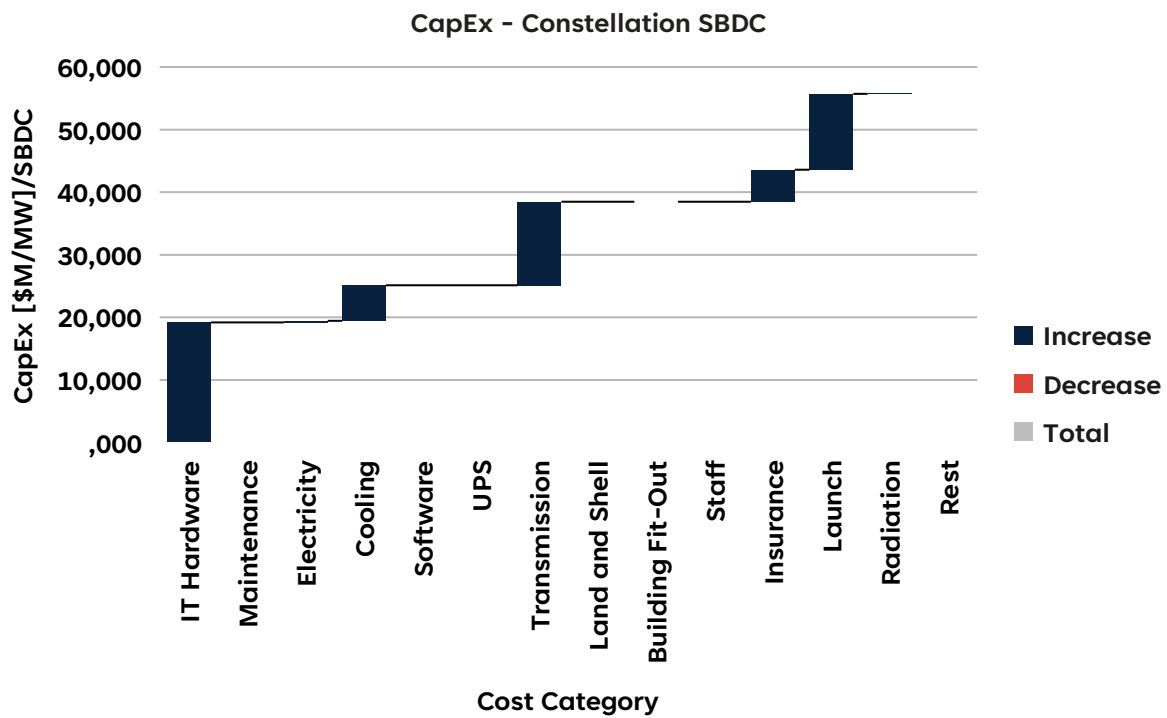


Figure 25: CapEx breakdown of the constellation SBDC.

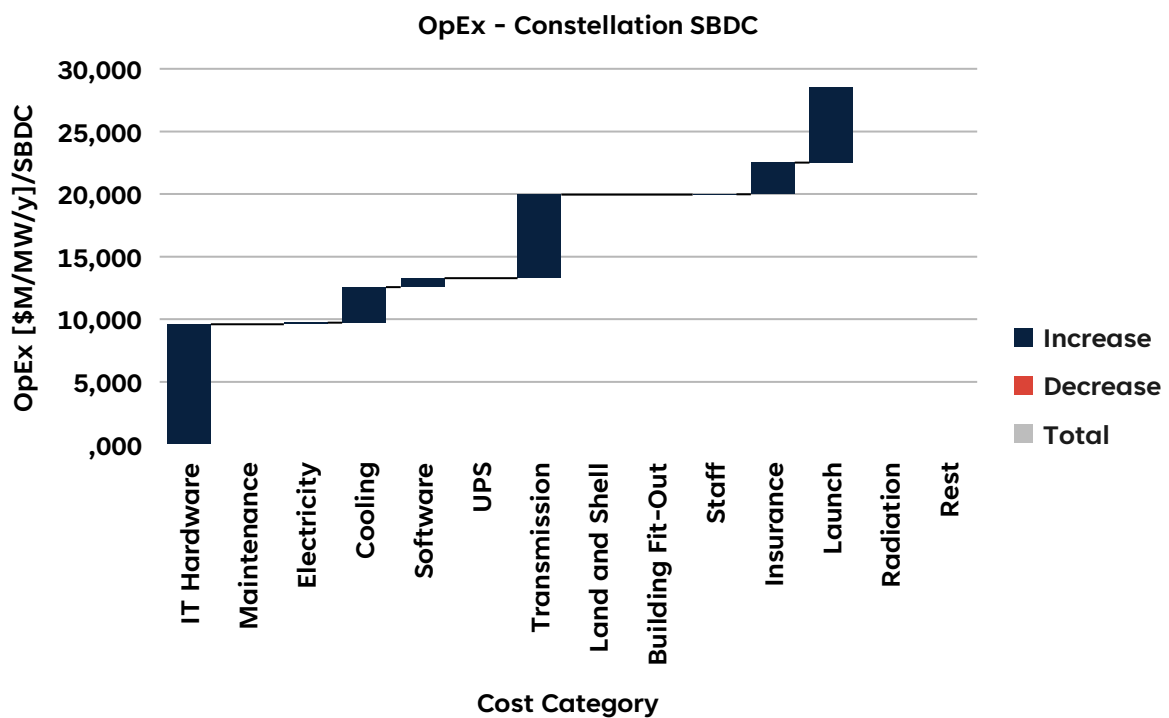


Figure 26: OpEx breakdown of the constellation SBDC.



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Yves Durand	(Ret.) Director of Technology, Thales Alenia Space
Rafal Graczyk	CTO, Edge Aerospace
Gunjan Hooja	Business Development & Strategic Partnerships Manager, SES Satellites
Jaroslav Jaworski	CEO, Edge Aerospace
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