Beyond Earth: Orbital Data Centres and In-Orbit Compute

Report written by the Satellite Applications Catapult with support from event partners and workshop insights

December 2025

UKRI Innovate UK

Catapult Satellite Applications

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Executive Summary

Global data generation is projected to reach 175 zettabytes by 2025, while terrestrial data centres already consume energy equivalent to the combined usage of Germany and France. This trajectory creates an urgent need for alternative infrastructure models that are sustainable, resilient, and scalable.

Orbital Data Centres (ODCs) and in-orbit compute offer a transformative solution by relocating compute capacity into space, leveraging abundant solar energy and radiative cooling. These platforms can alleviate terrestrial constraints, reduce environmental impact, and enable new capabilities for latency-sensitive and security-critical applications.

The Orbital Data Centres and In-Orbit Compute Day, hosted by Satellite Applications Catapult with partner Bird & Bird on 23rd September at Bird & Bird offices in London, convened stakeholders from across government, industry, finance, academia, and legal sectors. Discussions highlighted strong interest in hosted compute models, sustainability, and security, while also identifying risks such as funding gaps, technical constraints, and regulatory complexity. The event underscored the growing relevance of ODCs and in-orbit compute capabilities, and laid the groundwork for future collaboration and investment. This report summarises outputs from the event.

Value proposition of in-orbit compute:

- Sustainability: Space-based compute reduces carbon emissions, water use, and land footprint.
- Performance & Latency: In-orbit processing accelerates decision-making for defence, emergency response, and autonomous systems.
- Security & Sovereignty: Physical separation from terrestrial threats enhances resilience and supports sovereign cloud strategies.
- Scalability: Advances in launch economics, thermal management, and power systems make multi-megawatt orbital infrastructure feasible.

The market outlook:

- Base Case: $3.8B by 2035, driven by defence and sovereign demand.
- Bull Case: $20B+ by 2035 if launch costs fall below $200/kg and hyperscalers enter the market.

Strategic enablers:

- Anchor early adoption through defence and government procurement.
- Lead in standards, regulation, and sustainability frameworks.
- Capture a share of a multi-billion-dollar global market by aligning policy, investment, and industry mobilisation.

Next Steps: Establish a working group to define use cases, address technical and regulatory challenges, and develop a roadmap for leadership in orbital compute.

Introduction

Global data generation is projected to reach 175 zettabytes by 2025 [1], while terrestrial data centres already consume energy equivalent to the combined usage of Germany and France [2]. This creates an urgent need for alternative infrastructure models that are more sustainable, resilient, and scalable.

Orbital Data Centres offer a promising solution by relocating compute capacity into space, where solar energy is abundant and cooling can be achieved through radiative methods. These platforms could help alleviate terrestrial constraints, reduce environmental impact, and unlock new capabilities in latency-sensitive and security-critical applications.

This report explores the strategic potential of ODCs, drawing on insights from a multi-stakeholder workshop hosted by Satellite Applications Catapult and Bird&Bird in September 2025, and supported by market sizing research conducted by the Satellite Application Catapult.

State of the Race

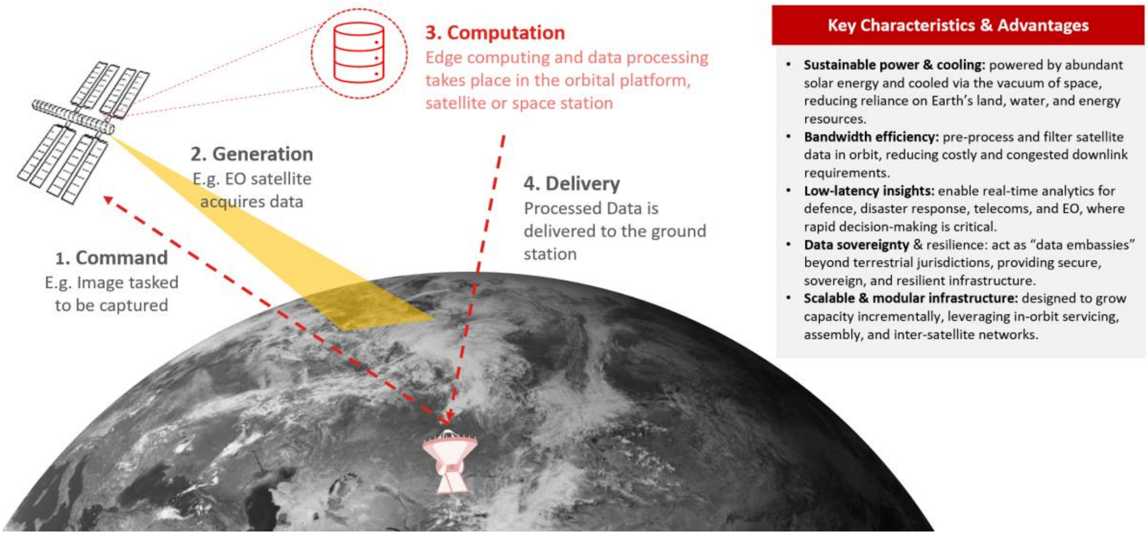
- **Google's Project Suncatcher (2025)**: a major tech-industry moonshot. In November 2025 Google made public a detailed study called *"Towards a future space-based, highly scalable AI infrastructure system design"* which outlines how fleets of satellites, equipped with solar arrays, optical inter-satellite links, and AI accelerators (TPUs), could enable truly scalable AI compute in orbit [3] [4]. The proposal argues that in the "right orbit," solar panels can collect near-continuous sunlight, and waste heat can be rejected via radiative cooling into deep space, turning orbital infrastructure into a potentially carbon-efficient, scalable alternative to terrestrial data centres.
- **Startups and private investment are accelerating**: Starcloud (formerly Lumen Orbit) recently announced plans for orbital data centres hosting high-performance GPU computing, funded by private investors including venture capital firms and national-security-linked investors [5] [6]. This shows that there is early commercial intent, not just academic or government interest.
- **Mega-operators repositioning for multi-orbit/cloud-plus-satcom future:** Operators such as SES, following its acquisition of Intelsat, are building significant global multi-orbit networks that could serve as infrastructure backbones for orbital compute and data services [7]. Their strategic repositioning suggests industry sees long-term value in combining connectivity, storage, and eventually compute in space.
- **Rapid technological and economic signals:** The parameters assumed by Project Suncatcher and similar proposals often include LEO launch costs declining toward ≤ US$200/kg, which many in the industry now see as plausible by the 2030s [3]. Meanwhile, advances in optical inter-satellite links (ISLs), radiation testing of accelerators (e.g. TPUs), and small-sat power/thermal design all contribute to closing the gap between what was theoretical and what may soon be actionable.
- **Shifts in macro-drivers:** With explosive growth in AI workloads, and associated energy demands, there is growing scrutiny of terrestrial data centres' carbon footprint, water use, and land use. Space-based compute offers an alternative by decoupling compute demand from terrestrial resource constraints. At the same time, geopolitical factors and data-sovereignty concerns are driving demand for resilient, globally distributed and jurisdiction-aware data infrastructure, putting a premium on "cloud sovereignty," which ODCs could uniquely deliver.
- **Move from niche research to global competition:** Between major cloud players (Google), startups (Starcloud), legacy satellite operators (SES/Intelsat), and emerging national and defence-driven programmes, ODCs are becoming a contested strategic frontier. Because many of these actors come with deep pockets, existing infrastructure-development capabilities, and long-time horizons, the risk is no longer that ODCs remain academic, the risk is they'll diverge widely in design, standardisation, and governance unless coordinated.

The Case for Orbital Compute

Definitions – Orbital Data Centres

In-orbit compute and orbital data centres refer to space-based infrastructure and architectures designed to process, store, and manage data directly in space rather than relying solely on terrestrial systems. These solutions enable enhanced autonomy, optimised bandwidth usage, and faster decision-making for satellites and constellations, while also offering terrestrial benefits such as reducing energy consumption, improving redundancy, and supporting decentralized applications. The concept spans multiple solution families, from traditional on-board data processing and edge computing with embedded AI, to networked on-orbit cloud architectures and dedicated orbital data centres, serving both intra-space markets (satellite operators and manufacturers) and terrestrial markets seeking sustainable, secure, and low-latency compute capabilities. The services should be viewed as part of a continuum:

- **On-board Data Processing** – Traditional satellite capabilities for operational data handling and sensor pre-processing.
- **On-board Edge Computing** – Enhanced processing on individual satellites, often leveraging embedded AI for autonomy.
- **On-Orbit Cloud Architecture** – Networked compute across constellations, enabling distributed processing and storage with connectivity to ground systems.
- **Orbital Data Centre** – Dedicated space infrastructure providing large-scale data centre capacity in orbit.



Drivers of Change

Proponents of ODCs highlight several potential advantages that could transform the way data is processed and managed. While these drivers of change present an ambitious vision for orbital compute, it is important to note that they remain largely theoretical at this stage. Significant technical, economic, and operational validation is still required to demonstrate their practicality and long-term viability.

- **Latency**: In-orbit compute can dramatically reduce the time required to process and act on data, especially in time-sensitive domains such as defence, emergency response, and autonomous systems. By processing data in space, decision-making timelines can be shortened from hours to minutes, enabling faster and more effective responses that could save lives, protect assets, and improve operational efficiency.
- **Sustainability**: Terrestrial data centres are major consumers of electricity and water, contributing to environmental degradation and placing strain on local resources. ODCs, powered by solar energy and cooled via radiative methods, offer a cleaner alternative that aligns with global sustainability goals. By shifting compute workloads off-planet, ODCs can reduce carbon emissions, water usage, and land footprint.

- **Security**: Hosting data and compute infrastructure in space provides physical separation from terrestrial threats such as cyberattacks, natural disasters, and geopolitical instability. ODCs can support sovereign data capabilities, zero-trust architectures, and off-planet backups for critical infrastructure, enhancing national resilience and continuity of operations.
- **Scalability**: Advances in power generation, thermal management, and launch economics are making it feasible to deploy kilowatt-class systems in orbit. These developments pave the way for gigawatt-scale infrastructure within the next decade, enabling ODCs to support increasingly complex workloads and serve a broader range of customers.
- **Geopolitical competition:** Strategic programmes in China and the US are accelerating investment in orbital compute, with initiatives such as Golden Dome and lunar infrastructure projects demonstrating serious intent. The UK must act swiftly to remain competitive, secure its strategic interests, and avoid falling behind in this critical domain.
- **Thermal & power budget feasibility:** Thermal management is a big mass -and thus cost- driver for ODCs [8]. A 2025 Nature Electronics study outlines how computational satellites equipped with high-efficiency solar arrays and radiative coolers can absorb waste heat and reject it to the cold vacuum of deep space, enabling near-carbon-neutral operations [9]. Furthermore, heritage systems such as the ISS's Active Thermal Control System (ATCS) demonstrate the viability of radiative-cooling loops for heat loads exceeding passive thermal control capabilities [10].

Growth in Space & Data Demand

- The global space economy reached US $415 billion in 2024, growing steadily due to commercial innovation and government investment. Satellites and space services accounted for 71% (~US $293 billion) of this revenue [11]
- Satellite data services market size is expected to grow from $14.44bn in 2027 to $55.17bn by 2032 at CAGR 21.1%, representing near a 4x increase over seven years, highlighting explosive growth potential [12]

Edge Computing Extended into Orbit

- Real-time processing of Earth Observation data onboard satellites saves bandwidth and latency, critical for disaster response and AI workloads [13]
- Advances in distributed satellite computing architectures (e.g., DSIN) and serverless Function-as-a-Service models for orbital edge computing are gaining traction [14]

Comms Tech Supporting Space Compute

- Laser communication (laser comms) is emerging as a game-changer for ultra-high bandwidth and resilient space-to-space links [15]
- Non-terrestrial networks (NTN) upgrades in 5G-Advanced are integrating satellite support, blurring the edge between space and terrestrial IoT networks.

Competition & Geo-political Drivers

- China has deployed the first 12 satellites of its Three-Body Computing Constellation, aiming for thousands of orbiting AI supercomputers, each performing ~744 TOPS, with inter-satellite laser links [16]
- Ex-Google CEO Eric Schmidt acquired launch provider Relativity Space to support the development of ODCs [17]
- US based Starcloud launched NVIDIA GPU to space in November 2025 to test AI processing applications [18] after raising $21 million in seed round earlier in the year [19].

Sustainability Driving Orbital Compute Rationale

- Terrestrial data centres consume over 415 TWh annually, stressing power grids and land resources. This underscores the strategic appeal of alternative approaches like orbital compute [12]
- In-space data centres benefit from natural radiative cooling (vacuum) and limitless solar energy, potentially offering greener alternatives to Earth-based facilities [15]

Value Proposition of ODCs

ODCs create value by offering performance gains, resilience, sustainability, and sovereignty advantages that terrestrial data centres cannot match, particularly for sovereign, latency-sensitive, and high-resilience applications.

Performance & Efficiency

- **Process-at-source:** Cut downlink volumes and latency by running AI/analytics in orbit before data hits the ground.
- **Global reach & uniform latency:** Low, predictable LEO latency and space-to-space routing; serve anywhere without terrestrial backhaul constraints.
- **Spectrum & optical backbones:** Leverage Ka/Ku and especially optical ISLs/downlinks to bypass congested terrestrial routes.
- **Scalable "edge in space":** Add compute/storage as modular nodes that collocate with (or relay between) constellations.

Resilience & Security

- **Resilience & continuity:** Off-planet infrastructure insulated from local outages, disasters, and some geopolitical risks.
- **Security isolation:** Physically air-gapped from the public internet; end-to-end encrypted links, zero-trust by design.
- **Operational autonomy:** Containerised workloads, onboard EDR, and autonomous fault recovery reduce human-in-the-loop reliance.

Sustainability

- **Abundant solar power:** High energy availability without grid constraints; passive radiative cooling (no water use).
- **Cooling in space:** Cooling methods taking advantage of higher ΔT in space

Sovereignty & Strategic Control

- **Ubiquitous vantage point:** Persistent, wide-area perspective for real-time multi-satellite data fusion.
- **Jurisdictional control:** Operate under satellite registry and controlled ground gateways to meet sovereignty goals (with caveats).

Market Sizing & Economics Scenario by 2035

By 2035, the market for Orbital Data Centres could range from niche demonstrations to a multi-billion-dollar extension of the global cloud, depending on launch economics, technology maturity, and adoption drivers.

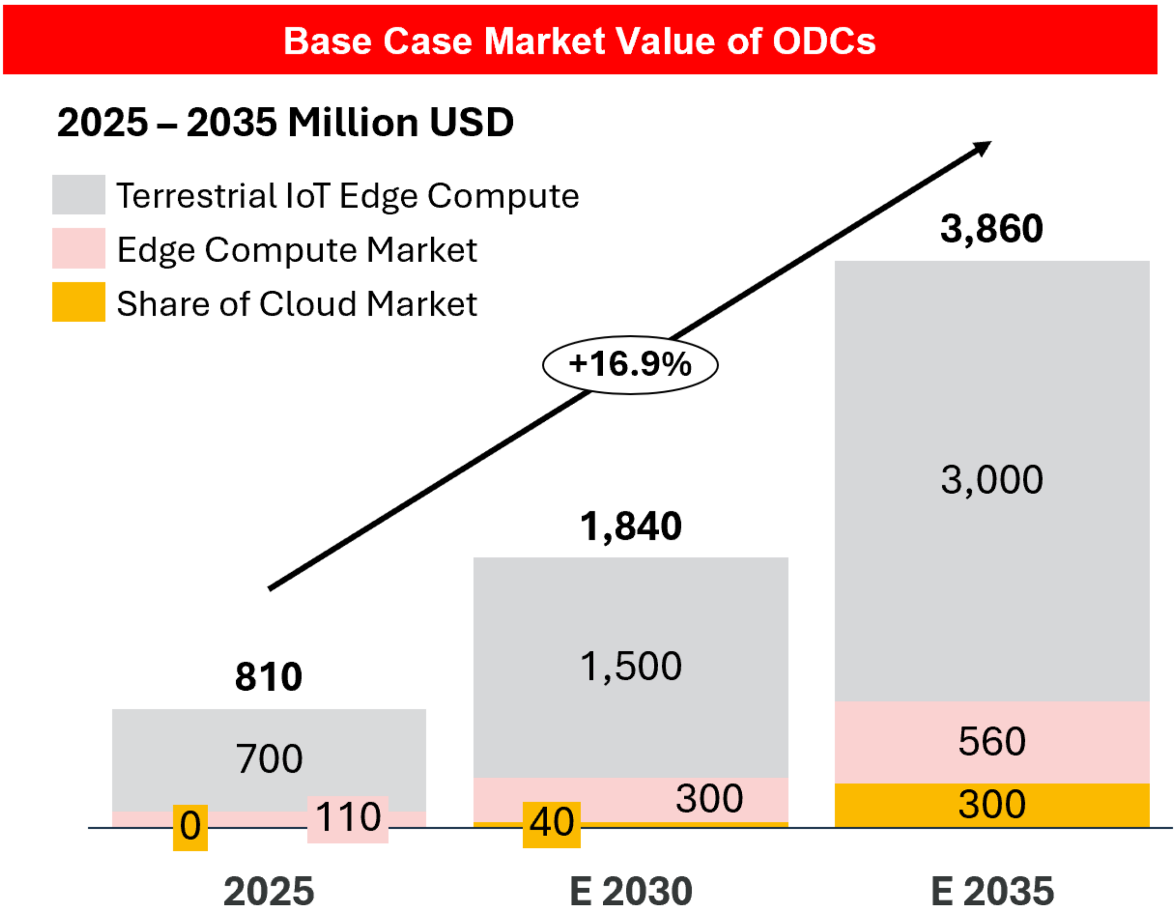
Metric	Bear Case	Base Case	Bull Case
Adoption use case	Mainly driven by demo missions	Strategic niche	Critical extension of the internet
Market size (annual)	**<$1B** (demo deployments, minimal commercial uptake)	**$2–4B** (Terrestrial IoT Edge Compute + Edge Compute only, limited cloud substitution)	**$20B+** (Terrestrial IoT Edge Compute + Edge Compute + up to 2% of global cloud captured)
ODC share of global cloud	~0%	~0.01%	~0.5–1%
Typical deployment	Isolated pilots, ISS-based payloads, sub-scale demonstrators	Dozens–hundreds of satellites (~1 MW capacity in orbit)	Multi-MW clusters in orbit; serviceable; hundreds of satellites with redundancy
Cost vs Earth (per CPU hour)	100×+ higher; uneconomic	~50–100× higher (launch + rad-hard premium still dominant)	~10× higher, falling (cheap launch + servicing narrowing gap)
Unit economics drivers	Launch costs >$1,000/kg; no servicing; high hardware failure risk; terrestrial breakthroughs outcompete	Launch costs $200–500/kg; steady defence and sovereign demand; partial servicing capability	Launch costs ~$100/kg or lower; frequent reusability (Starship-like economics); in-orbit servicing; ESG adoption push
Triggers	High launch costs, early failures, terrestrial data centres get greener/cheaper	Defence spend, early sovereign cloud, moderate launch cost drop	Cheap launch, hyperscaler entry, strong gov't backing, ESG/sovereignty drivers

Estimate Market Values based on Boston Consulting Group (BCG) report [20]:

- Terrestrial IoT Edge Compute Market estimated at $1.5B in 2030
- Edge Compute Market at $0.3B in 2030
- For the purposes of this report, 'Public Cloud' refers to global hyperscale and enterprise cloud spending (infrastructure + platform + storage) as of 2025, excluding private/enterprise-onsite data centres. The ~US$1.2 T figure is a conservative baseline prior to factoring in accelerated growth from agentic AI workloads.

Market Sizing: Our Base Case Scenario

We project the market for ODCs (full ODCs + on-board data processing + edge compute + cloud architectures) based on current infrastructure and market to reach $1.7 billion in 2030 and $3.8 billion by 2035, based on early defence and government spend and moderate launch cost drop.



Our base case assumes:

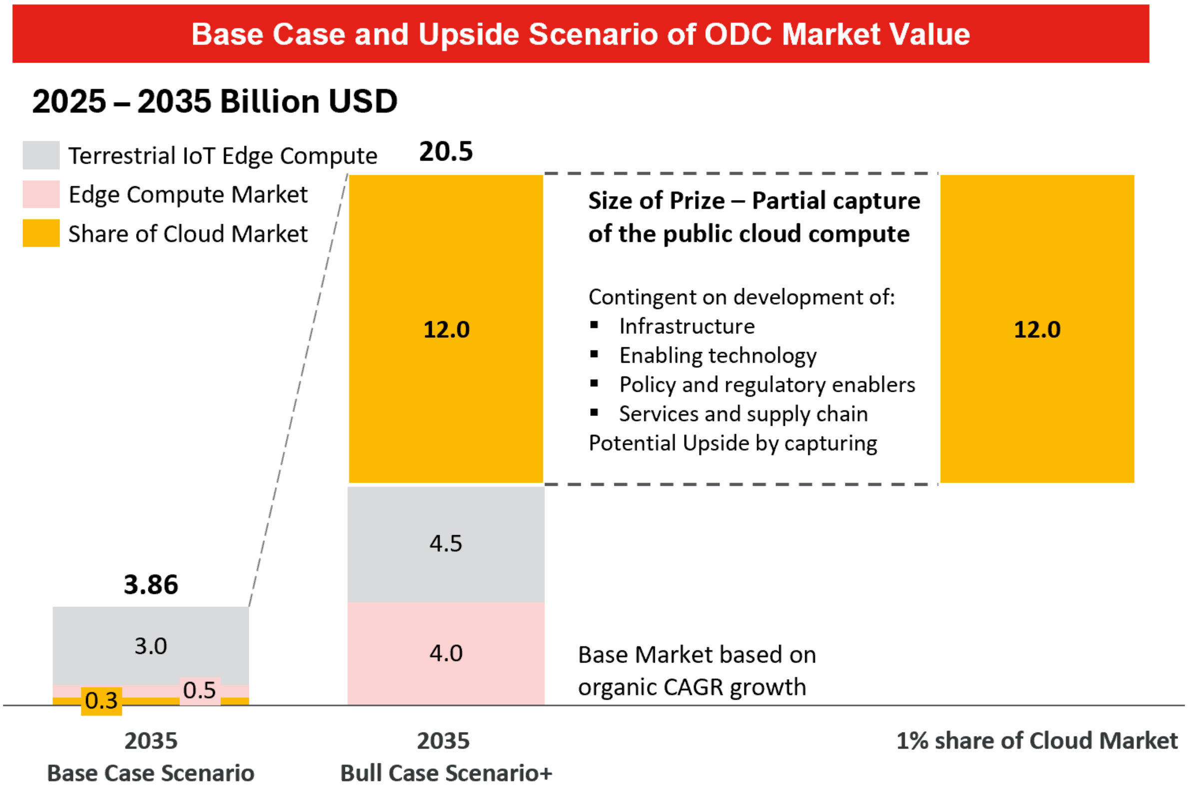
- Terrestrial IoT Edge Compute+ Space Edge Compute market value
- Launch costs $200–500/kg
- Steady defence and sovereign demand (sovereign cloud); partial servicing capability
- Limited cloud substitution for public use
- Assumes successful use of solar and radiative cooling; ODCs serve medium-power workloads (edge, data-preprocessing, storage), justified by the frameworks cited [21] [9] [10]

Sizing excludes:

- Any associated hardware revenues

Market Sizing: Our Bull Case Scenario

Our Bull Case market size projects a $20.5 billion market by 2035, contingent on having in place both on-orbit and on-ground infrastructure, along with associated services and supply chain – achievable by substantial reduction in launch costs, increased adoption by government and ESG impacts. [20] [22] [23] [24] [25]



Upside "Size of the Prize"

- Assumes GPU-class workloads become feasible in orbit thanks to high-density solar arrays and advanced radiator/cooling design, leveraging radiative cooling and space-based heat rejection, now supported by academic study and industry intent (e.g. Project Suncatcher, Starcloud).
- Represents revenues captured from major government anchor programmes (e.g. ISR "cloud in space") drive standardisation and scale.
- Based on BCG assessment: up to 1% of public cloud demand could migrate to in-space use cases under the right conditions.
- By 2035, this implies an additional $12B opportunity on top of the base market.
- Upside requires industry mobilisation plus government incentivisation to align timelines and investment.

Conditions for Realisation

- In-orbit as well as on-ground infrastructure deployment.
- Enabling Technology (i.e.) Radiation-tolerant processors.
- Policy & Regulatory: clear cybersecurity standards and compliance regimes.
- Associated services and supply chain.

Hypothesis and Assumptions Used

The market assessment is built on a set of explicit hypotheses and assumptions covering technology, adoption, regulation, sustainability, and long-term industrial migration.

Launch and Logistics economics

- Reusable launch systems (e.g., SpaceX Starship, Ariane Next) achieve cost-to-orbit reductions to below US$200/kg by early 2030s, enabling the economic deployment of orbital data centre (ODC) infrastructure. SpaceX projects Starship launch costs <US$200/kg in long-term planning [26]
- On-orbit logistics and servicing capabilities (refuelling, robotic maintenance) reach operational maturity by 2035, reducing lifecycle costs. Active servicing and assembly missions are already underway (Northrop Grumman MEV, ESA's EROSS IOD 2026 demo)

Reliability and Technical Maturity

- Radiation-hardened computing hardware achieves 3–5-year lifetimes, with fault-tolerant architectures minimising downtime. BIS Research forecasts US$1.8B space-based edge compute market by 2033 with growth contingent on hardened electronics [25]
- Optical inter-satellite links (OISLs) and high-throughput optical ground links become standard by 2030–2035, enabling ODCs to integrate with global networks. ESA's HydRON programme and Starlink's OISL deployments confirm trend [27]

Demand Drivers and Adoption Pathways

- Short-term (to 2030): Led by government/defence requiring sovereign, resilient data processing. BCG estimates US$270M by 2030 for initial defence-driven space edge services [20]
- Medium-term (2030s): Broader adoption by telecoms, EO, and sovereign cloud services. Global edge compute market projected US$424B by 2030; orbital will capture a fraction [28]
- Long-term (2040–2050): Industrial applications (semiconductors, orbital manufacturing, SBSP). UK's Space Forge demonstrated orbital semiconductor fabrication in 2024 [28]

Regulatory and Governance Evolution

- International frameworks for data sovereignty, liability, and debris management are formalised by 2030–2035, enabling wider adoption. UN COPUOS Long-Term Sustainability guidelines [29] and ESA space debris regulations are in motion
- Cybersecurity standards for orbital compute converge with terrestrial norms, supported by certification frameworks. WEF and ESA highlight orbital cyber vulnerabilities and the need for governance alignment [30]

Sustainability Imperatives

- Terrestrial data centres consume >415 TWh annually; orbital compute offers potential energy and water efficiency advantages. Terrestrial data centres now use ~2% of global electricity demand [31]
- Orbital compute becomes part of net-zero pathways, if launch emissions are offset. The EU ASCEND study showed space data centres could support climate goals if clean launch tech is developed

Industrial Migration Hypothesis (aspirational)

- By 2040s–2050s, part of global compute, manufacturing, and energy migrates off-Earth. ASCEND projects several € billion ROI by 2050 for 1 GW ODC capacity. [32]
- Requires breakthroughs in robotic in-orbit assembly, SBSP, and orbital servicing. ESA's SOLARIS and UK government SBSP studies confirm ongoing feasibility efforts

Strategic Opportunity for the UK

- **Operational advantage for defence**: Defence applications such as kill-chain acceleration, cyber resilience, and continuity of operations are likely to be the first to adopt ODC capabilities. These use cases offer clear value, stable demand, and alignment with national security priorities, making defence a natural anchor customer for early deployments.
- **Leadership in standards and regulation**: The UK has a strong track record in space law, cybersecurity, and regulatory innovation. By leading the development of international standards and frameworks for orbital compute, the UK can shape the rules of engagement, promote interoperability, and attract global partners.
- **Alignment with national policy**: ODCs support UK innovation and sustainability goals, offering opportunities for cross-sector collaboration, regional development, and economic growth. They align with initiatives such as the National Space Strategy, Net Zero targets, and digital infrastructure programmes.
- **Market potential**: Market sizing suggests the UK could capture a significant share of the projected £3.8B–£20.5B global ODC market by 2035, provided it acts decisively and strategically. Early investment, policy support, and industry mobilisation will be key to realising this opportunity.

Use Cases and Capabilities

Evolution of the ODC Market

The evolving ODC market can be traced across three clear stages: from recent technological advances, through major demonstrators and validations, to the large-scale projects and strategic movements now emerging.

2022-23

Technological Advances

- **Orbital edge AI/ML:** ESA's *Φ-Sat-1* enables AI inference in orbit [33]
- **High-speed connectivity:** Optical Inter-Satellite Links (OISLs) now widely deployed (e.g., Starlink, SDA Transport Layer), enabling distributed compute.
- **Hardened compute platforms:** HPE's *Spaceborne Computer-2* runs near-real-time compute on the ISS [34]

2023-24

Major Demonstrators & Validations

- **Axiom space:** plans to deploy its first two orbital data centre nodes by late 2027
- **Lonestar Data Holdings:** tested and operated a "Freedom Data Center" on the Moon and ISS, tackling challenges such as radiation, temperature extremes, and solar-powered operations [35]
- **Open Cosmos/ ESA:** *Φ-Sat-2* enables enhances AI and edge compute capabilities [36]
- **NASA / ISS missions:** HPE Spaceborne Computer-2 completed 2+ years of edge compute trials
- **AWS in orbit:** has demonstrated compute and ML services via D-Orbit/Unibap in orbit [37]

2024-25+

Large-Scale Projects and Movements

- **SES/ Intelsat Consolidation:** €2.8 bn acquisition strengthens its multi-orbit backbone for compute, connectivity, and storage [38]
- **Large Constellation** Programs (e.g., Amazon's Project Kuiper, Starlink) integrate optical ISLs and edge compute potential while expanding demand for orbital processing.
- **Relativity Space:** Ex-Google CEO Eric Schmidt acquired Relativity Space to support the development of ODCs [17]
- **China's Three-Body Constellation:** 2,800 satellites planned, each with AI supercomputer-grade processing (~744 TOPS per satellite).

Potential use cases for in-orbit data centres span multiple sectors, with near-term applications focused on efficiency and resilience, and longer-term visions centred on sovereignty, autonomy, and integration into critical global infrastructures.

	Today 2024-26	Next Step 2027- 2032	Future (2033+, if barriers fall)
Stage	**Hype, interest and experimentation**	**Niche and ultra high-value use cases**	**Mainstream adoption depending on uptake and cost breakthroughs**
Activities/ Adoption	Early terrestrial and ISS demonstrators on ISS/ Moon (Lonestar, HPE, AWS/ Unibap)	**Likely early adopters** • **Defence ISR/PED :** near real-time processing in orbit reduces tactical latency. • **EO pre-processing:** reduces bandwidth constraints, faster response in disasters. • **Ultra-secure sovereign data storage:** "data embassies" beyond Earth jurisdiction. • **Disaster response & resilience:** back-up compute infrastructure insulated from terrestrial outages.	**Potential mainstream sectors:** • Commercial cloud extension for latency-sensitive AI/ML. • Large-scale sovereign cloud deployments. • Industrial migration: manufacturing, SBSP integration.
Customer Signals	Governments funding pilots (defence ISR, disaster monitor)	Larger government contracts (defence driven); commercial dual-use driven funding	Governments funding pilots (defence ISR, disaster monitor)
Why in space?	Experimentation phase to validate latency reduction, resilience, and secure data sovereignty benefits.	These use cases justify high-cost premiums due to sovereignty, resilience, or operational criticality.	Cost reduction (launch <$200/kg, modular servicing) + ESG pressure (low water/energy use vs terrestrial data centres).

During the September workshop hosted by SAC and Bird & Bird, participants and panellists explored both near-term and longer-term use cases for orbital data centres (ODCs). These discussions reflected a range of perspectives on how ODCs might evolve to meet emerging needs in data processing, security, and sustainability. The host team compiled the ideas shared into a consolidated list, which captures the breadth of potential applications identified during the session.

Near-Term Use Cases

- **Edge AI for ISR and environmental monitoring**: This use case involves deploying artificial intelligence algorithms directly on satellites to process data at the point of collection. It enables rapid analysis of imagery and sensor data for applications such as military surveillance, wildfire detection, flood monitoring, and infrastructure assessment. By reducing the need to transmit raw data to Earth, it improves latency, lowers bandwidth costs, and supports faster decision-making.

- **Hosted compute for multi-client payloads**: Orbital platforms equipped with general-purpose GPUs or CPUs can be shared across multiple users, allowing organisations to rent compute time rather than launching dedicated hardware. This model lowers barriers to entry for smaller companies and research institutions, promotes service-based business models, and increases utilisation of orbital assets.

- **Cybersecurity and sovereign data backup**: ODCs can serve as secure, off-planet repositories for sensitive data, including government records, financial systems, and critical infrastructure backups. By implementing zero-trust architectures and strong data provenance protocols, they offer enhanced protection against cyber threats, physical disasters, and geopolitical disruptions.

- **Low-latency mobile applications**: Orbital compute can support direct-to-device connectivity for mobile users, particularly in remote or underserved regions. By processing data closer to the user and reducing reliance on terrestrial infrastructure, it enables faster access to services such as navigation, emergency alerts, and real-time communications.

- **Testing of capability in space prior to launch**: Startups and SMEs often face high barriers when transitioning from ground-based testing to orbital deployment. Hosted payloads and shared test platforms allow them to validate software, algorithms, and hardware in space conditions before committing to full-scale missions. This reduces risk, accelerates development, and improves investor confidence.

- **Space domain awareness (SDA)**: SDA involves monitoring and understanding activities in orbit, including satellite movements, debris tracking, and potential threats. In-orbit compute enables real-time fusion of sensor data, autonomous detection of anomalies, and faster dissemination of insights to operators and decision-makers.

- **Emergency management and disaster response**: ODCs can support rapid analysis of satellite imagery and sensor data during crises such as earthquakes, hurricanes, and wildfires. By enabling near real-time insights, they improve coordination among responders, optimise resource allocation, and enhance situational awareness.
- **Real-time EO data triage and compression**: Earth observation missions generate vast volumes of data, much of which is redundant or low priority. In-orbit compute can triage and compress this data before transmission, reducing bandwidth requirements, lowering costs, and ensuring that critical insights reach users faster.

Longer-Term Use Cases

- **Space-to-space cloud for deep space missions**: As human and robotic missions expand beyond low Earth orbit, latency constraints make Earth-based compute impractical. ODCs can provide local processing capabilities for lunar bases, Mars missions, and interplanetary spacecraft, supporting autonomy, navigation, and scientific analysis.
- **Orbital data archiving and embassy concepts**: These concepts involve creating resilient, sovereign infrastructure in space to store critical data and support continuity of operations. In the event of terrestrial disruptions, governments and organisations could access secure backups and maintain essential services from orbit.
- **Quantum computing in space**: The space environment offers natural advantages for quantum systems, including low temperatures and isolation from terrestrial noise. ODCs could host quantum processors for applications such as cryptography, optimisation, and simulation, unlocking new capabilities in science and security.
- **Radiation intelligence and geospatial analytics**: Satellites equipped with radiation sensors can collect valuable data for space weather forecasting, environmental monitoring, and health applications. In-orbit processing enables faster analysis and integration with other datasets, supporting decision-making across sectors.
- **Zero Trust Architecture for space data**: As orbital networks become more complex and interconnected, ensuring data integrity and security is paramount. Implementing zero-trust principles in space, where every transaction is verified and authenticated, can protect against spoofing, tampering, and unauthorised access.
- **Resilience of global data networks**: Much of the world's internet backbone relies on undersea cables, which are vulnerable to disruption. ODCs can provide alternative routing and backup capabilities, enhancing the robustness of global communications and reducing dependence on terrestrial chokepoints.
- **Golden Dome defence applications**: Inspired by terrestrial missile defence systems, this concept envisions a protective layer of orbital infrastructure capable of detecting and responding to threats. ODCs would play a central role in processing sensor data, coordinating responses, and maintaining situational awareness.
- **Orbital manufacturing and industrial migration**: In the long term, high-impact industrial processes, such as semiconductor fabrication, pharmaceutical production, and materials research, could be relocated to orbit. ODCs would support these activities by providing compute power for automation, quality control, and data analysis, while reducing environmental burdens on Earth.

Frictions and Risks

Technical Challenges

- **Lifecycle mismatch**: The rapid pace of innovation in compute hardware, particularly in AI and edge processing, means that orbital systems must be designed to accommodate upgrades and replacements more frequently than traditional satellite platforms. Without modularity or in-orbit servicing, systems risk becoming obsolete before their operational life ends.
- **Uplink bottlenecks**: Even with onboard processing, transmitting data to Earth remains a challenge. Spectrum availability is limited, and licensing processes are slow and fragmented across jurisdictions. This creates delays and restricts the volume of data that can be shared with terrestrial systems.
- **Radiation and thermal management**: Space presents a harsh environment for electronics. Radiation can degrade components and corrupt data, while thermal extremes require sophisticated cooling systems. These engineering challenges must be addressed to ensure reliability, longevity, and scalability of ODC platforms.
- **Infrastructure gaps**: The current orbital ecosystem lacks sufficient terminals, relays, and servicing capabilities to support widespread deployment of ODCs. Building out this infrastructure will require coordinated investment in launch capacity, satellite buses, and in-orbit logistics.
- **Cloud integration**: Seamless connectivity between orbital and terrestrial cloud systems is essential for user adoption. This requires standardised APIs, secure data protocols, and robust interoperability frameworks to ensure that orbital compute can plug into existing digital workflows.

Market and Investment Barriers

- **Lack of flagship use case**: Without a high-profile, repeatable demonstration of value, many stakeholders remain sceptical. A compelling use case, such as disaster response or defence ISR, could serve as a catalyst for broader adoption and investment.
- **Fragmented funding**: The UK's innovation landscape is characterised by siloed budgets and long procurement cycles. This fragmentation slows progress and makes it difficult for startups to navigate the system. Coordinated funding across departments and agencies is needed to accelerate development.
- **Launch dependency**: Many business models assume continued access to low-cost launch services, often from a single provider. This creates a single point of failure and exposes projects to delays, cost increases, and geopolitical risks. Diversifying launch options and investing in domestic capacity will be critical.
- **Limited VC appetite**: Venture capital in the UK tends to be risk-averse, particularly in deep tech and space. Liquidity challenges and long-time horizons make it difficult for startups to secure funding. Public-private co-investment models and innovation-friendly procurement can help bridge this gap. Notably, VC follows credible demand; anchor contracts for sovereign use cases de-risk and crowd-in private capital.
- **High CAPEX and uncertain ROI**: Building and launching orbital infrastructure is expensive, and returns are often delayed or uncertain. Without clear pathways to revenue, many investors hesitate. Demonstration missions, anchor customers, and service-based models can help de-risk investment.
- **Unclear business models**: The market for orbital compute is still emerging, and many potential customers are unfamiliar with its capabilities. Business models must be refined to address pricing, service tiers, and integration with existing workflows. Education and engagement will be key.

Regulatory Complexity

- **Jurisdictional ambiguity**: Space law is still evolving, and questions remain about who owns data, who is liable for failures, and how disputes are resolved. These uncertainties create risk for operators and investors, and must be addressed through international agreements and national legislation.

- **Export controls and sovereignty**: Many countries impose strict controls on space technology and data, limiting collaboration and market access. Navigating these regulations requires specialised legal expertise and proactive engagement with policymakers.

- **Lack of standards**: Without universal standards for orbital compute, interoperability is limited and integration is costly. Early development of technical, operational, and security standards will support scalability and reduce friction.

- **Cybersecurity concerns**: As orbital systems become more connected, they become more vulnerable. Ensuring data provenance, integrity, and confidentiality is essential, particularly for defence and critical infrastructure applications. This requires robust encryption, authentication, and monitoring protocols.

- **Spectrum and liability**: Access to radio frequencies is tightly regulated, and liability for interference or damage is complex. Reforming spectrum allocation processes and clarifying liability regimes will be necessary to support growth and innovation.

Strategic Enablers

Defence and Government Procurement

- **Immediate value:** Defence use cases such as kill-chain acceleration, space domain awareness, and cyber resilience offer clear operational benefits and are aligned with national security priorities. These applications are likely to be the first to adopt ODC capabilities, providing a stable and strategic demand base that can anchor early deployments and justify public investment.

- **Pooled funding:** Coordinated funding across government departments, such as defence, science, innovation, and infrastructure, can reduce duplication, increase efficiency, and accelerate progress. By pooling resources and aligning objectives, the UK can support cross-cutting initiatives that benefit multiple sectors and stakeholders.

- **Dual-use leverage:** Many orbital compute applications serve both civil and defence needs. For example, Earth observation data can support both military surveillance and environmental monitoring. Leveraging these dual-use opportunities can unlock broader investment, attract commercial partners, and increase the return on public spending.

- **Procurement as catalyst:** Government procurement can play a catalytic role in market development by validating technologies, creating demand signals, and de-risking innovation. Challenge-led procurement models, milestone-based contracts, and innovation-friendly frameworks can support startups and SMEs, stimulate competition, and accelerate adoption.

Modular Infrastructure and Standards

- **Standardisation**
  Developing common satellite buses, interfaces, and protocols can reduce integration costs, improve interoperability, and support scalability. Standardisation enables plug-and-play architectures, simplifies mission planning, and facilitates collaboration across organisations and borders.

- **Open platforms**
  Open-source software environments and shared development tools can accelerate innovation, reduce duplication, and foster community engagement. By promoting transparency and collaboration, open platforms can support rapid prototyping, testing, and deployment of orbital compute applications.

- **Interoperability**
  Multi-client architectures and interoperable systems are essential for scalability and flexibility. Ensuring that different platforms, payloads, and services can work together seamlessly will enable a diverse ecosystem of users, providers, and applications.

- **Federated models**
  Shared constellations and federated infrastructure models can reduce capital expenditure, increase utilisation, and promote collaboration. These models allow multiple stakeholders to share resources, coordinate operations, and benefit from economies of scale.

- **Servicing and upgrades**
  Robotic maintenance, in-orbit servicing, and modular designs can extend asset lifetimes, reduce costs, and support technology refresh. These capabilities are critical for addressing the lifecycle mismatch between satellites and compute hardware, and for enabling long-term sustainability.

Education and Awareness

- **Sector bridging**
  Bridging the gap between the space and IT sectors is essential for adoption and innovation. Cross-sector collaboration can unlock new use cases, integrate orbital compute into existing workflows, and build a shared understanding of opportunities and challenges.

- **Public engagement**
  Engaging the public, particularly younger generations and sustainability-conscious users, can build support, drive demand, and shape the narrative around orbital compute. Education campaigns, outreach programmes, and storytelling can highlight the benefits and inspire participation.

- **Talent development**
  Developing a skilled workforce with expertise in space engineering, cloud computing, cybersecurity, and data science is critical for long-term success. Education and training programmes, apprenticeships, and interdisciplinary initiatives can build cross-sector fluency and support career pathways.

- **Campaigns and outreach**
  Public-private initiatives, industry events, and media engagement can raise awareness, build trust, and promote adoption. These efforts should highlight real-world use cases, showcase success stories, and address concerns around cost, risk, and regulation.

- **Transparent messaging**
  Clear, consistent, and transparent communication of benefits, risks, and opportunities is key to stakeholder buy-in. Messaging should be tailored to different audiences, including policymakers, investors, users, and the public, and should emphasise value, impact, and alignment with national goals.

Recommendations

We recommend establishing a dedicated working group of interested parties to accelerate the UK's strategy for ODCs. This group should focus on identifying and refining use cases, addressing technical and regulatory challenges, mapping market and investment barriers, and defining strategic enablers. Its primary output should be a detailed roadmap that sets out priorities, timelines, and actions for UK leadership in this emerging domain.

Organisations and stakeholders wishing to participate in this initiative are invited to contact the Satellite Applications Catapult to join the working group.

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Appendix

Acknowledgements

This whitepaper is the result of a collaborative effort across the Satellite Applications Catapult:

- **Anja Frey,** Beyond Earth Mission Manager
- **Ricky D'Costa,** Strategy & Consulting Team

We would like to thank our event partners Bird & Bird and the organising committee for their insights, support and engagement with the workshop and the revision of this whitepaper.

Equally, we would like to acknowledge contributions during the workshop from individuals from the following organisations, who gave up their time to drive the formation of this piece:

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Airbus Defence & Space	Philip Allen	Programme Manager
Amentum	Chris Brunskill	Principal Consultant - Space
Analysys Mason	Antoine Grenier	Partner
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