

What if AI data centres were put in space?



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Despite massive investment, AI data centres are increasingly running into constraints, particularly with regard to electricity, leading to suggestions to put them in orbit. While this makes it possible to take advantage of abundant solar power, it also comes with significant challenges. The main barrier is economic, rather than technical, with future launch costs a key determinant. Space data centres pose important questions on data and orbital regulation and sustainability, which may require updating or clarifying existing digital and space treaties and legislation.

Introduction

The past few years have seen considerable interest in generative AI, particularly large language models (LLMs). This has translated into [massive investment](#) amounting to hundreds of billions of euros per year, especially in the US, in AI data centres designed around Graphics Processing Unit (GPU)-based platforms. Such breakneck expansion is increasingly running into constraints, particularly with regard to electricity availability.

Running AI models requires large amounts of [power](#) (as well as [water](#), much of which is used to produce the electricity required), with data centres responsible for 1.5 % of global electricity consumption (2 % in the EU) and growing at 12 % annually. Moreover, they are often geographically concentrated, for example in [Ireland](#), where they account for over 20 % of electricity consumption. Future scenarios suggest that this demand could continue to increase rapidly, although this should be taken with the caveat that investment in AI might be a [bubble](#), LLMs may be supplanted by other [models](#) with different compute needs, and chip design [innovations](#) beyond GPUs may provide energy efficiency gains.

This situation has given rise to the idea of deploying compute in space to take advantage of the free, abundant solar energy. Originally focused on [orbital processing](#) of observational data and space mission support, the concept has rapidly evolved into the deployment of AI data centres in orbit to service ground-based needs. Recently, the strongest push has come from the US, with the [merger](#) between SpaceX and xAI linked to a request to put a [million](#) satellites in orbit, as well as interest from Google with project [Suncatcher](#), and startups such as [Starcloud](#) and [Axiom](#). Meanwhile, [China](#) has also launched pilot satellites intended to be the first in a future constellation, and in the EU the Horizon Europe-supported [ASCEND](#) project has concluded a feasibility study, aiming towards an operational system from 2030.

Potential impacts and developments

Launch costs represent a key constraint for any orbital infrastructure. The introduction of reusable rockets has led to a considerable [decrease](#) in recent times, to around several thousand euros per kilo of payload. This reduction is expected to [continue](#) thanks to improved heavy rockets and reusable second stages, with the European Space Agency (ESA) aiming for €280/kg with a new [super-heavy lift launcher](#). Most ideas for future space data centres would involve either large constellations or modular construction, allowing build-up to occur over time. Even so, this would require a very high launch cadence, with a complete data centre likely needing upwards of one hundred launches, followed by a significant proportion yearly to replace satellites at end of life; this compares to around [300](#) space launches overall in 2025.

The main attraction of placing data centres in space is solar power: for objects located above the atmosphere, insolation (incoming solar radiation) can be several times greater than on the ground. The ideal choice would be a terminator [sun-synchronous orbit](#), allowing satellites to keep pace with the dawn/dusk line and ensuring constant solar exposure on one side, while keeping the other dark to assist with cooling. Solar panels would need to be very large – up to a gargantuan 4 km per side, as [envisaged](#) by Starcloud for a 5 GW data centre; a small satellite with the equivalent of a server rack might make do with a more manageable 60 m² and 28 kW, as [deployed](#) on the International Space Station (ISS). Newer thin-film solar panel [technology](#) may help keep the weight down.

If power is the main advantage, cooling is possibly the major challenge. Although space is cold, it is also a vacuum, meaning cooling can only take place via radiative emission. This can be achieved by coupling a coolant loop (the ISS uses ammonia) with large radiators pointing towards deep space, which would be of comparable size to the solar panels but considerably [heavier](#). The spacecraft's cooling system is particularly vulnerable: any rupture, for example from a meteoroid strike, can cause coolant loss and damage the electronic systems. Given radiative cooling scales as the fourth power of temperature, further advances may come from lighter radiators running at higher temperatures. The other main concern in orbit is radiation, which can cause random bit flips and whose impact over time can lead to a degradation of performance or malfunction. Recent work from [Google](#) and Starcloud, which has [deployed](#) a NVIDIA H100 chip in orbit, has given promising indications, but fault tolerance, error correction, redundancy (deliberate duplication of critical components or systems), and shielding are all required.

Any assembly or maintenance would pose a significant challenge. Heavy AI workloads can lead to relatively high [chip failure rates](#), which, added to radiation effects, imply short lifespans of a few years. Depending on the concept, this would require redundancy or satellite replacement, with a weight or cost penalty, or else robotic maintenance in orbit, which still needs further development. Finally, there is the issue of communications. Large amounts of data from the ground, to be used for training, may simply be physically carried by '[data shuttles](#)', while server-side communications, needing high data rates, could use [optical communication](#) between satellites, in turn implying close proximity. Google's plans, for example, envisage satellites hundreds of metres apart. With space debris and collisions being a critical [issue](#), this would represent a major challenge in terms of the coordination of collision avoidance manoeuvres, which may be frequent given the sizes of the constellations being proposed.

Anticipatory policymaking

Deploying data centres in space poses important challenges, but does not appear to face insurmountable technical barriers and might be feasible even with current technology. The main hurdle is rather economic, with a mildly optimistic [estimate](#) placing near-future costs around three times those on the ground, although opinions are divided on whether such optimism is [justified](#) or [not](#). Further innovation could help, with the evolution of launch costs a key determinant. This may lead to interesting synergies, with further technological and skills development benefiting other potential uses of space such as [space-based solar power](#).

The current legal framework leaves space data centres in a [grey zone](#): the United Nations' [Outer Space Treaty](#) establishes no sovereignty in outer space, with launch states (a concept that presents its own [issues](#)) instead bearing responsibility and liability for space activities. Drafted in the 1960s, this treaty lacks explicit provisions regarding data. Article VIII of the treaty refers to jurisdiction over a space 'object, and over any personnel thereof', which has prompted some stakeholders to urge regulators to explicitly consider the concept of a '[digital flag state](#)'. Furthermore, relevant laws and treaties relying on the territorial location of data may require clarification. Examples include the [GDPR](#)'s concept of transfers of personal data to third countries and the recently signed UN [Convention against Cybercrime](#), which includes ships and aircraft but not satellites under its jurisdictional provisions. Likewise, legislation dealing with space activities may need to account for considerable processing of data originating from the ground rather than space. Extending the definition of space-based data and primary providers of space-based data in the [Space Act](#), for example, could offer additional clarity. The overall situation is complex, involving potential multiple layers of overlapping jurisdiction. In the future, [in-orbit assembly](#) and AI agents risk further increasing this complexity. These issues highlight that [extraterritorial](#) application, as conceived in the GDPR or the Space Act, will be a crucial factor in the future regulation of space data centres.

The potential scale of orbital data centres is also important to consider. A 1 GW data centre, similar in scale to the largest under construction on the ground, could require a total payload upwards of 10 000 tons, or over three times the total payload mass launched in [2025](#). This risks potential infrastructure bottlenecks, such as the limited availability of launch facilities or liquid oxygen. It also raises sustainability questions, given that lifetime emissions may be [larger](#) than on the ground. Furthermore, the [pollution](#) of the upper atmosphere that would be caused by de-orbiting large numbers of end-of-life satellites is still poorly understood. Finally, it poses a critical, geopolitically relevant question regarding orbital [congestion](#), as international regulation of slots in low Earth orbit is currently only done indirectly through radio spectrum [assignment](#) by the International Telecommunications Union, generally on a first-come, first-served basis.

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