

NEWS RELEASE

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NTU Singapore scientists propose carbon-neutral data centres in space

Study shows how satellites could harness unlimited solar energy and the cold vacuum of space to power a greener digital future

An out-of-this-world idea: placing data centres in space could pave the way for sustainable computing with unlimited solar energy and free cooling, says scientists from **Nanyang Technological University, Singapore (NTU Singapore)**.

The researchers outline a practical path to building carbon-neutral data centres in Low Earth Orbit (LEO), a concept particularly relevant to land-scarce cities like Singapore, where limited land and high real estate costs make conventional data centres increasingly expensive.

Published in the peer-reviewed journal *Nature Electronics*, the study presents a framework for how satellites equipped with advanced processors could serve as orbital edge and cloud data centres.

Led by **NTU Associate Provost (Graduate Education) Professor Wen Yonggang**, who is the **Alibaba-NTU President's Chair in Computer Science and Engineering**, the new paper asserts that space offers two unparalleled environmental advantages, virtually unlimited solar energy and natural radiative cooling enabled by the extreme cold temperatures.

Together, these conditions could enable orbital data centres to operate with net-zero carbon emissions. The timing is crucial, as AI-driven computing demand is projected to rise by 165 per cent by 2030¹.

In Singapore, data centres already account for about seven per cent of national electricity use, a figure expected to reach 12 per cent by 2030².

¹ Goldman Sachs Research. (2025, February 4). *AI to drive 165% increase in data centre power demand by 2030*. Goldman Sachs Insights. <https://www.goldmansachs.com/insights/articles/ai-to-drive-165-increase-in-data-center-power-demand-by-2030.html>

² Infocomm Media Development Authority (IMDA). (2025, February). *Turning the red dot, green: Helping data centres get better at staying cool*. IMDA Blog. <https://www.imda.gov.sg/resources/blog/blog-articles/2025/02/red-dot-analytics-help-data-centres-be-cool>

“Space offers a true sustainable environment for computing. We must dream boldly and think unconventionally, if we want to build a better future for humanity,” said Prof Wen, who also holds the role of **Dean, Graduate College** and is a faculty member from the **College of Computing and Data Science**.

“By harnessing the sun’s energy and the cold vacuum of space, orbital data centres could transform global computing. Our goal is to turn space into a renewable resource for humanity, expanding AI capacity without increasing carbon emissions or straining Earth’s limited land and energy resources,” explains Prof Wen, a serial innovator who first invented and demonstrated multi-screen casting technology in 2013, now widely used across computers, tablets, mobile phones and TVs.

Harnessing the physics of space for sustainability

Unlike Earth-based data centres that struggle with cooling and power demand, particularly in dense urban environments where both energy and land are limited, space facilities could rely entirely on sunlight for power and dissipate heat directly into deep space, which has an average temperature of 2.7 Kelvin (–270.45 degrees Celsius).

This makes space an ideal environment for high-performance computing. Low Earth Orbit (LEO), located roughly 160 to 2,000 kilometres above Earth, offers a cost-effective altitude already used by many commercial satellite systems.

The team has proposed two models in which this concept could work:

1. **Orbital Edge Data Centres** – Imaging or sensing satellites equipped with AI accelerators could process raw data directly in orbit, transmitting only the essential processed information to Earth. This approach can reduce data transmission volumes by over a hundred times, significantly lowering energy consumption and latency.
2. **Orbital Cloud Data Centres** – Constellations of satellites fitted with servers, broadband links, solar panels and radiative coolers could collectively perform complex computing tasks, from scientific simulations to AI model training.

The researchers noted that rather than building a single massive facility in space, these distributed constellations are technologically feasible with today’s satellite and computing advancements and could be scaled up over time.

To validate the carbon-neutral potential of such a system, the team worked with NTU deep tech spin-off **Red Dot Analytics** – co-founded by Prof Wen – to develop a digital twin model of the space-based data centre.

Their virtual model simulated expected power consumption, cooling and solar energy generation, showing that the cold vacuum of space will allow heat to be released more efficiently than on Earth.

Land scarcity and increasing costs of building data centres

The study notes that land and energy constraints make data centres costly in cities like Singapore, the world's second most expensive market for such facilities³, with costs averaging US\$13.80 per watt of IT load or about US\$11.7 million per megawatt.

High land prices, infrastructure costs and power-supply limits constrain physical expansion, prompting renewed interest in sustainable, space-efficient alternatives.

In contrast, orbital data-centre models avoid these constraints, requiring no physical land, minimal cooling infrastructure, and offering global scalability without geographical limitations.

Life-cycle sustainability and technological readiness

While rocket launches remain carbon-intensive, the NTU study introduces a new metric, **life-cycle carbon usage effectiveness (CUE)**, which showed that solar-powered orbital data centres could offset their launch emissions within a few years of operation.

Advances such as reusable rockets, electrical slingshot launchers, radiation-hardened electronics and space-qualified chips are also accelerating progress.

Companies like AMD have already developed space-grade processors⁴, while NTU's deep-tech spin-off **Zero Error Systems** provides fault-tolerant semiconductor technology⁵ that allows consumer-grade hardware to operate reliably in space.

NTU Vice President (Innovation and Entrepreneurship) Professor Louis Phee said the study reflects the innovative spirit that NTU nurtures in its students and scientists.

"To tackle humanity's greatest challenges, we need creative and interdisciplinary researchers working hand in hand with entrepreneurs," said Prof Phee.

"Over the past decade, NTU has built a strong foundation of patents and technology spin-offs that are poised to tap emerging trends such as sustainable computing and the space economy. These efforts are opening new markets for Singapore and reinforcing our leadership in sustainability and advanced computing."

This research reflects NTU Singapore's commitment to addressing global challenges through innovation and sustainable technologies, as part of its Sustainability Manifesto.

³ **Singapore Business Review.** (2024, October 9). *Singapore emerges as the world's 2nd most expensive data centre market.* Singapore Business Review. <https://sbr.com.sg/information-technology/news/singapore-emerges-worlds-2nd-most-expensive-data-centre-market>

⁴ AMD. (2022, November 15). *AMD announces completion of Class B qualification for first space-grade Versal adaptive SoCs enabling on-board AI processing in space.* AMD Newsroom. <https://www.amd.com/en/newsroom/press-releases/2022-11-15-amd-announces-completion-of-class-b-qualification-.html>

⁵ Zero Error Systems. (2025, February 27). *ZES debuts radiation-tolerant System-on-Module for space applications.* Zero Error Systems. <https://zero-errorsystems.com/zes-debuts-radiation-tolerant-system-onmodule-for-space/>

NTU is ranked 5th globally and 1st in Asia for the subject of Data Science and Artificial Intelligence in the 2025 QS World University Rankings by Subject.

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Media contact:

Lester Kok
Senior Assistant Director
Corporate Communications Office
Nanyang Technological University, Singapore
Tel: +65 6790 6804
Email: lesterkok@ntu.edu.sg

About Nanyang Technological University, Singapore

A research-intensive public university, Nanyang Technological University, Singapore (NTU Singapore) has 35,000 undergraduate and postgraduate students in the Business, Computing & Data Science, Engineering, Humanities, Arts, & Social Sciences, Medicine, Science, and Graduate colleges.

NTU is also home to world-renowned autonomous institutes – the National Institute of Education, S Rajaratnam School of International Studies and Singapore Centre for Environmental Life Sciences Engineering – and various leading research centres such as the Earth Observatory of Singapore, Nanyang Environment & Water Research Institute and Energy Research Institute @ NTU (ERI@N).

Under the NTU Smart Campus vision, the University harnesses the power of digital technology and tech-enabled solutions to support better learning and living experiences, the discovery of new knowledge, and the sustainability of resources. Ranked amongst the world’s top universities, the University’s main campus is also frequently listed among the world’s most beautiful. Known for its sustainability, NTU has achieved 100% Green Mark Platinum certification for all its eligible building projects. Apart from its main campus, NTU also has a medical campus in Novena, Singapore’s healthcare district.

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