MAKING SPACE FOR OFF-EARTH CLOUD COMPUTING INFRASTRUCTURE

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BILLIONS FOR AI DATA CENTERS

BUSINESS

Meta to spend up to $65B on massive AI data center: ‘Defining year for artificial intelligence’

By Reuters

Published Jan. 24, 2025, 11:31 a.m. ET

Microsoft to spend $80bn on AI data centers in 2025

Company says US will have to be smart to win AI race with China

January 06, 2025 By: Matthew Gooding Have your say

Google expects 2025 capex to surge to $75bn on AI data center buildout

xAI raises another $6 billion for supercomputing environment Colossus

It may be even bigger than its $9 billion predecessor

DOD DOD CLOUD CLOUD

The Pentagon is developing a follow-on to the $9 billion Joint Warfighting Cloud Capability contract vehicle it awarded in 2022 to cloud-service providers Amazon Web Services, Google, Microsoft and Oracle.

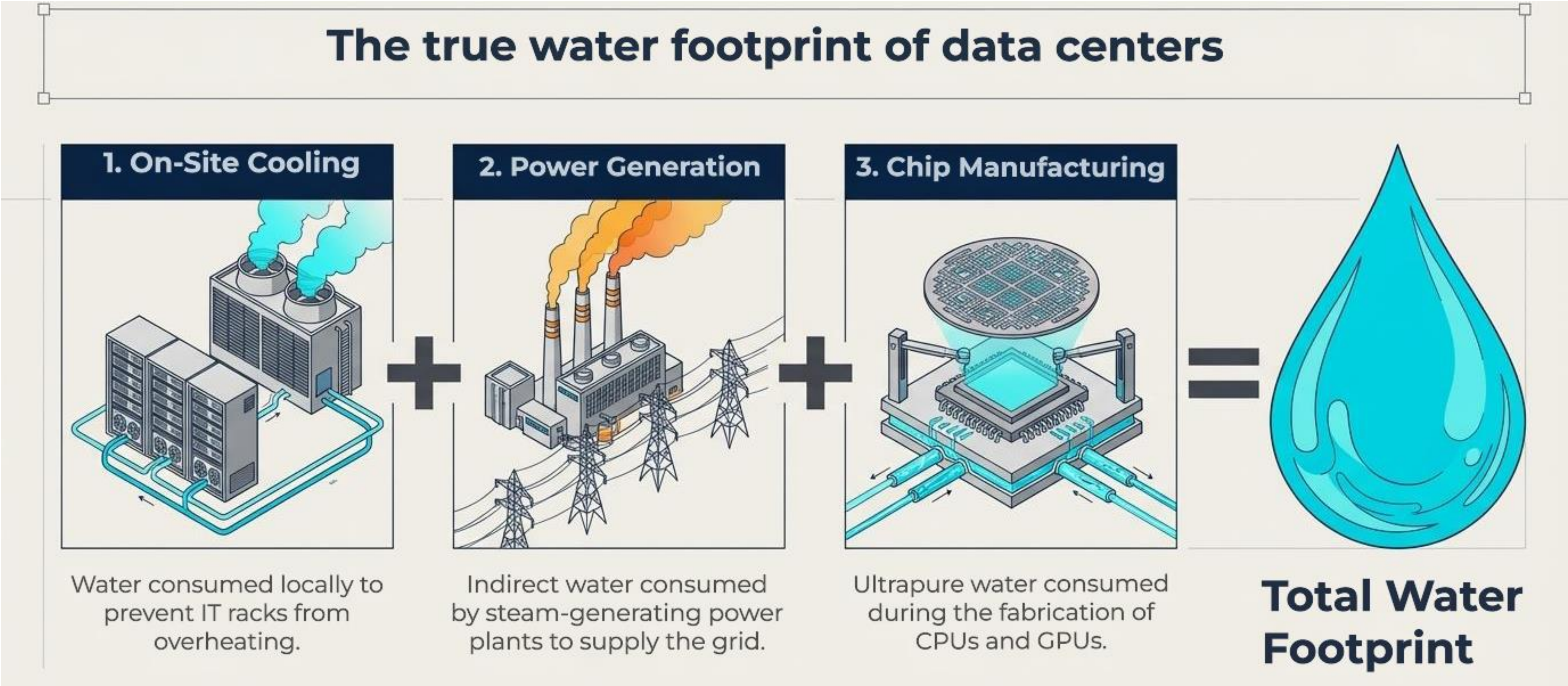
The Pentagon’s sequel to JWCC — dubbed JWCC Next — will similarly be a multi-award contract “but at a bigger scale” than its predecessor, according to John Hale, product management and development chief at the Defense Information Systems Agency.

Amazon to Invest $100B in AI Data Centers Over Next Decade

Amazon plans to invest $100B in new data centers to bolster its AI infrastructure and maintain its lead in the cloud computing market.

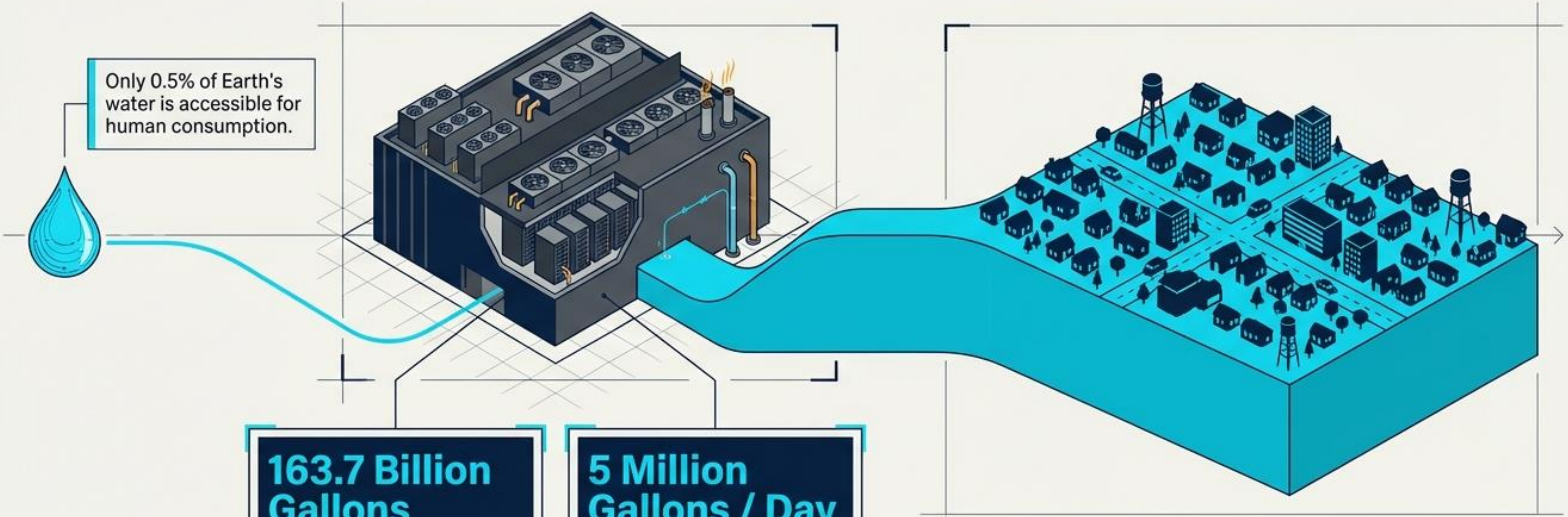
GROWTH OF TERRESTRIAL DATA CENTERS IS AN EMERGING CRISIS

- **$10B (or more)** to build hyperscale centers
- **Enormous** geo-footprint
- **$50-100M** annual operating costs
- **10%** of annual energy use by 2030
- **Water budget** ~ mid-sized US city
- **Significant** thermal, noise, and carbon footprint
- **Vulnerable** to hostile attacks
- **Limited by** bandwidth and latency, restricting use for global coordination, military and space missions


The true water footprint of data centers
1. On-Site Cooling
Water consumed locally to prevent IT racks from overheating.
2. Power Generation
Indirect water consumed by steam-generating power plants to supply the grid.
3. Chip Manufacturing
Ultrapure water consumed during the fabrication of CPUs and GPUs.
Total Water Footprint

The thirst of digital infrastructure rivals entire municipalities.

Only 0.5% of Earth's water is accessible for human consumption.



163.7 Billion Gallons

Total annual water consumption of the 5,426 U.S. data centres.

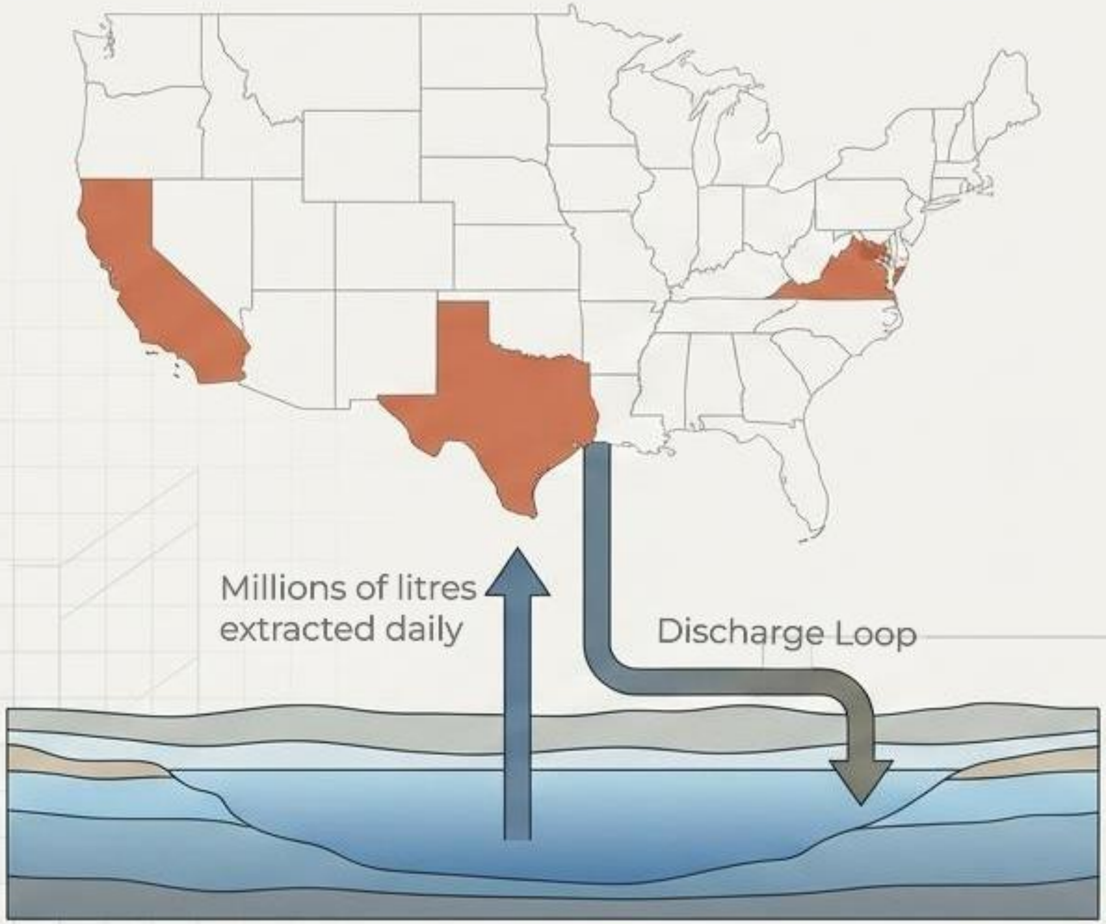
5 Million Gallons / Day

The peak water draw of a single large data centre.

5 million gallons a day is equivalent to the water usage of a town populated by 10,000 to 50,000 people. Humans can only survive three days without it.

Localized Cost of Global Compute

Data centres process global digital requests, but their environmental toll is extracted from highly localised, often water-stressed watersheds.



Depletion

Drawing down vital reservoirs and local groundwater reserves.

Discharge Toxicity

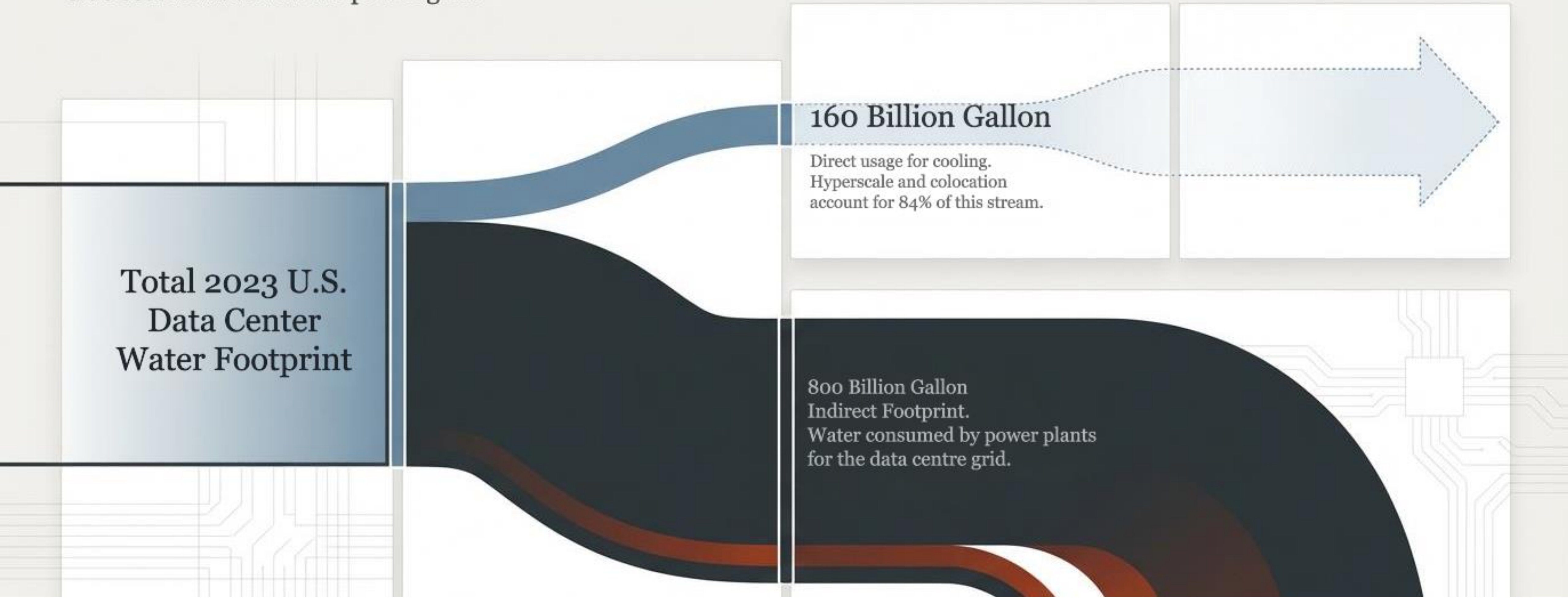
Return water: elevated temperatures and high concentrations of calcium and silica.

System Strain

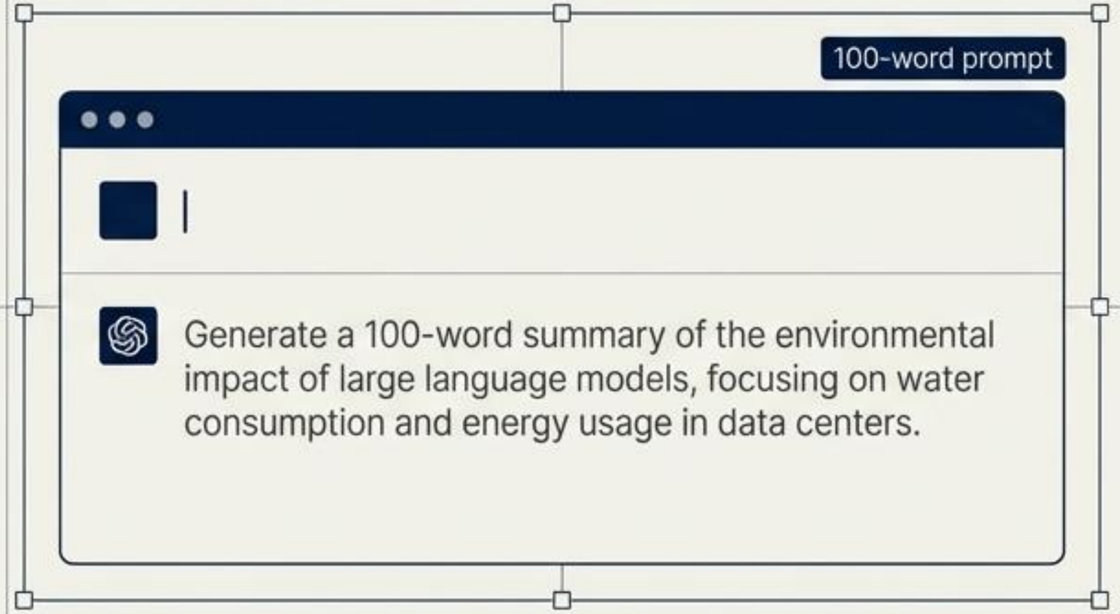
Heavily concentrated mineral discharge stresses local municipal water treatment plants.

The Billion-Gallon Baseline

The industry tracks the water it uses to cool servers, but the true cost is hidden in the power grid.



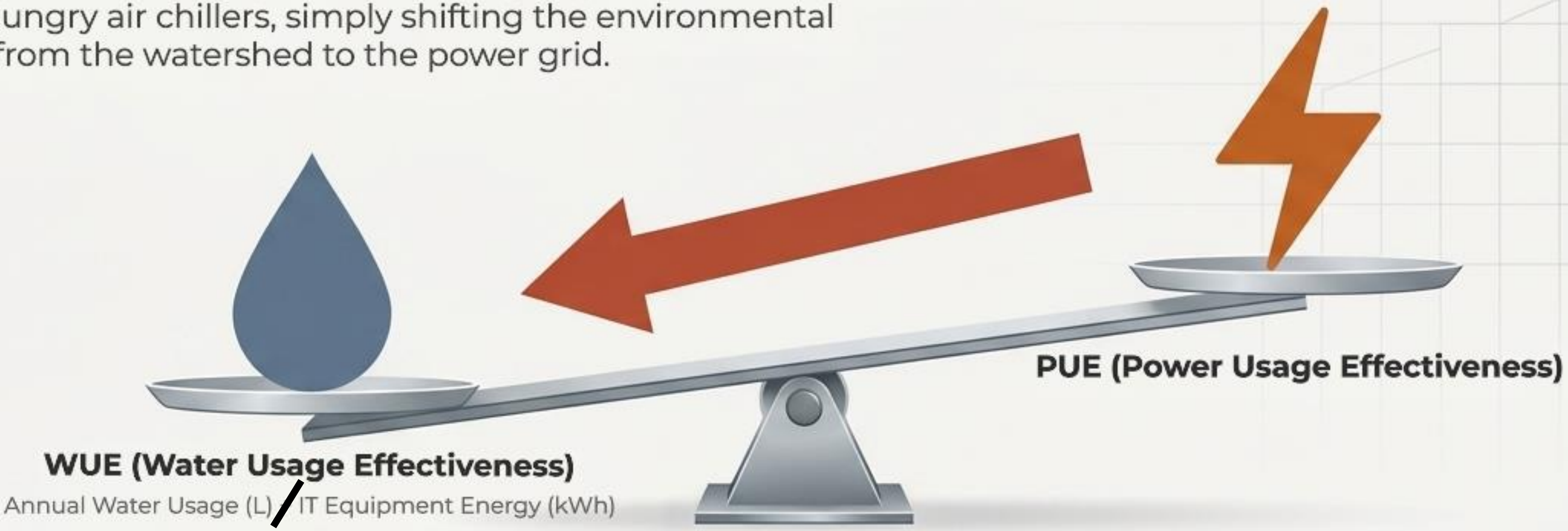
Every generative AI interaction extracts a physical toll.



High-density chips required for Large Language Models generate immense heat. A single 100-word AI prompt consumes exactly one standard bottle of water (519ml) to cool the processors running the calculations.

Tug-of-Wa(te)r

Lowering water consumption historically requires switching to power-hungry air chillers, simply shifting the environmental burden from the watershed to the power grid.



Current Reality

Average facility WUE sits at 1.8 L/kWh.

The Goal

Industry leaders target highly efficient operations of <0.2 L/kWh.

The Blind Spot

Accurate WUE tracking requires isolated IT power metering, which older retrofitted facilities lack.

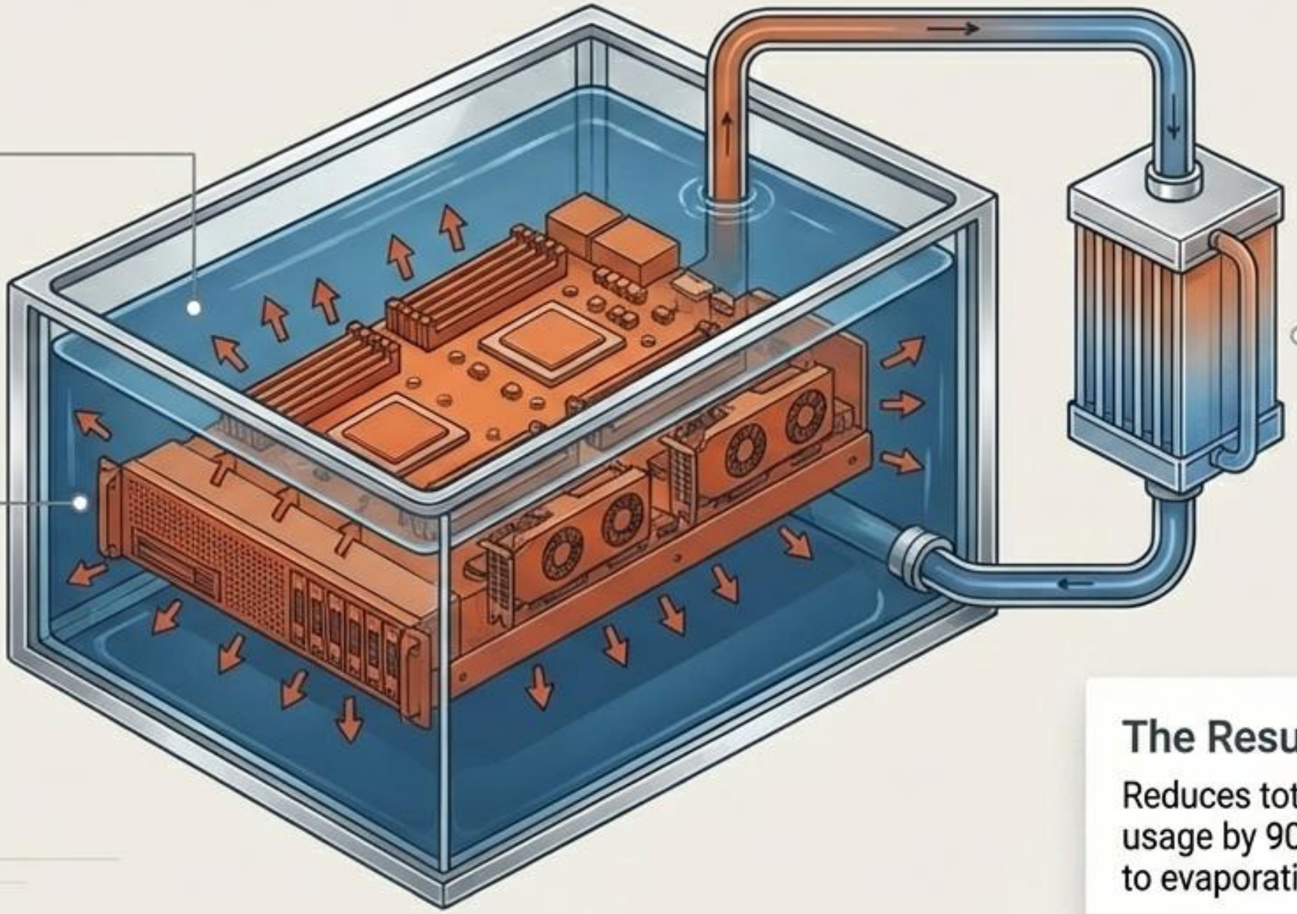
Evaluating the Cooling Landscape

Legacy systems force a compromise between water loss and grid strain.
High-density AI requires entirely new thermal architecture.

Technology	Heat Dissipation	Water Conservation	Grid Efficiency	AI-Density Readiness
Evaporative Cooling	◕	◔ 85% withdrawn water lost	●	○
Air Cooling / Chillers	◑	●	○ Heavy grid strain	○
On chip cooling	●	◕	◕	●
Immersion Cooling	●	●	●	●

The Mechanics of Immersion Cooling

By sealing the thermodynamic cycle, immersion technology fundamentally decouples high-performance computing from water consumption.



Dielectric Fluid

Highly thermally conductive, but strictly non-electrically conductive.

Total Submersion

Eliminates the need for mechanical fans and air handlers entirely.

The Result

Reduces total facility water usage by 90% to 95% compared to evaporative systems.

The AzSCI ~~Solution~~

The AzSCI Thermal Challenge

THE VACUUM PARADOX

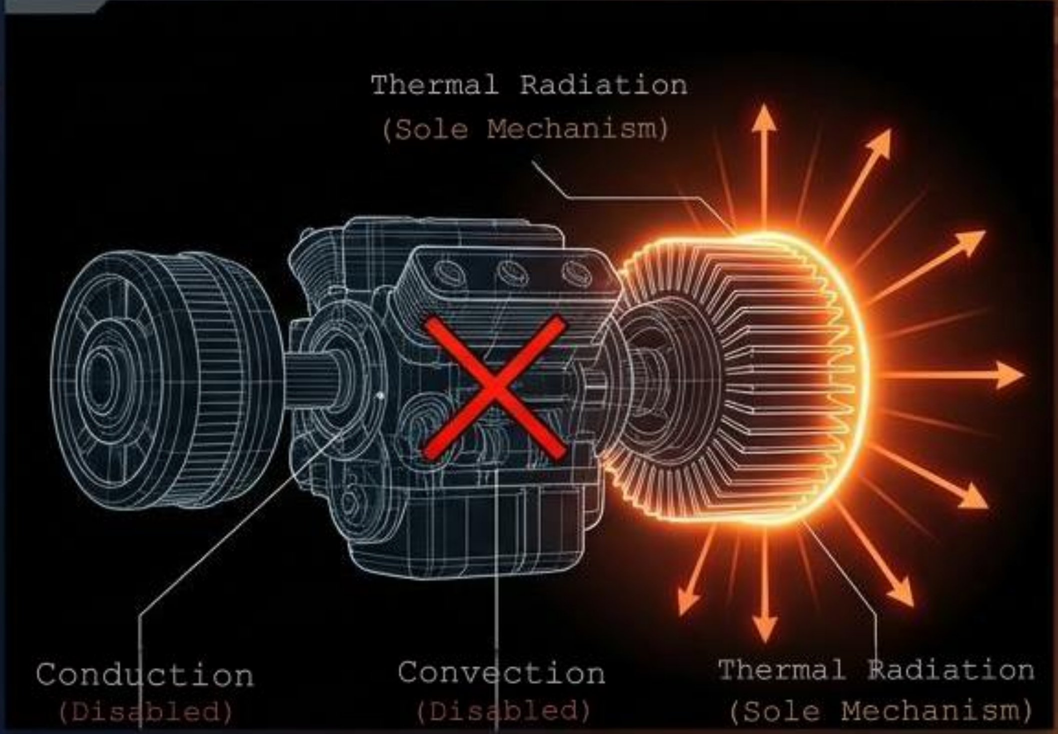
THE INTUITION

The Myth: Space is freezing (2.7K), so cooling must be easy.

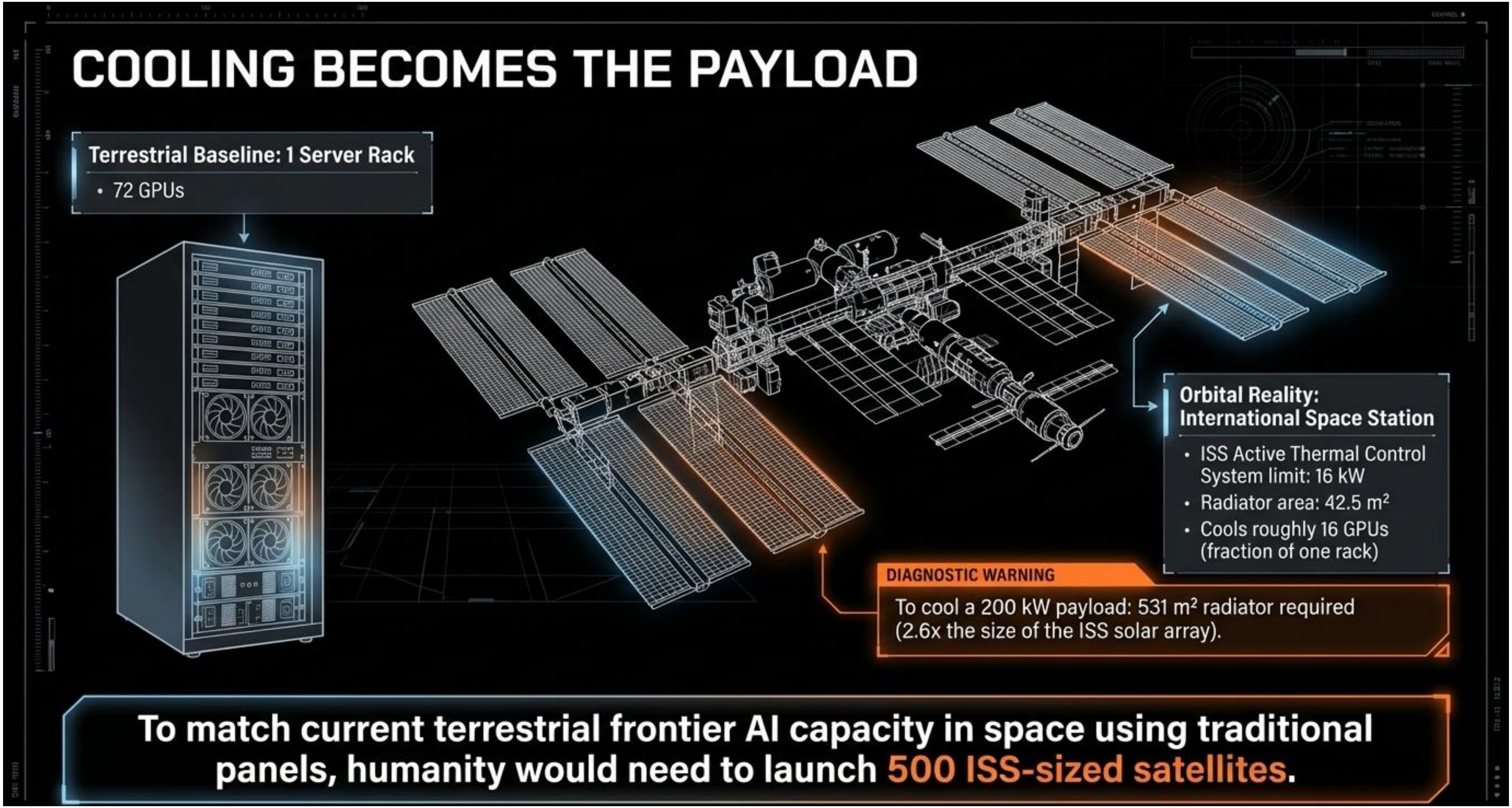
THE REALITY

The Physics: Space doesn't have a temperature-only matter does. A vacuum is the ultimate thermal insulator.

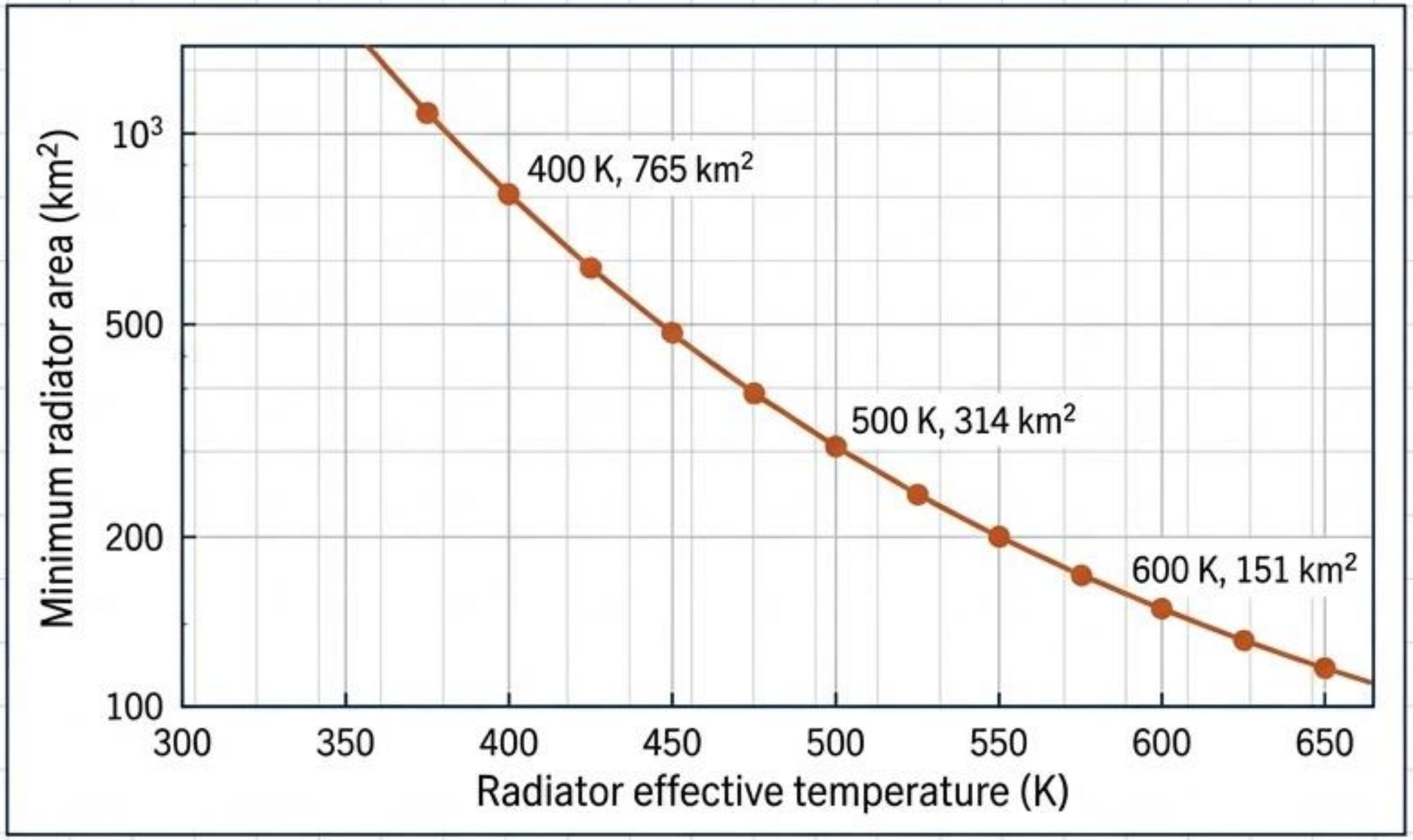
THE LOSS OF COOLING



Without air to absorb heat or convection to move remove heat, radiative cooling is the only way out


COOLING BECOMES THE PAYLOAD
Terrestrial Baseline: 1 Server Rack
• 72 GPUs
Orbital Reality: International Space Station
• ISS Active Thermal Control System limit: 16 kW
• Radiator area: 42.5 m²
• Cools roughly 16 GPUs (fraction of one rack)
DIAGNOSTIC WARNING
To cool a 200 kW payload: 531 m² radiator required (2.6x the size of the ISS solar array).
To match current terrestrial frontier AI capacity in space using traditional panels, humanity would need to launch 500 ISS-sized satellites.

The Terawatt Radiator Burden is an Immovable Physics Boundary

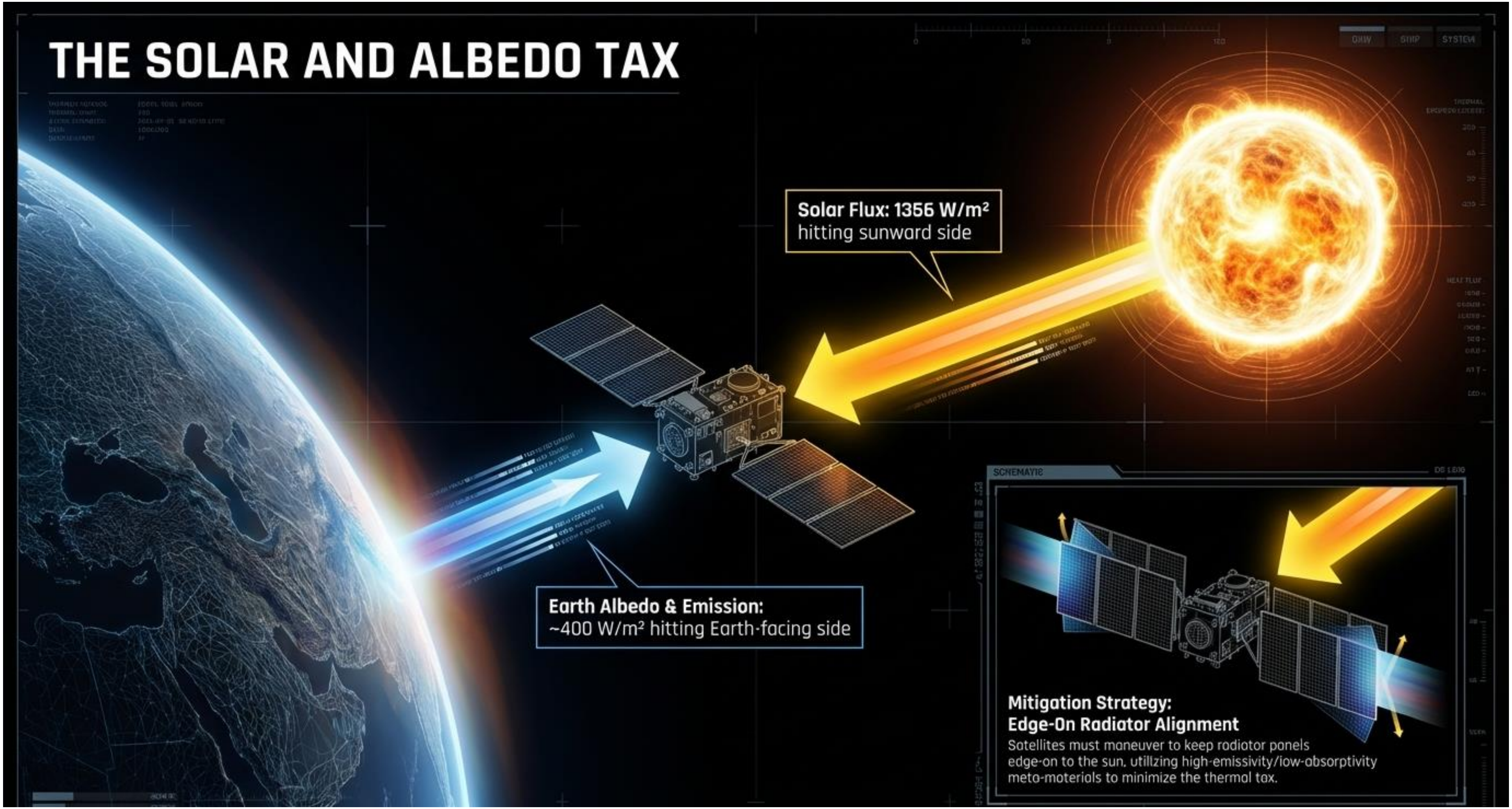


Stefan-Boltzmann Reality

1 TW of waste heat at 400 K requires a minimum of 765 km^2 of radiator area (assuming perfect emissivity).

Pushing the system to 500 K still requires a minimum of 314 km^2.

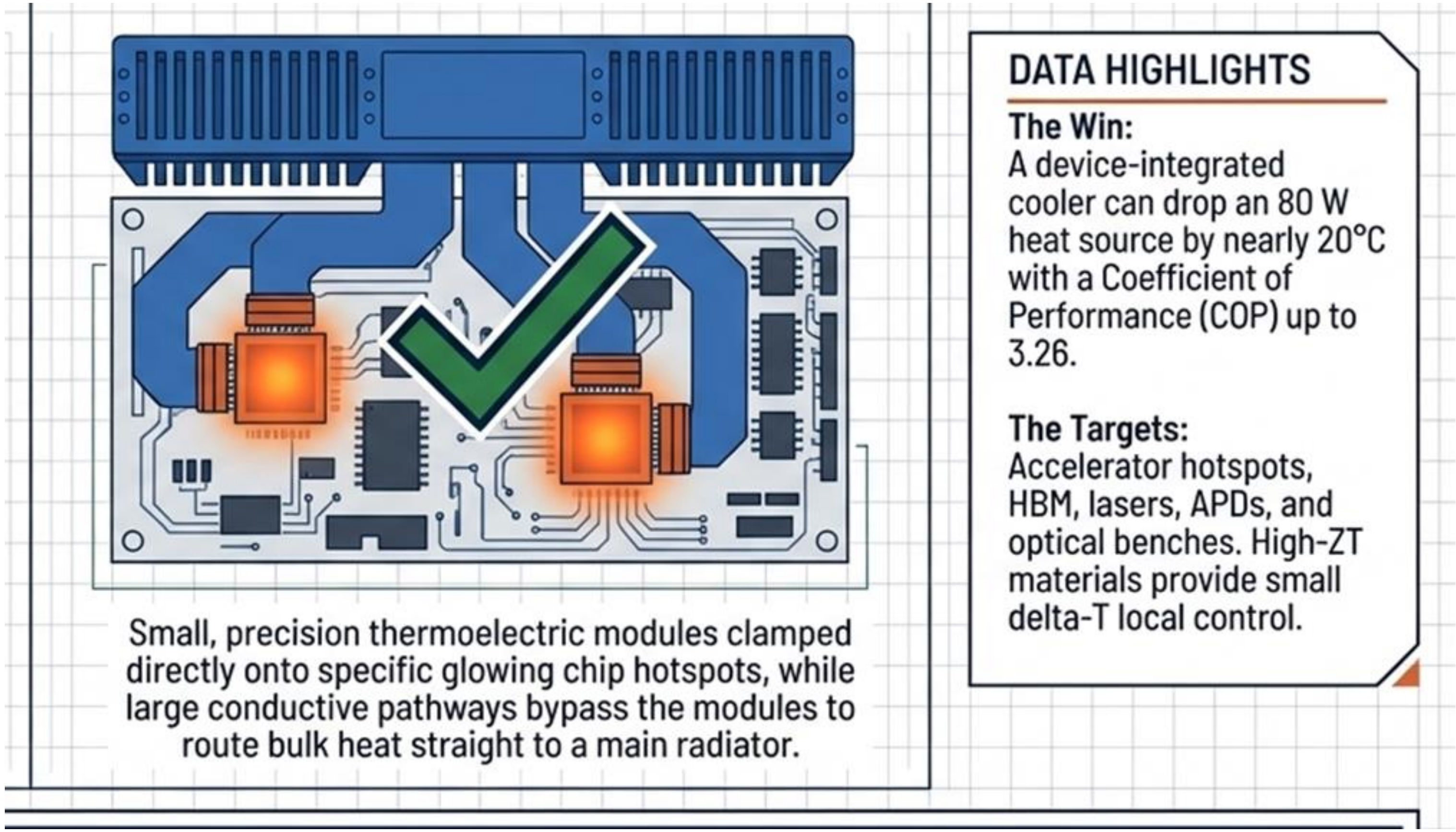
Clever packaging and advanced chips do not bypass the macro-scale requirement for power collection and convective-free heat rejection in a vacuum.



THE SOLAR AND ALBEDO TAX
Solar Flux: 1356 W/m²
hitting sunward side
Earth Albedo & Emission:
~400 W/m² hitting Earth-facing side
Mitigation Strategy:
Edge-On Radiator Alignment
Satellites must maneuver to keep radiator panels edge-on to the sun, utilizing high-emissivity/low-absorptivity meta-materials to minimize the thermal tax.

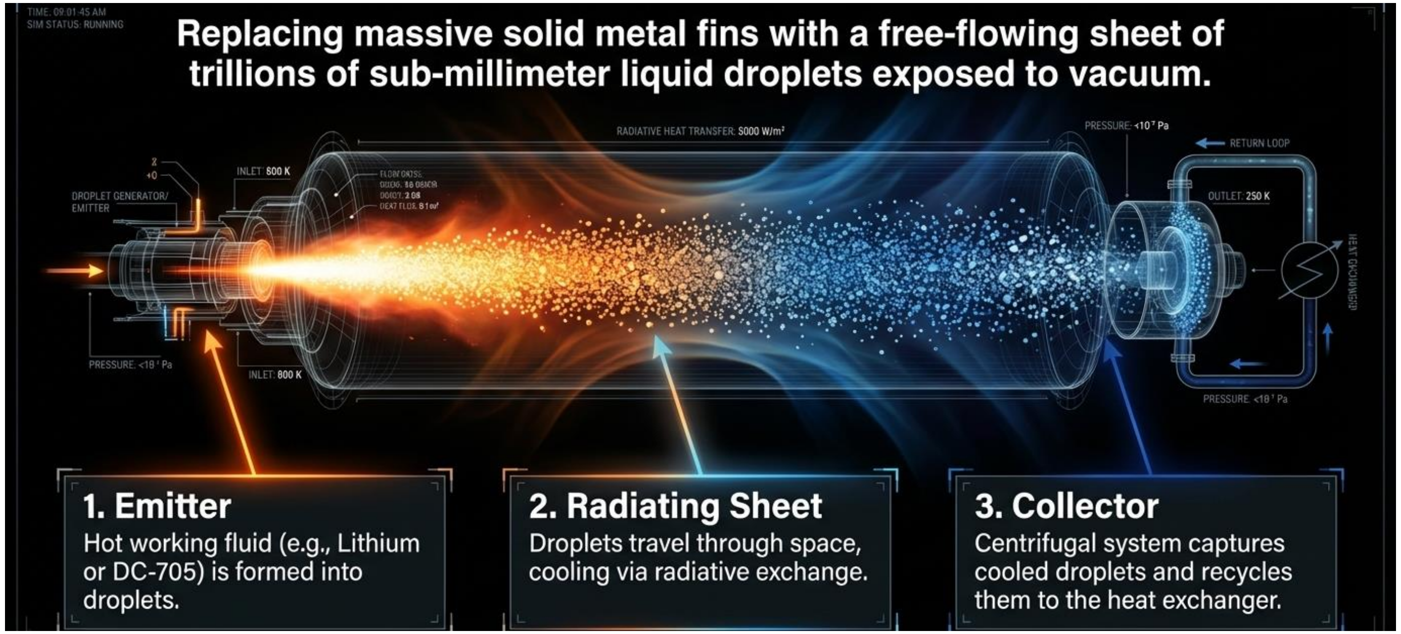
The AzSCI Strategy: On Chip thermoelectrics coupled with liquid drop radiators

On-chip and in-package thermoelectrics



The AzSCI Strategy: On Chip thermoelectrics coupled with liquid drop radiators

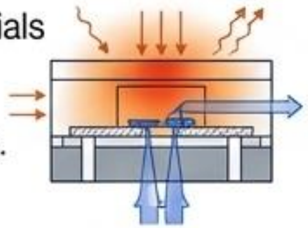
liquid drop radiators



The Development Ladder: From Experiments to Constellations

Phase 1

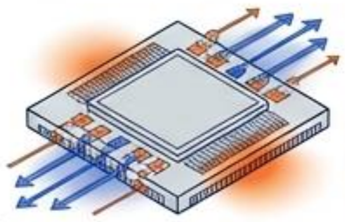
Focus:
Truth data on materials and devices under thermal-vacuum-radiation conditions.



Output:
TE-stabilised optical engine;
SPAD/SNSPD hybrid receiver;
rad-hard PIC test chip

Phase 2

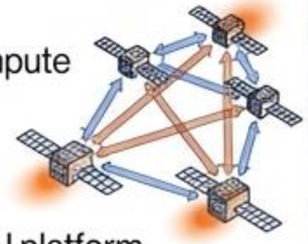
Focus:
Validating tile-level economics.



Output:
kW-class compute tile with optical crosslink, TE package control, and detector-based control plane

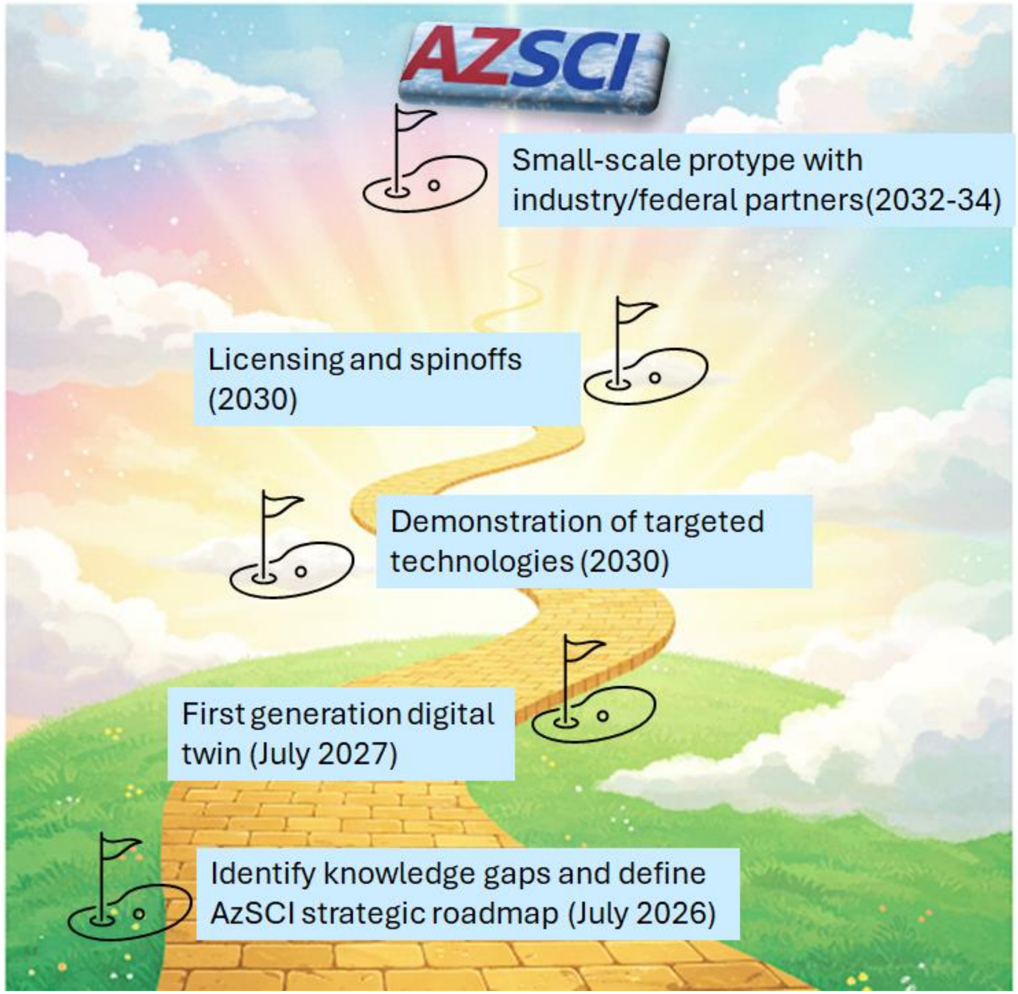
Phase 3

Focus:
Modular orbital compute demonstrators.



Output:
Multi-node optical AI platform with serviceable tiles and hierarchical workload orchestration.

AzSCI's mission: Use Space-based Technologies to Tackle Overarching Global Energy, National Security, and Data Management Needs



- **Constellation** of modular small satellites, each acting as an autonomous computing and data-processing subsystem
- **High-bandwidth**, low-latency, and secure in-orbit, **photonics**-driven computing mesh
- Uninterrupted **solar power**
- **Ultra-efficient** software and hardware architectures that support hybrid and self-adaptive systems
- **Adaptable** and resilient: on-orbit reconfiguration for rapid hardware swaps or upgrades
- **Multi-layer** network space architecture (LEO, MEO, GEO)
- **Inexpensive** data networks
- **Invulnerable** to physical and cyber attacks

RECLAIMING SPACE & RESOURCES

WE WILL MOVE THE CLOUD TO THE SCI
(SCI pronounced SKY- Space Cloud Infrastructure)

Acknowledgements

- The BIG Idea Challenge-office of Research and Partnerships at the University of Arizona
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