Orbital AI Data Centers: CO2 Cluster Mesh Thermal Architecture for 100 kW and 1 MW Space Systems

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https://www.infinityturbine.com/orbital-data-centers-using-cluster-mesh-supercritical-co2-power-systems-by-infinity-turbine.html

A technical analysis of heat generation, thermal balance, and radiator sizing for orbital AI data centers, featuring a CO_2-based Cluster Mesh architecture optimized for 100 kW and 1 MW satellite platforms.

This webpage QR code

PDF Version of the webpage (maximum 10 pages)

Orbital AI Data Centers: CO2 Cluster Mesh Thermal Architecture

In space, heat is both a liability and an asset. This article maps how a CO_2 Cluster Mesh system can transform thermal management into a unified power, cooling, and transport architecture for orbital AI infrastructure.

Orbital AI Data Centers: CO_2 Cluster Mesh Thermal Architecture
Introduction: The Real Constraint in Space Is Heat Rejection
In terrestrial data centers, cooling is dominated by convection and fluid loops. In orbit, the governing physics changes fundamentally:
• No convection
• No ambient heat sink
• Heat rejection only via radiation
This forces a design inversion:
On Earth: Generate power → remove heat
In Space: Manage heat → everything else follows
For AI satellites operating at 100 kW to 1 MW, thermal design—not power generation—is the primary system constraint.

Thermal Balance Fundamentals
At steady state:
Electrical Power In ≈ Heat Out
For AI compute systems:
• ~95–100% of electrical input becomes heat
• Minimal mechanical output
Core Equation:
$Q\_rejected = \varepsilon \cdot \sigma \cdot A \cdot T^4$
Where:
• ε = emissivity (0.85–0.92 typical)
• σ = Stefan-Boltzmann constant
• A = radiator area (m^2)
• T = radiator temperature (K)

Radiator Sizing Assumptions
We define realistic orbital parameters:
• Emissivity (ε): 0.9
• Radiator temperature: 300 K (27°C) baseline
• Deep space sink: ~3 K (idealized)
• Effective radiative flux ≈ 400–500 W/m^2
For engineering conservatism, we use:
450 W/m^2 net rejection capability

System Case 1: 100 kW AI Satellite
Thermal Load
• Compute + electronics: 100 kW