

National Aeronautics and
Space Administration

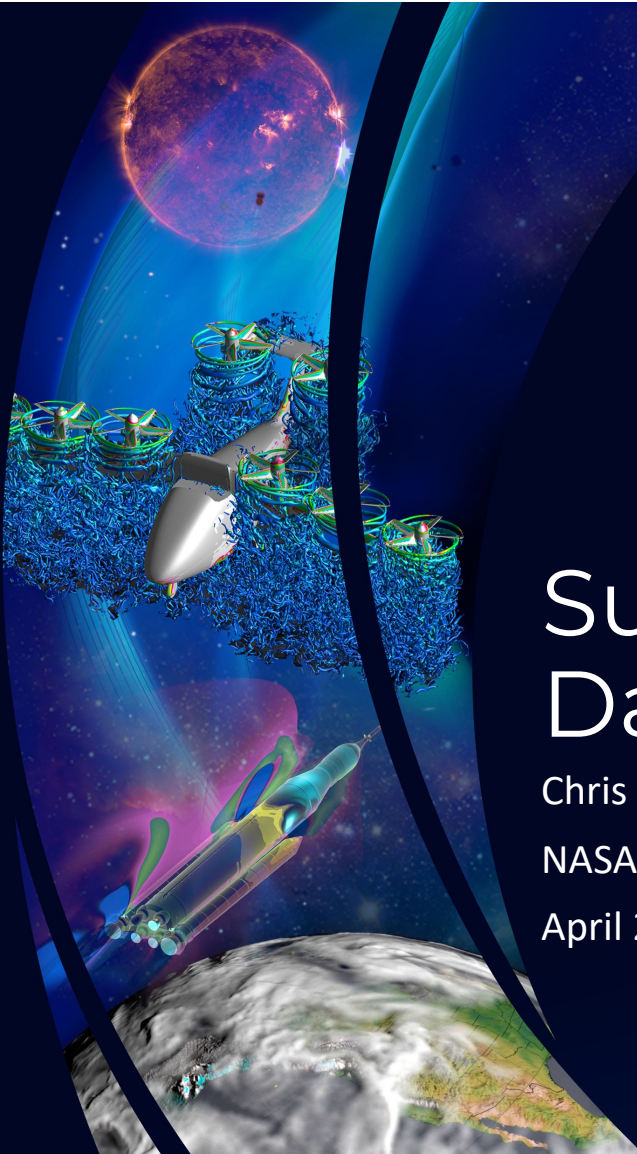


Supercomputing Modular Data Centers

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What is a Modular Data Center?

- Modular Data Centers are a pre-fabricated building built in factory for the specific purpose of hosting computers.
- Modular Data Centers have all the features of a “brick and mortar” data center, just on a smaller physical scale.
- Modular Data Centers are custom built to provide to desired features:
 - Robust Structural Enclosure
 - Power & Cooling
 - Network
 - Fire Suppression
 - UPS/Generator
 - Redundancy
- NASA Ames has 4 Modular Data Centers that are perfect for high-density supercomputing.



Why has NASA Ames Embraced Modular Data Centers?

- The short answer is they are Cost Effective!
- With our primary facility at capacity, Modular Data Centers have allowed NASA Ames to double our IT footprint and provide more computing resources for our users.
- NASA Ames has been doing Modular Data Centers since 2016.
- Our Modular Data Centers cost a fraction of "Brick & Mortar" data centers on a \$ per Megawatt IT comparison.
- Modular Data Centers utilize a "Build it When You Need It" Approach, reducing the upfront Capital Expenditures to build the Facility.
- New Modules are installed at the R&D099 Modular Supercomputing Facility (MSF) when Existing Modules are Full
 - A module is 1400 sqft. with another 1400 sqft. for Infrastructure
 - The MSF has 48K sqft. capacity for 12 Compute Modules plus disk drive modules, UPS, and generators.
- Modules reduce Operating Expenses
 - Cooling costs are only for the installed compute.
 - Traditional "Brick & Mortar" data centers build out the entire space upfront, requiring the need to cool unused spaces.

Modular Data Centers are Energy Efficient

- Our Modular Data Centers use less energy to cool the computers than a traditional data center.
- The Power Usage Effectiveness (PUE), the ratio of total data center energy usage to IT energy usage, for our modular data centers is significantly less than our N258 data center.
- When compared to installing the IT in our traditional data center, computing in the modular data centers saves NASA over \$1 Million annually in energy.

Facility (Computer Name)	PUE	Server Rack Density
NASA - Agency Wide	1.48	
N233A	1.50	13 kW/rack
N258 (Pleiades)	1.38	28 kW/rack
R&D088 Module 1 (Electra1)	1.02	28 kW/rack
R&D088 Module 2 (Electra2)	1.05	71 kW/rack
R&D099 Module 1 (Aitken)	1.05	90 kW/rack
R&D099 Module 2 (Next Gen)	1.05	334 kW/rack

NASA Ames Represents just over 50% of NASA's IT energy usage

Modular Data Centers are Water Efficient

- Taking advantage of Northern California's moderate temperature and low humidity reduces operating expenses.
- Our Modular Data Centers are unique from other sites in that we do not use Mechanical Refrigeration to cool our computers. We operate quite a bit warmer than traditional data centers.
- Evaporative coolers are specified for their low water use. The coolers use water when day-time temperatures rise and are dry through the night and morning.
 - 90° F cooling water permits extended dry operation and uses less water, yielding a Water Usage Effectiveness (WUE) for Compute Module 1 of 0.10L per kWh; US Department of Energy reports the WUE of an average data center is 1.8L per kWh. WUE is calculated as the (Annual Water Used) / (IT Energy Used).
- When compared to installing the IT in our traditional data center, cooling with evaporative coolers in the modular data centers saves NASA over \$1 Million annually in energy.





R&D088

Prototype Modular Data Center Facility Built in 2016 & 2017

Two Side-by-Side Modular Data Centers (MDC).

Site electrical capacity is 2.3MW at 415V/3 Phase. The 415V supply voltage does not require additional transformers for IT equipment, eliminating transformer losses and improving energy efficiency.

MDC 1

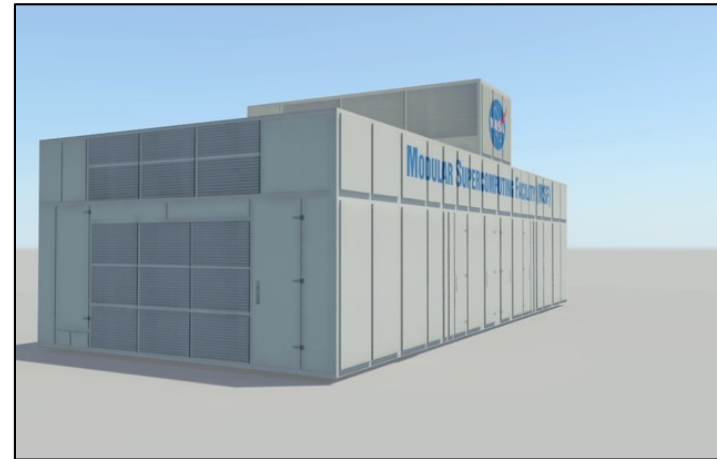
- 18 air cooled racks with total maximum power draw of 440kW.
- Filtered outside air cools racks. At outside air temperature over 81° F, evaporative cooling is used to decrease the air temperature to the racks.
- PUE = 1.02

MDC2

- 16 Apollo 8600 (HPE E-Cells) with total maximum power draw of 1200 kW.
- Liquid-on-Chip Cooling: water cooled heatsinks on processors – 80F Cooling water made by two 160 Ton Evaporative Coolers on the module roof.
- PUE = 1.05

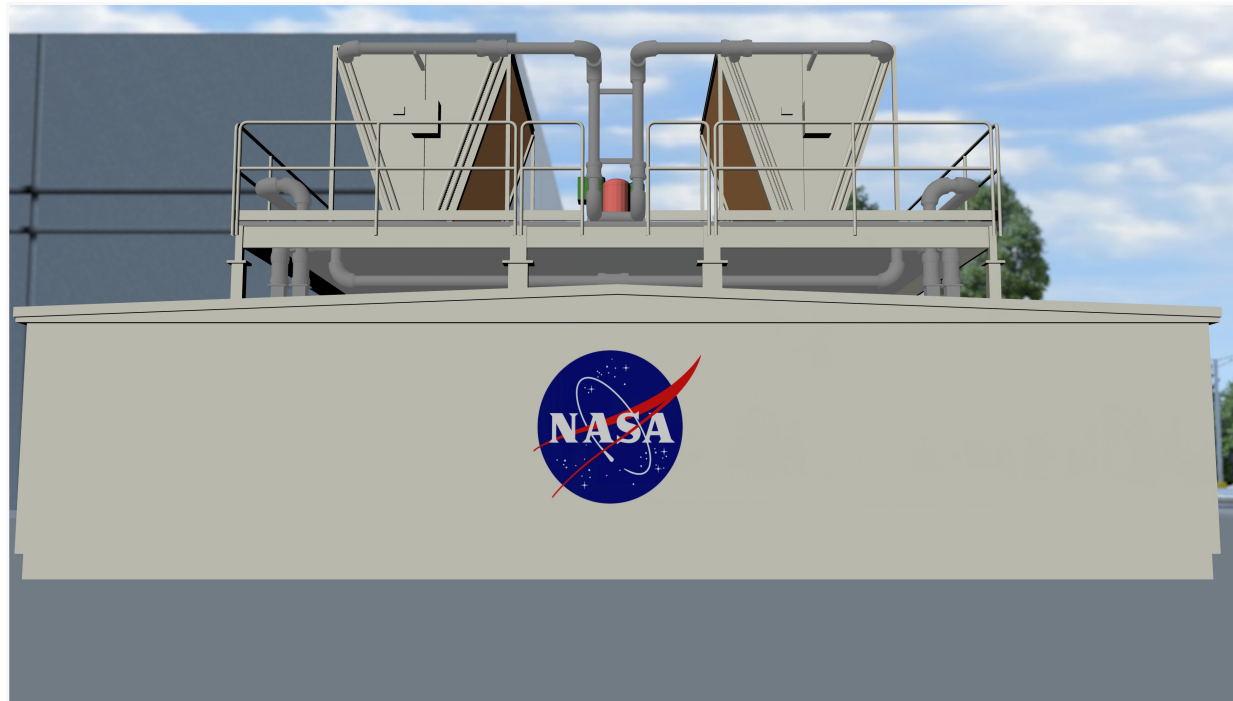
The Prototype: Our First Module

- Facility was constructed to site 2 modules.
 - Mat slab foundation placed, water piping, new conductors from substation, and new 13.8kV-415V Transformer installed.



- Filtered Outside Air Cooling to Compute Racks with Evaporative Cooling for Hot Days.
- No Mechanical Refrigeration! 440kW of IT cooled by 8kW of Fans.

Modular Data Center Cooling Animation





R&D099

Modular Supercomputing Facility Built in 2019.

R&D099 is a 1.1 Acre concrete pad capable of siting 12 Compute Modules plus up to 3 data/enterprise modules.

Site electrical capacity is 30MW at 24.9kV/3 Phase. Each module requires a dedicated cooling infrastructure and step-down transformer to power the IT in the module.

Compute Module 1

- 24 Liquid-on-Chip Compute Racks with total maximum power draw of 2100 kW (8 Apollo 8600 & 16 Apollo 9000). In addition, the Apollo 9000 has water cooled circuit boards, eliminating fans.
- 90F Cooling water made by two 300 Ton Evaporative Coolers located in the equipment yard behind the module.
- PUE = 1.05

Compute Module 2

- Module delivered June 2024 and installation tasks are nearly complete.
- Designed for up to 24 Liquid-on-Chip Compute Racks with total maximum power draw of 3000 kW.
- Module to house Milan Racks (460 kW) and Next Gen Compute Racks (1300 kW)
- 90F Cooling water made by two 450 Ton Evaporative Coolers located in the equipment yard behind the module.
- PUE = 1.05