



Modular HPC Centers NASA Advanced Supercomputing Facility at Ames Research Center

Chris Tanner

Facility Manager, NASA Advanced Supercomputing (NAS) Division

Christopher.tanner@nasa.gov

September 2023

Supercomputing Facility @ Ames

3 Separate Data Centers

- Building N258, a traditional legacy data center, built in 1986. Home to Pleiades & Cabeus Computers, Data Storage, and offices for 200 NAS staff. Peak performance: 7.1 PFs; PUE: 1.36.
 - 4MW IT equipment, approximately 300 racks.
 - 1MW Cooling System (3+1 Chillers & Cooling Tower). Raised floor cooling with rear-door heat exchangers on compute racks.
 - 6MW capacity Rotary UPS for entire building load.
- R&D088, Prototype Modular Data Center Facility, built in 2016 & 2017. Home to Electra Computer. Peak performance 8.3 PFs; PUE: 1.04.
 - 1.4 MW - 18 air cooled racks (HPE E-Cells) & 16 HPE Apollo 8600.
 - MDC1 uses filtered outside air & evaporative cooling over 81° F.
 - MDC2 uses water cooled heatsinks on processors – process water cooled by dry air and evaporative cooler to 80° F.
- R&D099, Modular Supercomputing Facility, built in 2019. Home to Aitken Computer. Peak performance: 13.1 PFs; PUE: 1.044.
 - 2.1 MW - 8 Apollo 8600 & 16 HPE Apollo 9000
 - Water cooled heatsinks on processors plus Apollo 9000 has water cooled circuit boards, eliminating fans – process water cooled by dry and evaporative cooler to 90° F.



NAS Resources for NASA Users



HECC Hardware Assets

5 Compute Clusters

- Aitken 24 Racks / 3,200 nodes / 13.1 PF / 10,204 SBU/hr
- Pleiades 143 Racks / 10,310 nodes / 6.83 PF / 7,600 SBU/hr
- Electra 24 Racks / 3,456 nodes / 8.32 PF / 4,815 SBU/hr
- Cabeus 10 Racks / 57 nodes / 2.08 PF / 1,595 SBU/hr
- Endeavour 2 Racks / 2 nodes / 155 TF / 81.2 SBU/hr

1 Visualization Cluster 1-billion-pixel display / 128 nodes / 2.61 PF

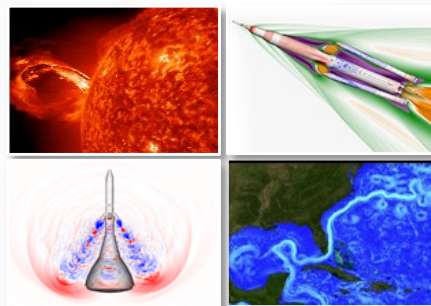
13 Lustre File Systems 118.1 PB

3 NFS File Systems 3.3 PB

2 BeeGFS File Systems 1.5 PB

1 VAST File System 2.5 PB

Archive System 1,572 PB



NAS Facility Extension

- One-acre 30 MW site to house HPC systems in modules.

HECC provides a suite of complimentary services to the user community to enhance the scientific and engineering results obtained from the hardware assets.

- Systems: Customized solutions including compute and storage solutions to meet specific project or mission requirements. Cloud access for immediate or non-standard computing.
- Cloud Resources: Customized cloud access for hybrid data pipelines, traditional simulations and exploratory research.
- Application Performance and Productivity: Software solutions provided to research/engineering teams to better exploit installed systems.
- Visualization and Data Analysis: Custom visualization during traditional post-processing or concurrent during simulation to understand complex interactions of data.
- Networks: End-to-end network performance enhancements for user communities throughout the world.
- Data Analytics: Exploitation of data sets through neural nets and emerging new techniques.
- Machine Learning: Custom environments to enable learning through advanced data techniques.
- Custom Data Gateways: Custom data portals to support diverse programs and projects.

HECC Overview

HECC – PPBE24 Briefing

Why Did We Move to Modular?

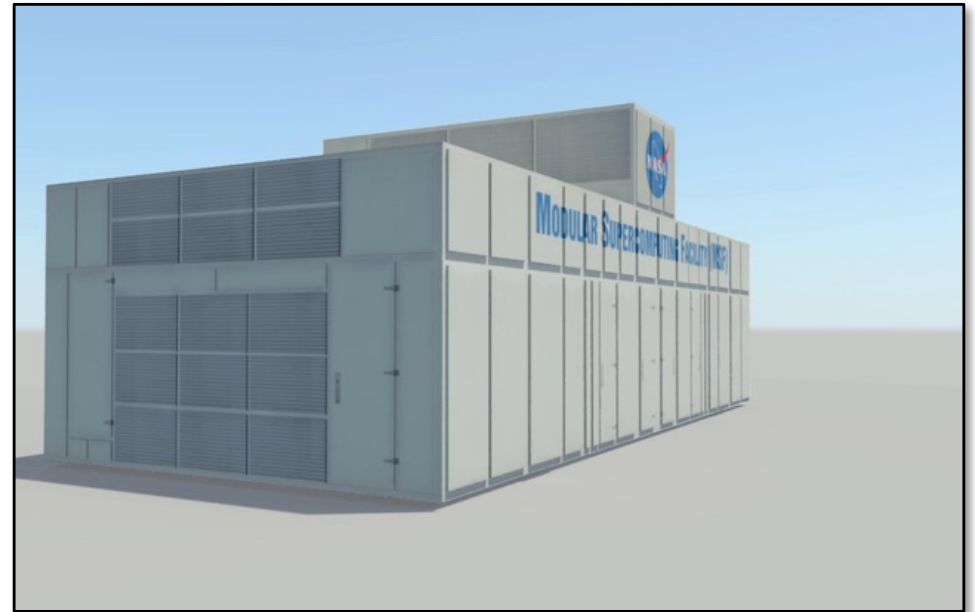


- The calculation used to be very simple...
 - When the cost of maintaining a group of nodes for three years exceeded the cost to replace those nodes with fewer nodes that did the same work, we replaced them.
- Now, not so much...
 - We look at the total computing our users get and procure new nodes within our budget and remove enough nodes to power and cool the new nodes.
 - This means that we are not able to actually realize all of the expansion we are paying for.
- When running out of floor space, power, and headroom in cooling, contracted a 3rd part survey in 2014-15, to determine the “best” approach for expanding the facility.
- Modular Data Centers provide the ability to scale up...
 - A “Build it When You Need It” Approach, reducing the upfront Capital Expenditures to build the Facility.
 - New Modules can be installed when Existing Modules are Full.
 - 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.

The Prototype: Our First Module



- Filtered Outside Air Cooling to Compute Racks with Evaporative Cooling for Hot Days.
- No Mechanical Refrigeration! 350kW of IT cooled by 8kW of Fans.



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

HECC Overview

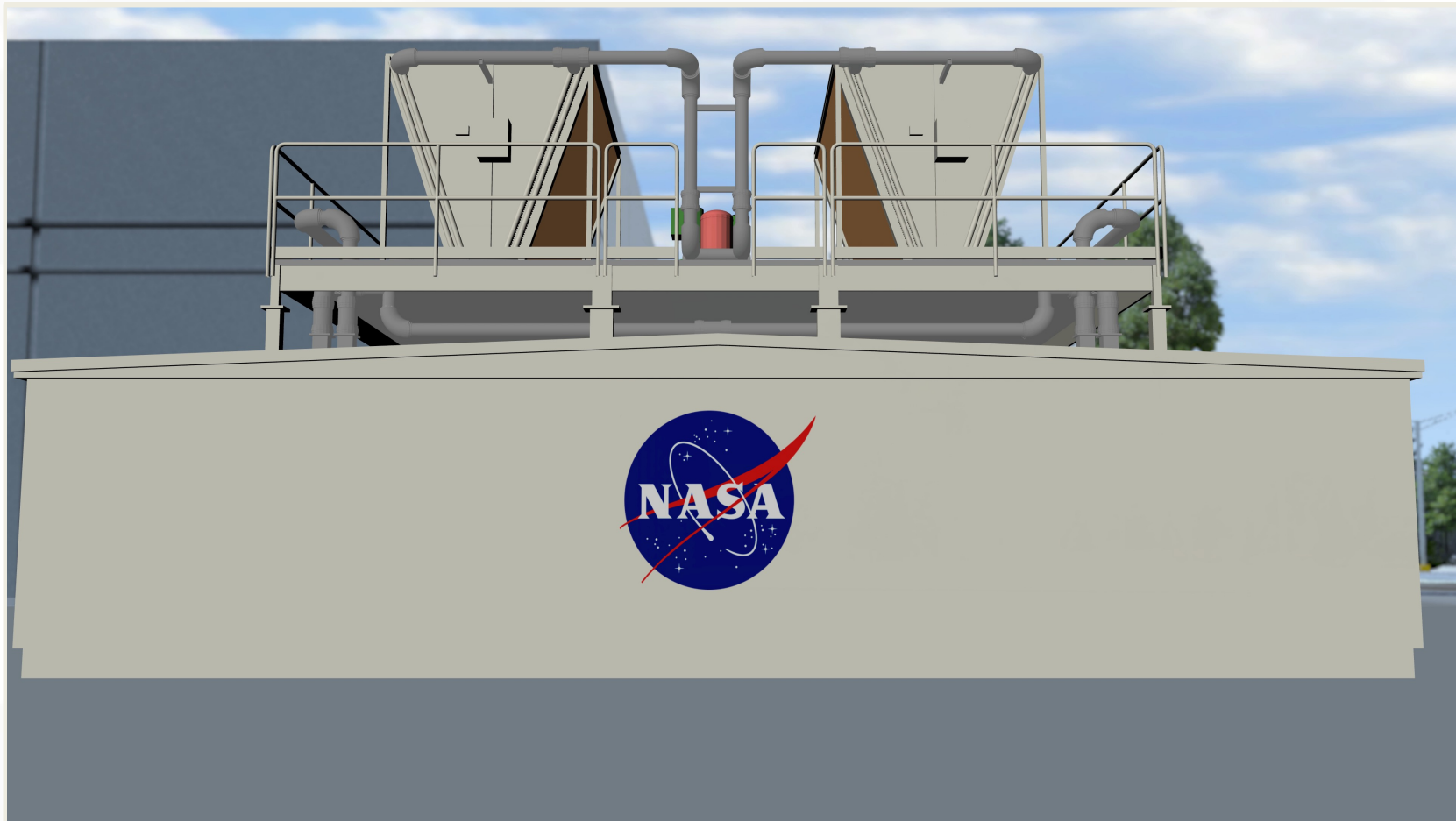
Module 2: Water Cooled Prototype



- Module 2 sits directly next to Module 1
- Module 2 is Double the Nodes of Module 1 & 3X the power consumption
- Water cooled heatsinks directly on processors.
- 80F Cooling water made by Evaporative Coolers on the module roof.



Module 2 Cooling Animation



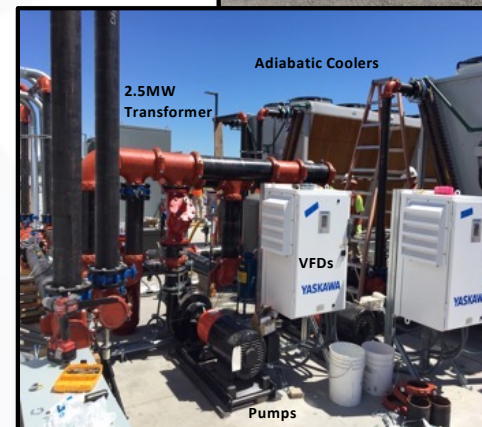
HECC Overview

NAS Facility Expansion

Modular Data Centers are the Future of NAS



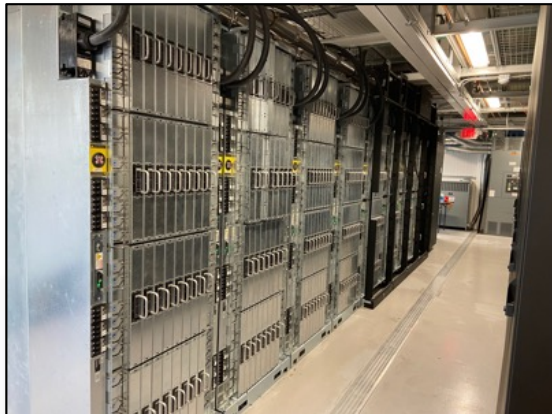
- In 2017, after successful completion of our prototype modules (R&D088 housing Electra), NAS committed all future expansion to a modular data center facility.
- Deployed energy-efficient and cost-effective infrastructure capable of housing a 1,000,000-core system.
 - One-acre site can hold 12 compute modules and 3 data modules.
 - A 115kV breaker & 30MW 115kV–25kV transformer was installed in the N225B substation.
 - Conduit holds the electrical cables connecting N225B to R&D-099 and data cables connect N258 to R&D-099.
 - 25kV switchgear was placed on the site to distribute up to 30 MW to the modules.
 - A fire road and fencing were built.



Modular Supercomputing Facility



- The facility was commissioned on July 24, 2019.
- Since the initial deployment consisting of 1 row of racks, Aitken has expanded 3 times and is now fully populated with 3 rows.
 - The system, Aitken, was named after the lunar crater, Aitken, part of the very large South Pole-Aitken basin. The crater was named after the astronomer Robert Aitken (12/31/1864 – 10/29/1951).
- Aitken has network connectivity to N258 through four 288-strand Single Mode Fiber cables.
- Aitken is now the largest (in terms of cores and memory) and fastest computer at NASA.



HECC Overview

OpEx & Sustainability



- Sustainability objective at NAS is focused on both energy and water usage and is one of the factors in our design and procurement process.
- Sustainability reduces operating expenses.
- Aitken module in R&D099, with a power draw of 2.1 MW supports 90° F warm-water cooling. When compared to our traditional data center, the evaporative coolers annually save:
 - Over 6 million kWh (~\$750K), and
 - Over 5.5 million gallons of water (~\$70K).
- 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 the Module 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).



Modular Data Center Best Practices



- Take advantage of the moderate temperatures and low humidity in locations such as Northern California
- Optimize the infrastructure at the outset to accommodate future growth.
- Construct new facilities that are easily scalable, that are modular, and can be added/replaced/removed easily.
- Optimize the site to mitigate the impact of flooding and earthquakes.
- Minimize the power usage effectiveness (PUE) for low operating costs.
- Build and operate a Pilot Facility to validate that a low PUE was actually achievable given the state-of-the-art technology.

Questions?

Christopher.tanner@nasa.gov

www.nas.nasa.gov