

Frontier Overview

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OLCF Annual User Meeting
October 2022

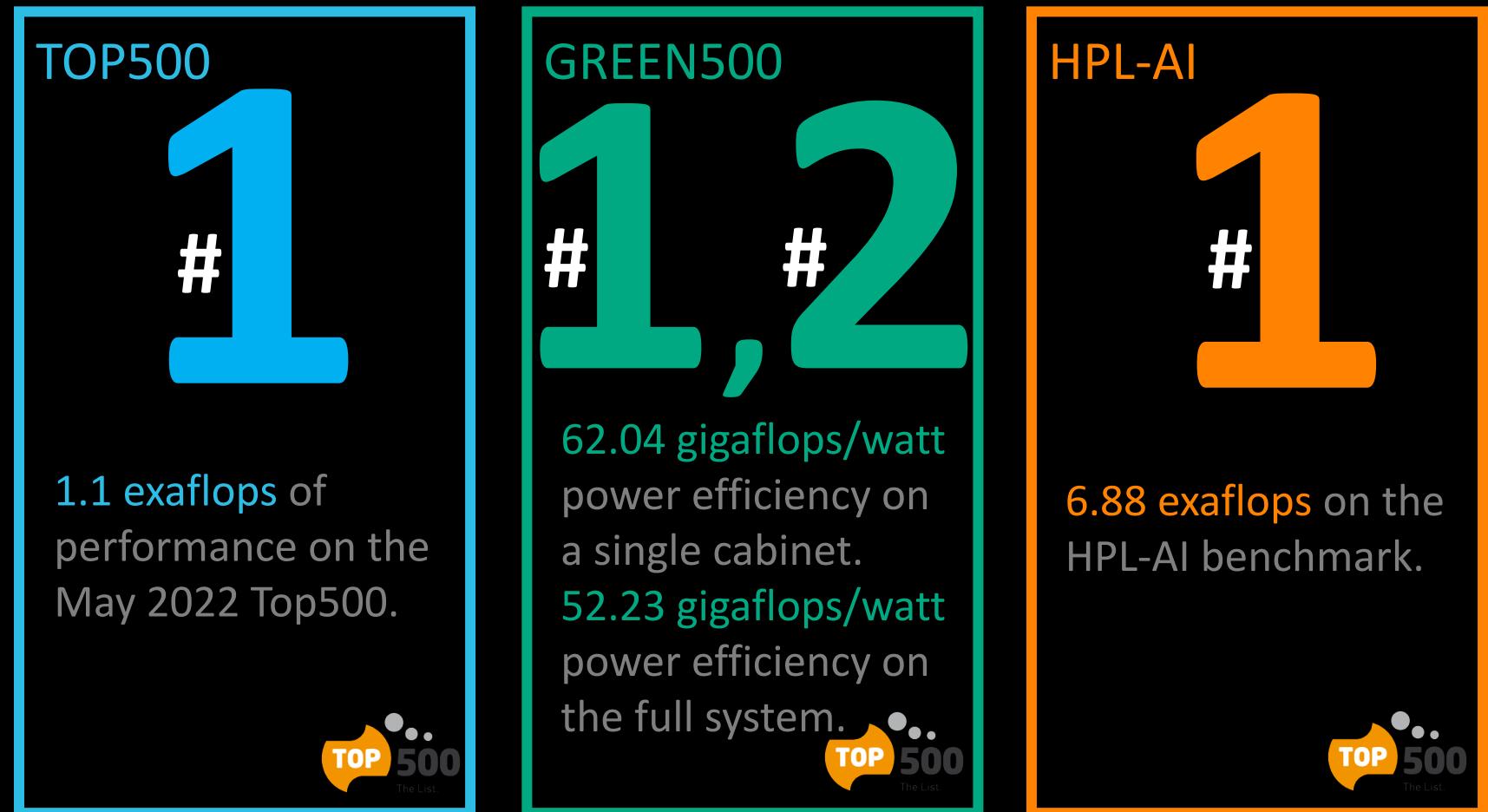
ORNL is managed by UT-Battelle LLC for the US Department of Energy



OAK RIDGE NATIONAL LABORATORY'S FRONTIER SUPERCOMPUTER



- 74 HPE Cray EX cabinets
- 9,408 AMD EPYC CPUs, 37,632 AMD GPUs
- 700 petabytes of storage capacity, peak write speeds of 5 terabytes per second using Cray Clusterstor Storage System
- 90 miles of HPE Slingshot networking cables

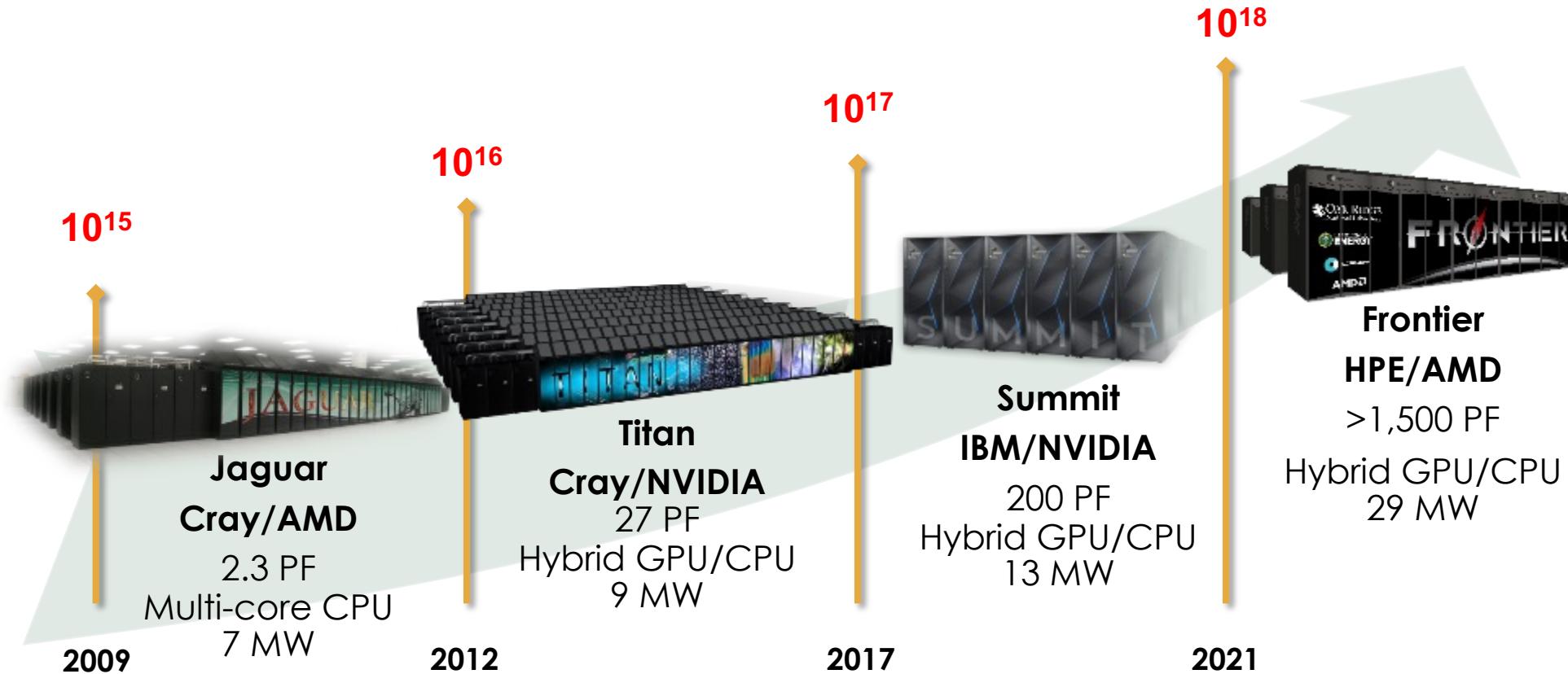


Sources: May 30, 2022 Top500 release

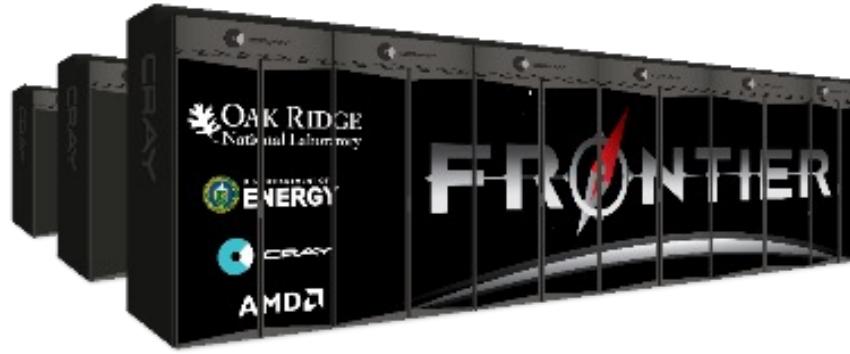
Oak Ridge Leadership Computing Facility – a DOE Office of Science User Facility

Mission: Providing world-class computational resources and specialized services for the most computationally intensive global challenges

Vision: Deliver transforming discoveries in energy technologies, materials, biology, environment, health, etc.



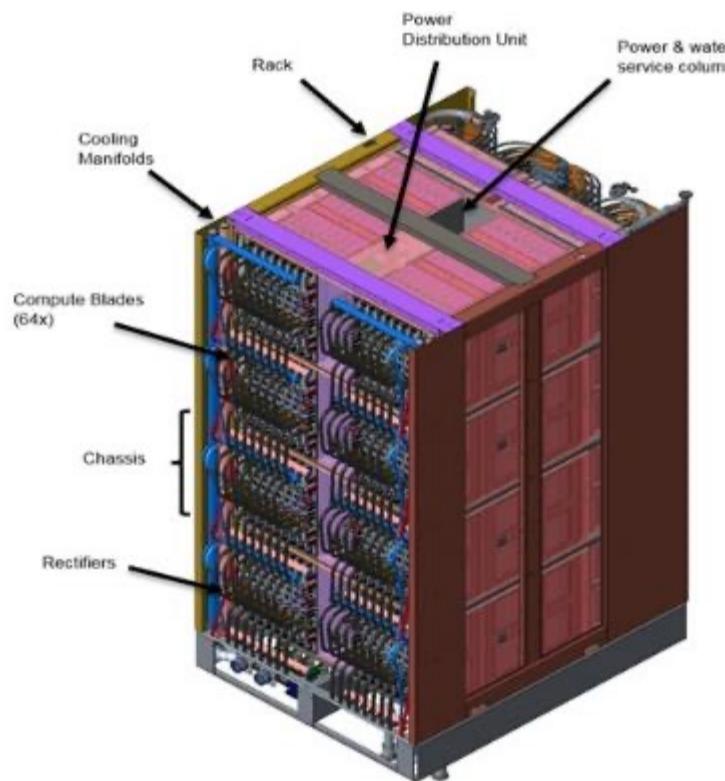
Frontier System



System

- 74 compute racks
- 29 MW Power Consumption
- 9,408 nodes
- 9.2 PB memory
(4.6 PB HBM, 4.6 PB DDR4)
- Cray Slingshot network with dragonfly topology
- 37 PB Node Local Storage
- 716 PB Center-wide storage
- 4000 ft² foot print

Frontier Cabinet



Olympus rack

- 128 AMD nodes
- 8,000 lbs
- Supports 400 KW

Frontier Node

AMD extraordinary engineering

- 1 AMD “Trento” CPU (optimized Milan)
- 4 AMD MI250X GPUs
- 512 GiB DDR4 memory on CPU
- 512 GiB HBM2e total per node
- 4 Cassini NICs connected to the 4 GPUs

Compute blade

- 2 AMD nodes

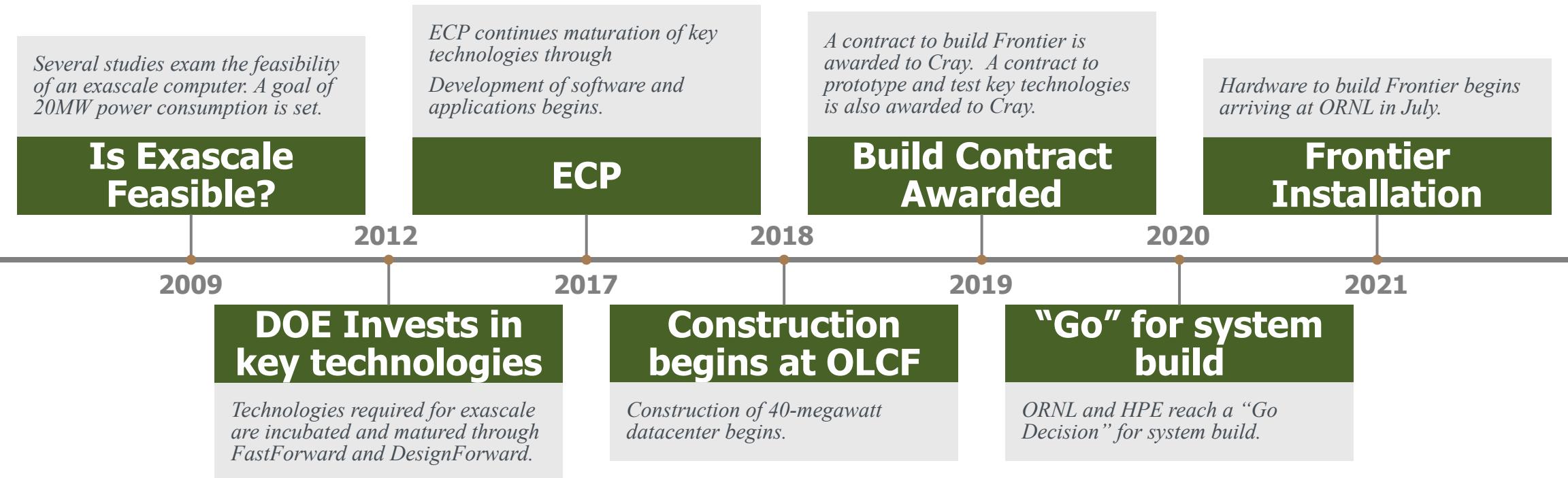


All water cooled, even DIMMs and NICs

What does it take to build a leadership class computer?

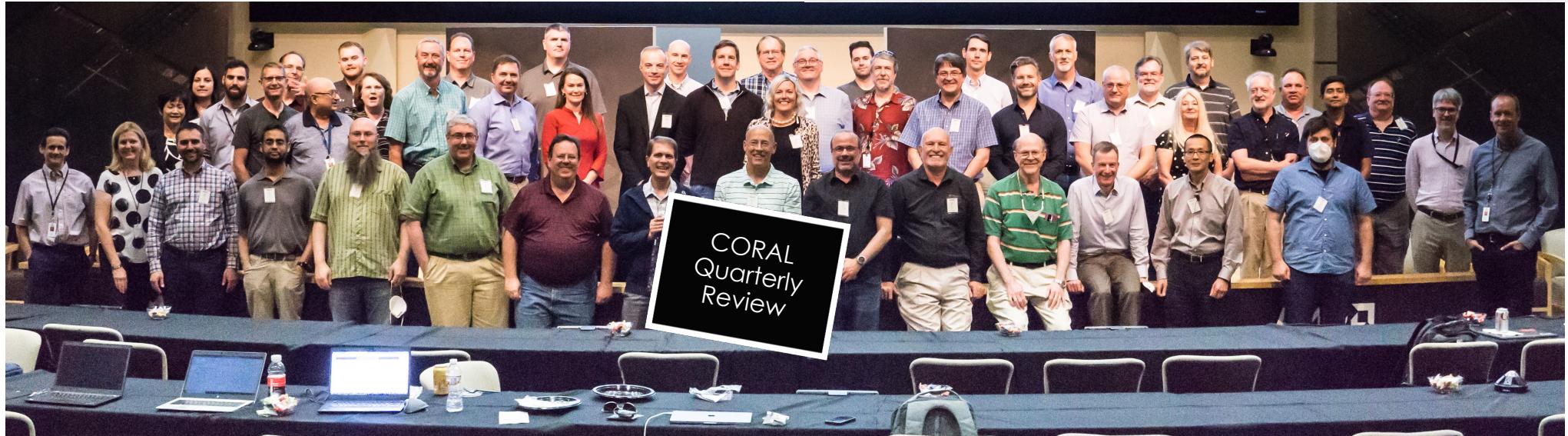
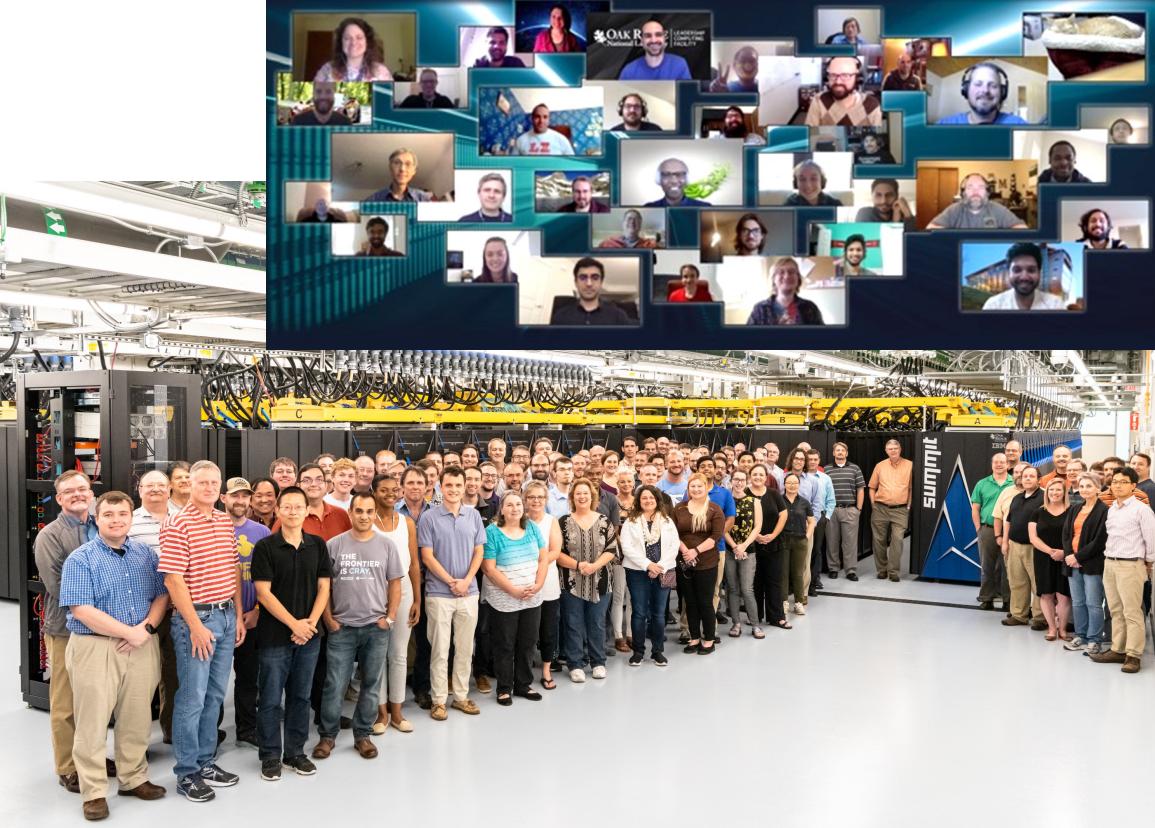
- Time
- Many talented people
- A little excavation and demolition
- Great partners

Decadal effort to deliver U. S. Exascale systems lead to Frontier



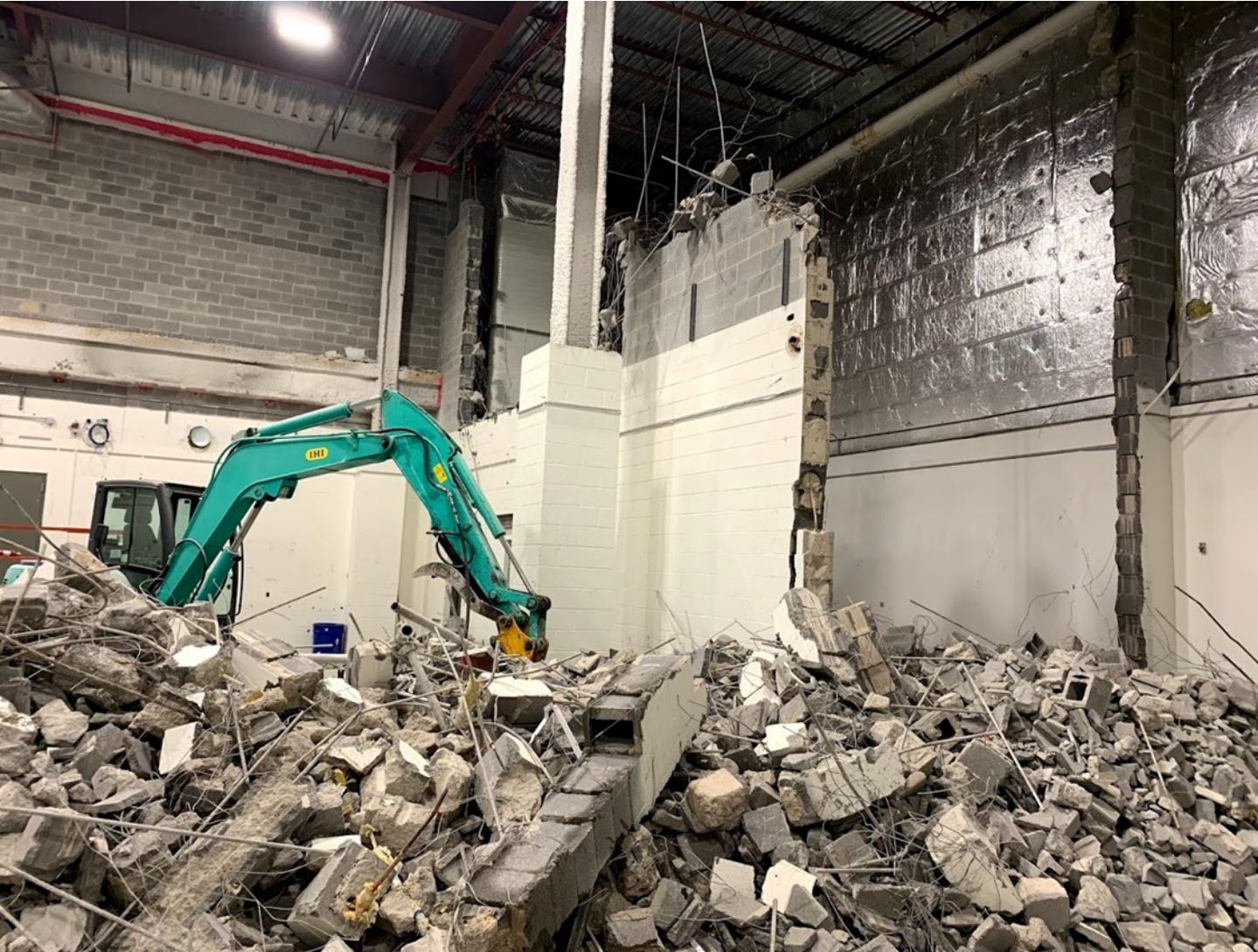
Many Talented People

- Broad support from DOE HQ and Site Office
- 150 experts from 6 labs met in late 2018 to review technical proposals for Frontier
- 1,000 ECP staff
- 90 OLCF staff
- 20 application teams through ECP
- Over 200 electrical and mechanical workers
- Over 300 HPE and AMD engineers



A Little Demolition

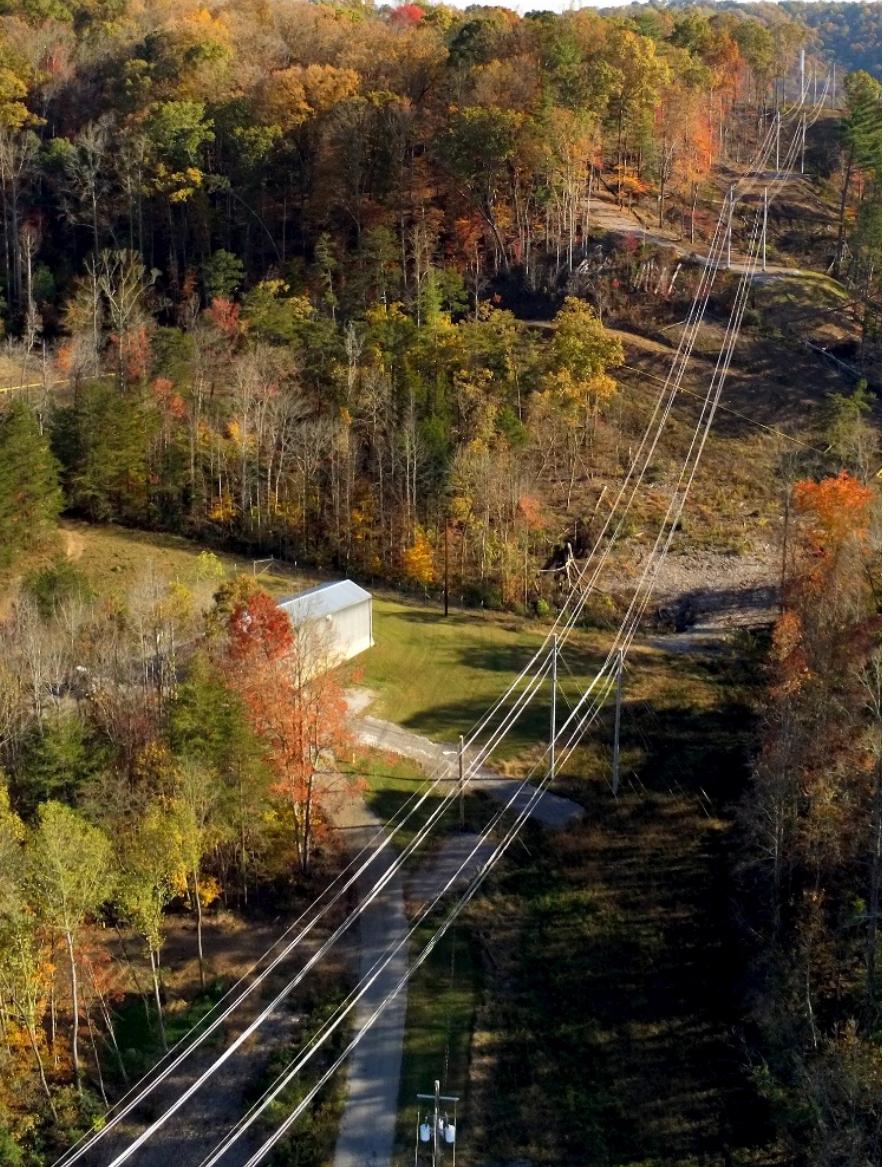
- 30 offices, 8 laboratories, and a 20,000 s.f. data center



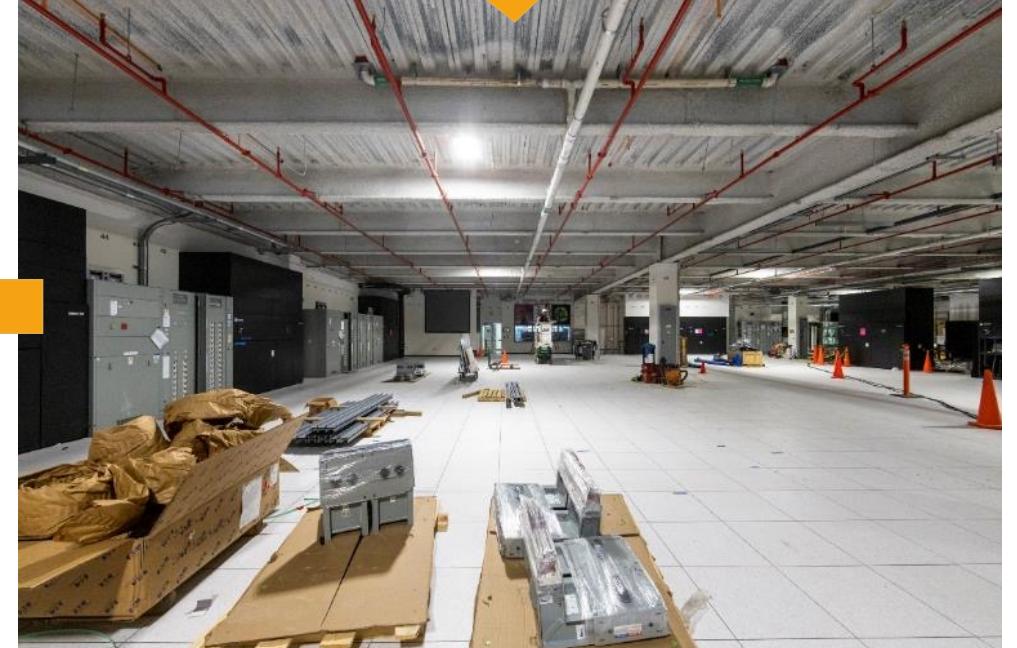
Became the space for 40 MW of cooling



2.5 miles of new power lines installed



The old Titan data center becomes the new Frontier data center



Great partners

- A pandemic, the supply chain, and tremendous complexity...oh my!

By the end of 2020 the Chip Shortage Had Hit in Earnest!

World-wide chip shortage is a BIG problem if you are trying to acquire chips to build an Exascale Computer. When HPE began ordering parts, suppliers said the lead time on orders had increased an additional 6-12 months

60 Million parts needed for Frontier

685 Different part numbers used in Frontier

167 Frontier part numbers affected by the chip shortage

(more than 2 million parts from dozens of suppliers worldwide)

12 Part numbers blocked building the first compute cabinet

15 Part numbers shortage for AMD building all the MI250 cards for Frontier

It wasn't just exotic parts like CPUs or GPUs, rather parts needed by everyone – in cars, TVs, electronics, such as, voltage regulators, oscillators, power modules

Frontier Build– Supply Chain Remained a Constant Battle Delaying Final Delivery from Summer to Fall of 2021

HPE saw commitments for parts deliveries from sub contractors being broken weekly as the chip shortage got worse. Had to call every supplier every week (sometimes every day)

HPE and AMD had 15 people whose sole job was to try to find the needed parts or alternatives for Frontier. Using HPE's size to negotiate with suppliers, looking for handfuls of parts in warehouses or at other companies who were also stuck because of chip shortage.

April 30 – July 15: Initial shortage of 167 part numbers reduced down to 1 part number

- An oscillator needed for Slingshot blade
- July 15th only found enough to build 63 of 74 cabinets (still looking for about 8,000 more)
- It took three more weeks to find all 8,000

PCA Shortages	4/30	5/7	5/14	5/21	5/28	6/4	6/11	6/18	6/25	7/2	7/9	7/16
Critical Shortages	167	69	46	39	30	28	28	11	6	3	2	1
New Shortages	0	0	0	1	0	0	0	1		0	0	0
Total	167	69	46	40	30	28	28	12	6	3	2	1

The final parts arrived the morning the last Frontier node was assembled

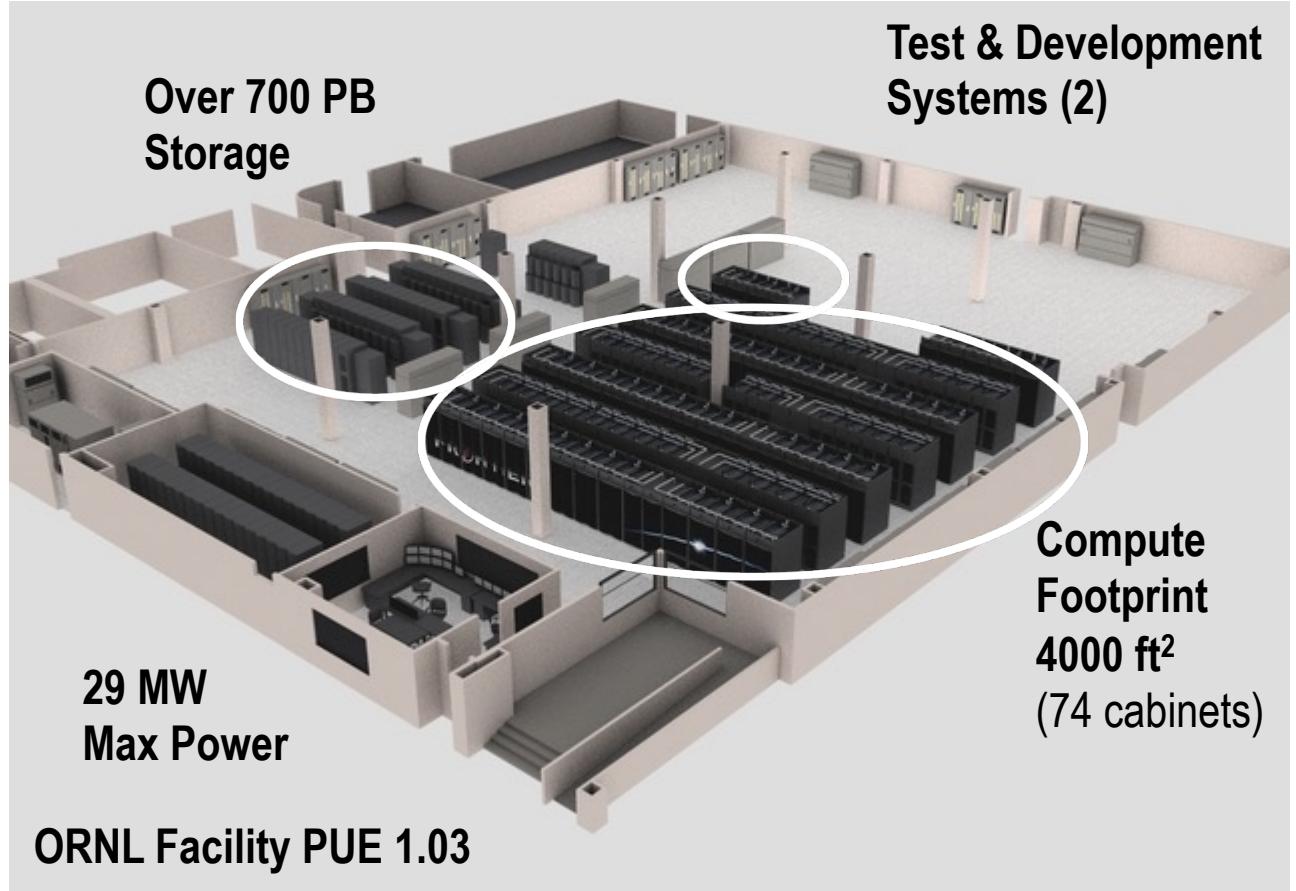
Last Cabinet of Frontier Delivered to ORNL October 18th

Thanks to Heroic Efforts of the HPE and AMD teams



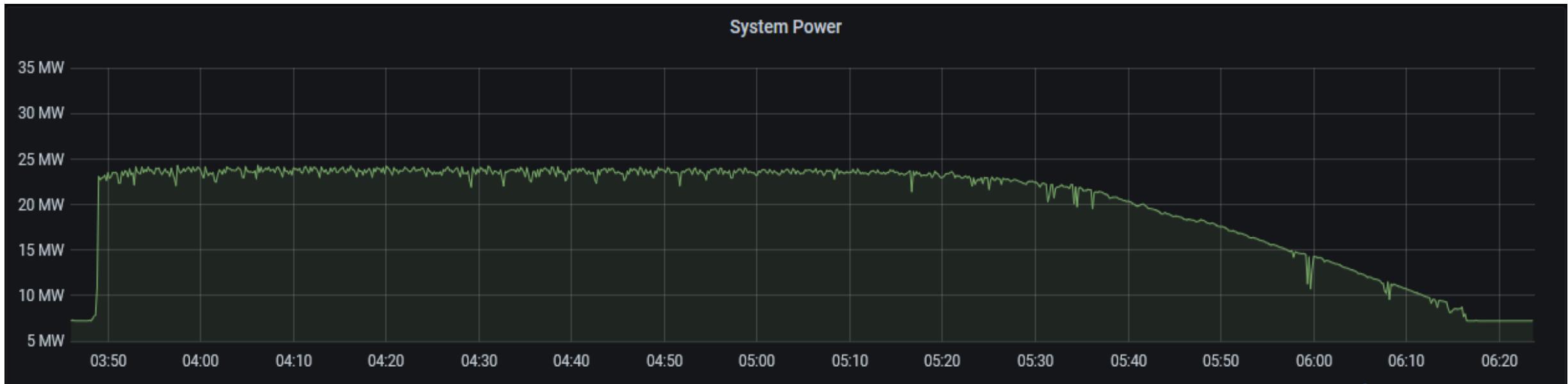
Last cabinet being rolled into place.
(Each cabinet weighs 8,000 lbs.)

After the cabinets arrived they had to be connected. There are 81,000 cables between all the Frontier nodes



Then system tuning began

- We fell into a pattern of repairing hardware, updating software, and tuning the system by day
- And running benchmarks like HPL at night



- In May, as time was running out for the June Top500, we had a successful exascale HPL run:

9,248 nodes of Frontier achieved 1.102 EF using av. 21.1 MW
#1 TOP500 list
#2 Green500 achieving over 52 Gflop/W

Energy Efficient Computing – Frontier achieves 14.5 MW per EF

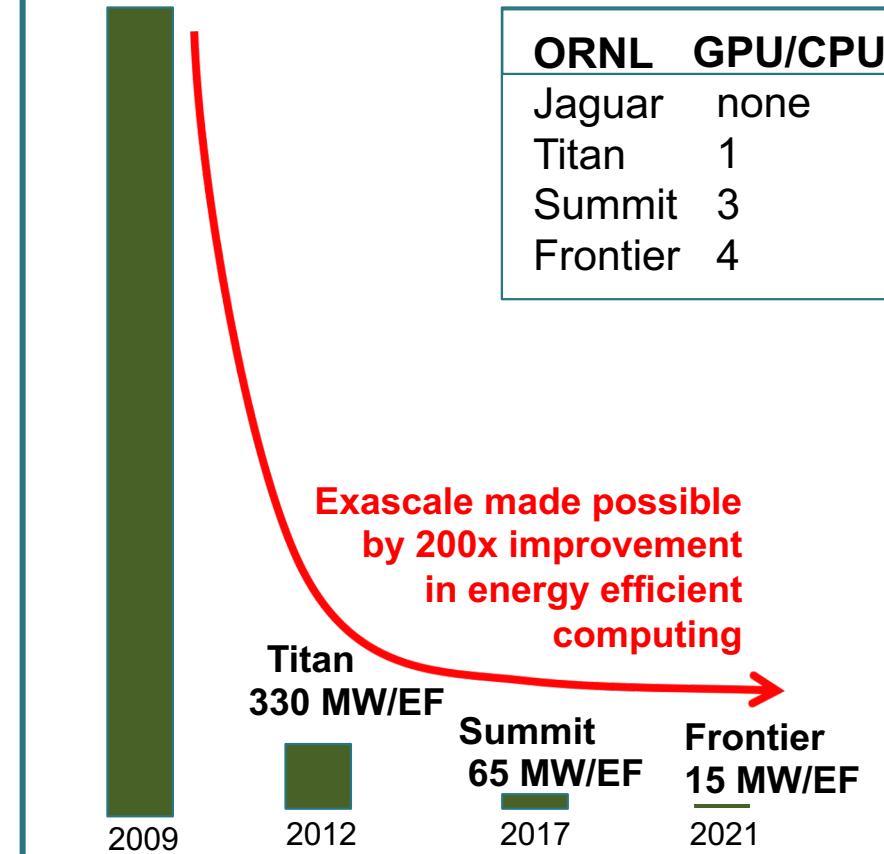
Since 2009 the biggest concern with reaching Exascale has been energy consumption

- ORNL pioneered GPU use in supercomputing beginning in 2012 with Titan thru today with Frontier. Significant part of energy efficiency improvements.
- ASCR [Fast, Design, Path] Forward vendor investments in energy efficiency (2012-2020) further reduced the power consumption of computing chips (CPUs and GPUs)..
- 200x reduction in energy per FLOPS from Jaguar to Frontier at ORNL
- ORNL achieves additional energy savings from using warm water cooling in Frontier (32 C).
ORNL Data Center PUE= 1.03

Frontier first US Exascale computer
Multiple GPU per CPU drove energy efficiency

Jaguar 3,043 MW/EF

ORNL	GPU/CPU
Jaguar	none
Titan	1
Summit	3
Frontier	4



Next Steps

- Complete work to ready Frontier for production by the end of the year
- Begin User Programs in January 2023

Thank You

