OAK RIDGE National Laboratory | LEADERSHIP COMPUTING FACILITY

August 5, 2025

Oak Ridge Leadership Computing Facility
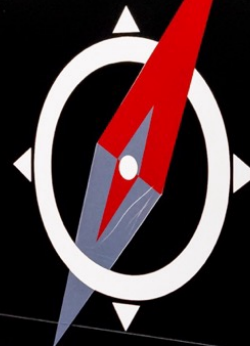
Two Decades of Leadership
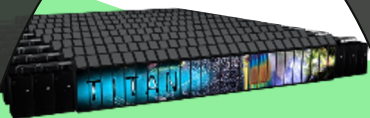
Arjun Shankar, Ph.D.

NCCS/OLCF Division Director, ORNL

U.S. DEPARTMENT OF **ENERGY**

ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY

OLCF has pushed the boundaries of computing performance for two decades

OLCF-3 Titan #1

Cray XK7
First Hybrid GPU + CPU

AMD CPUs + NVIDIA GPUs

2012

OLCF-4 Summit #1

IBM AC922
IBM CPUs + NVIDIA GPUs QCUP

2018

OLCF-5 Frontier #1

HPE Cray EX 235a
HPE Interconnect + AMD CPUs and GPUs
Quantum Testbeds

2022

OLCF-6 Discovery

In development
Extreme Bandwidth
ModSim +
AI + workflows

2028

ARTIFICIAL INTELLIGENCE

?

OLCF-7

Future
HPC + AI + Quantum

QUANTUM

2032

QUANTUM SCIENCE CENTER

QUANTUM BRILLIANCE

IQM

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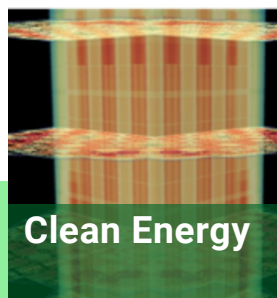
Flagship Instrument for Computational Discovery

OLCF MISSION

Providing world-class computational resources and services;

Solving the most computationally intensive global challenges

Exascale is a tipping point

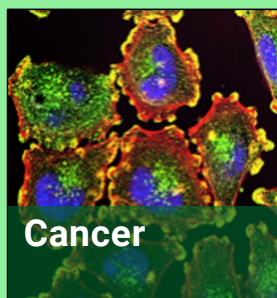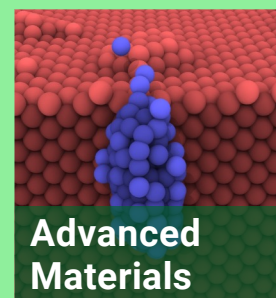Frontier enables scientists to solve harder problems than they thought possible.
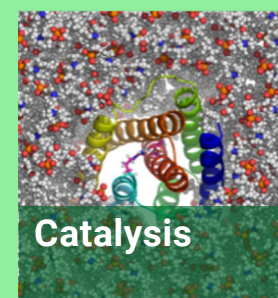

Clean Energy

Resilient Power Grid

Earth Systems
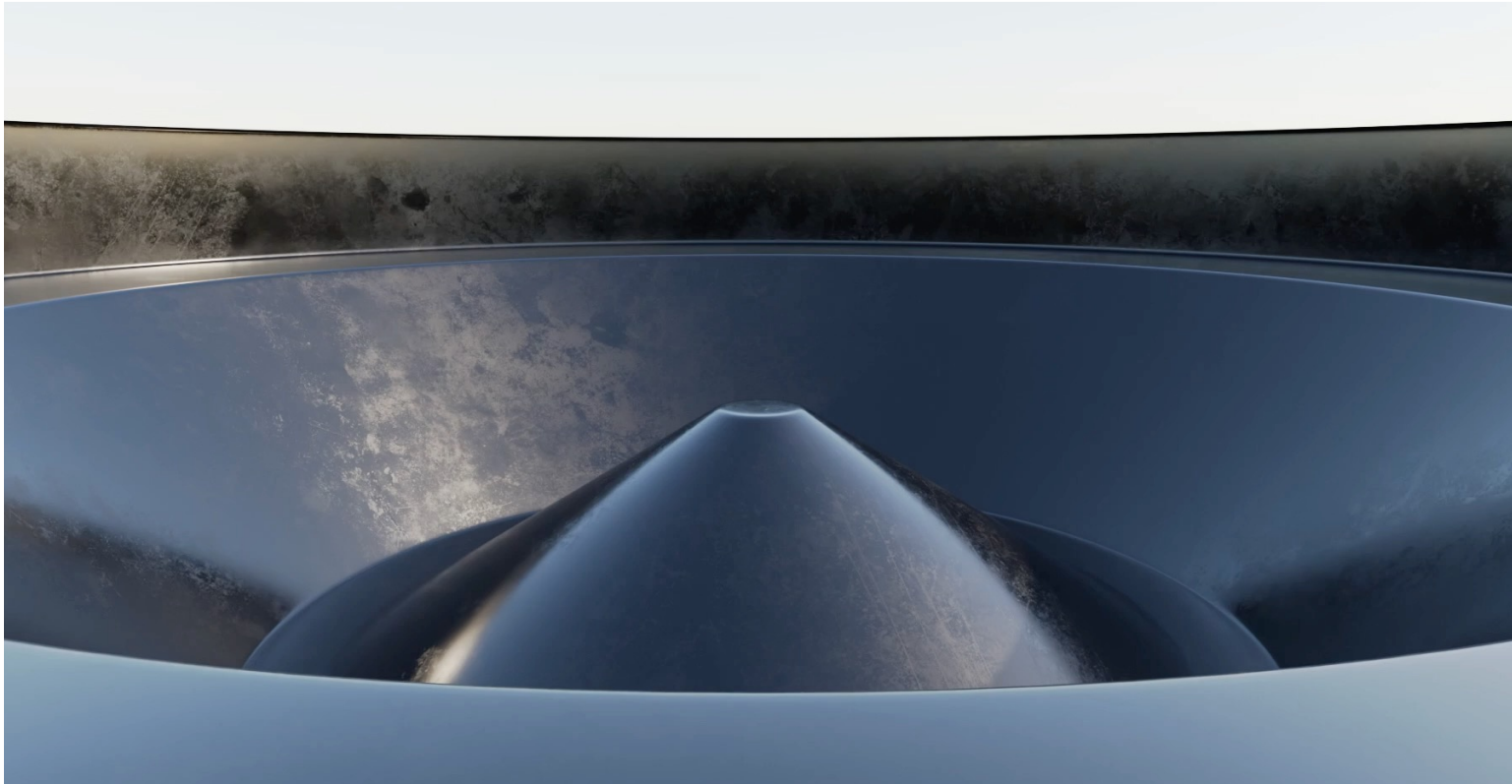
Cancer

Advanced Materials

Catalysis

Enable science advancements on the most globally important problems: energy security, earth science, health, materials, and physical laws, which continue to get bigger and harder

Sample DOE and National Mission Domains

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Exascale computing is helping design more efficient combustion processes for transportation

Frontier is helping researchers digitally recreate complex combustion environments in unprecedented detail

Scientists on the Combustion-Pele project used Frontier to simulate the direct injection and compression ignition inside a high-pressure diesel engine in unprecedented detail. The team hopes to expand the simulation to capture the thousands of elementary reaction steps inside a jet engine. PI: Jacqueline Chen, Credit: Marc Day/NREL

Record-Breaking Run on Frontier Sets New Bar for Simulating the Universe in the Exascale Era

World's largest simulation of the cosmos lays new computational foundation for simultaneous extreme-scale dark matter and astrophysical investigations
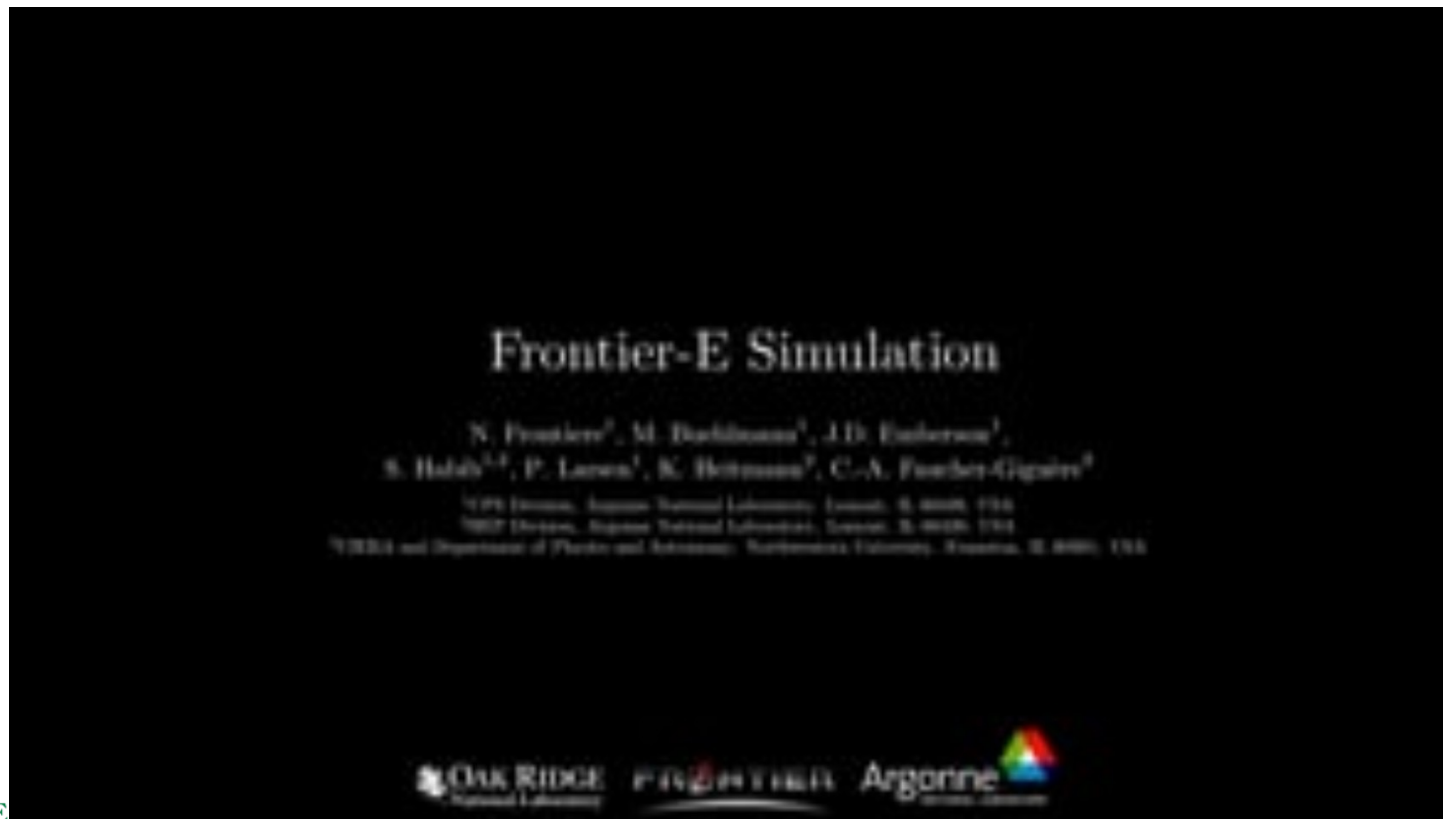
Frontier is helping NASA prepare to land humans safely on the surface of Mars
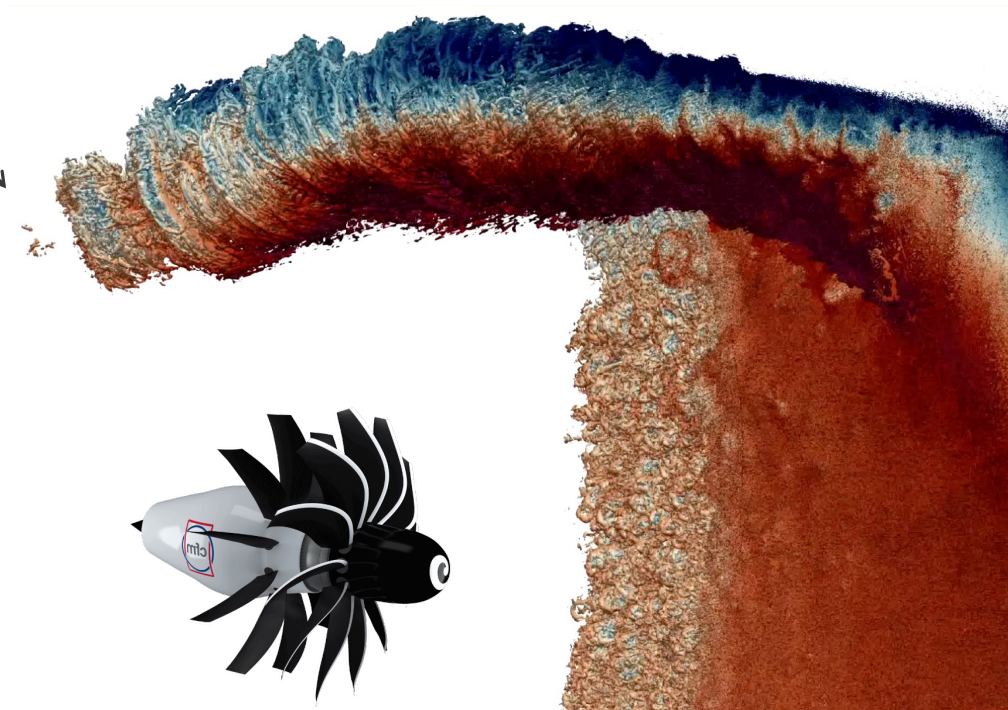
Technologies and systems for landing on Mars can't be comprehensively tested on Earth beforehand, leaving researchers to rely on the exascale power of Frontier to simulate a human-scale Mars lander
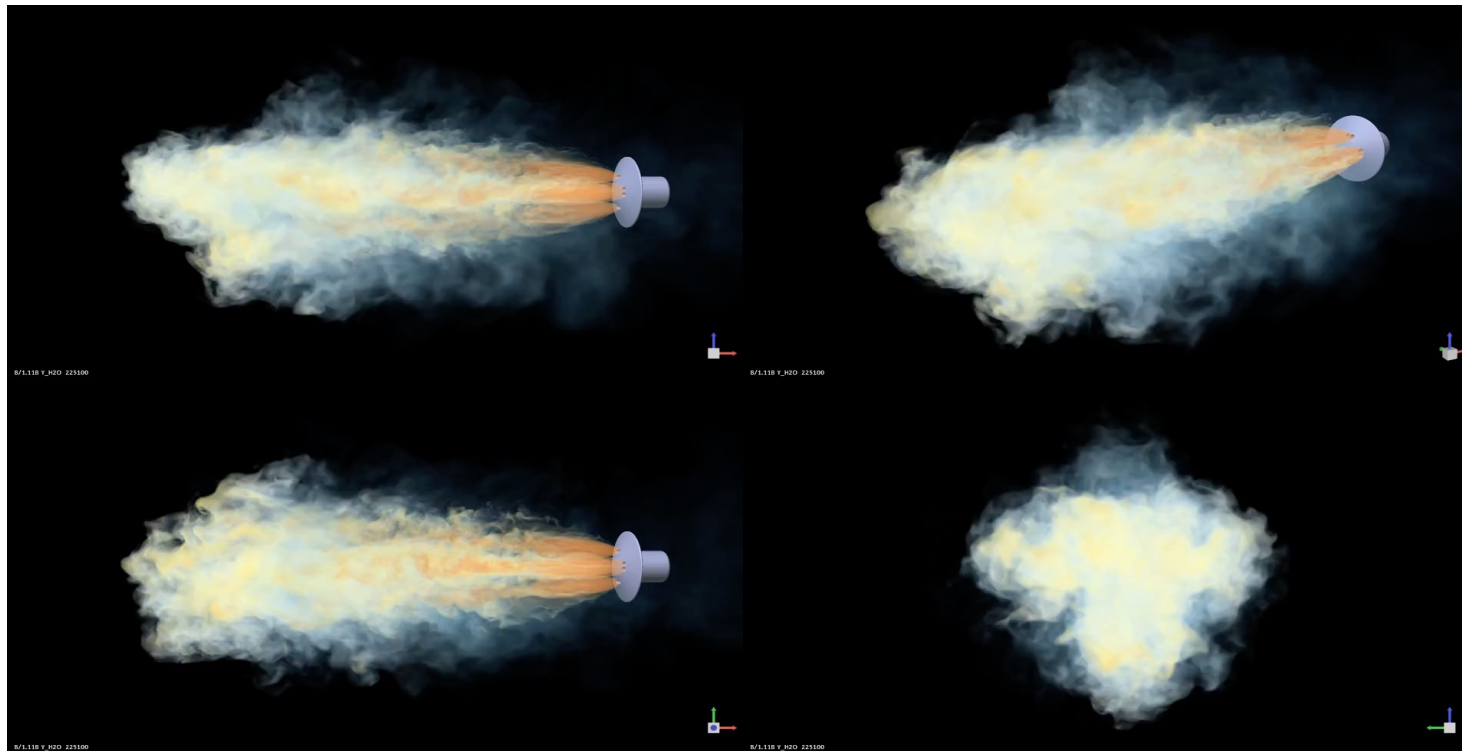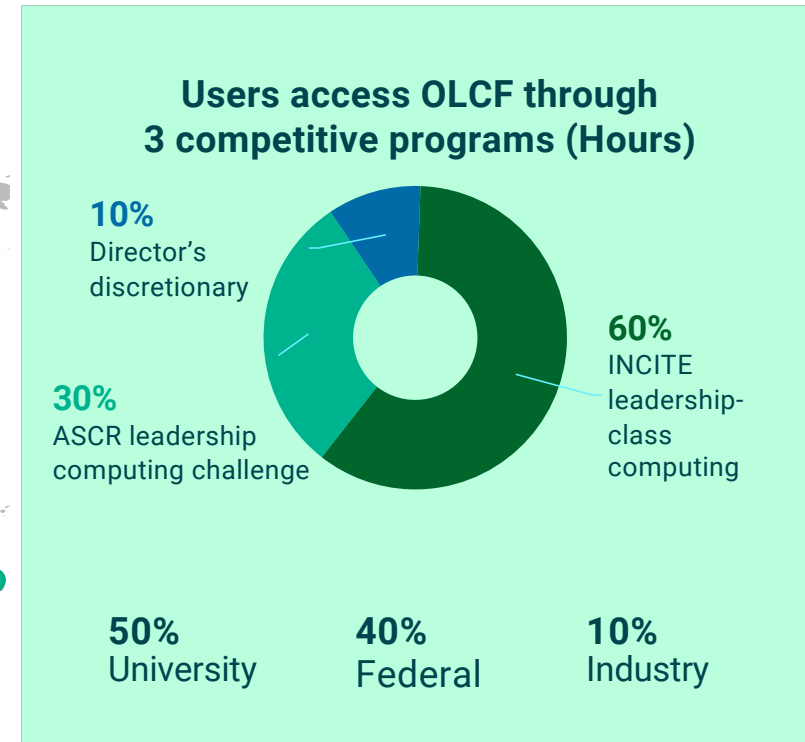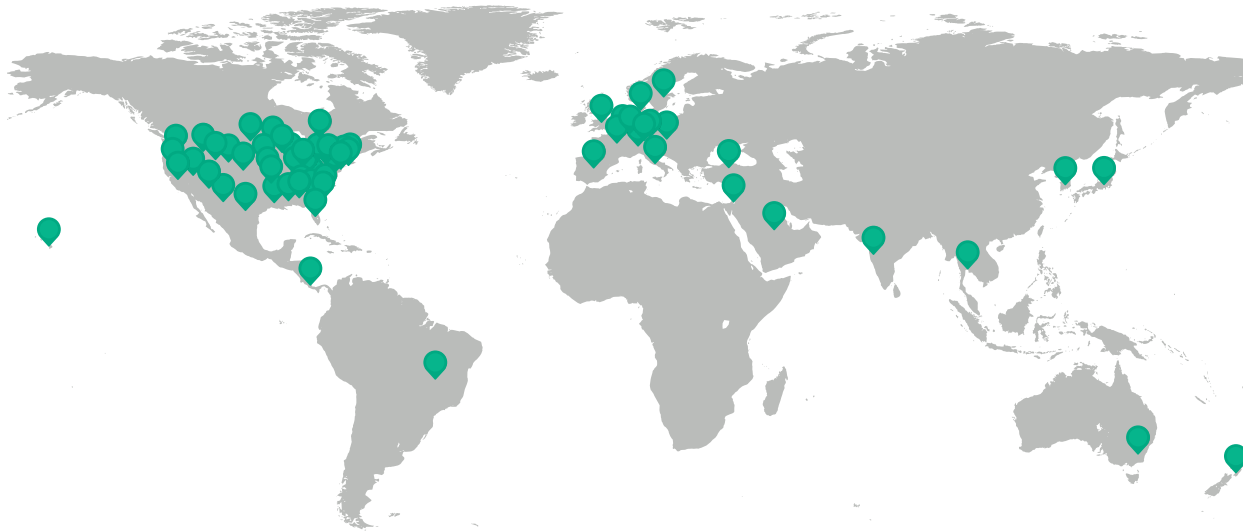

The NASA-led research team's work has used OLCF resources for many years. Once they were able to access Frontier, the team focused on the ultimate simulation they had hoped for years: a truly autonomous, closed-loop test flight leveraging the world's most powerful supercomputing system. Shown here is a volume rendering of H_2O mass fraction shown for a static Mach 1.4 flight condition. (Credit Patrick Moran/NASA)

Flight-scale aeroacoustic simulations on Frontier are helping advance breakthrough propulsion design

GE Aerospace's new open fan engine architecture seeks to achieve at least 20% lower fuel consumption compared to today's most efficient engines

GE visualization of turbulent flow in the tip region of an open fan blade only made possible using the Frontier supercomputer (right). Credit: CFM, GE Research.

OLCF by the Numbers

Users access OLCF through 3 competitive programs (Hours)

- **10%** Director's discretionary
- **30%** ASCR leadership computing challenge
- **60%** INCITE leadership-class computing

50% University **40%** Federal **10%** Industry

1,954 annual users
25 countries

301 unique
institutions

175 industrial projects
in the past 5 years

6,300 peer-reviewed
publications since 2012

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What does the future hold?

OLCF Driving AI Progression to Frontier AI Models

OLCF-7

Next-generatio
Leadership
Architectures:

HPC+ AI +
Quantum

**Discovery,
2028- (OLCF-6)**

Frontier (2022-)

Summit (2019-2025)

Titan (2013-2018)

Smart Exascale
Ecosystem (c. 2028)

First Exascale Machine:

- First LLM on
Leadership
Machines (FORGE,
2023)

- Mixture of Experts
(ISC, 2024)

- First
Supercomputer
Digital Twin (2024)

- Connectivity to AI
appliances

- Connectivity to
data streaming
and Integrated
Science

- Connectivity to
Quantum

2017

- First Deep-
Learning
Campaign at
Leadership
Supercomputing
Scale

"Smartest
Supercomputer":

- First to break Exaflop
barrier in mixed
precision

- First Gordon Bell with AI

OLCF's QCUP provides users with access to quantum computing resources.

IBM

- General-purpose transmon systems provide up to 133 qubits.
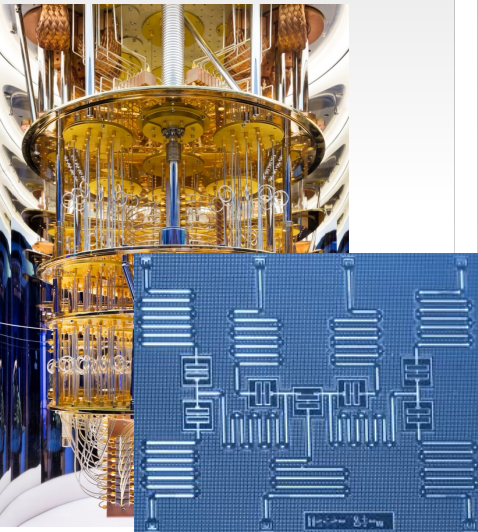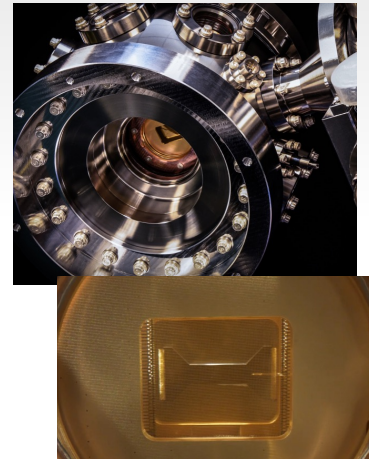

IQM

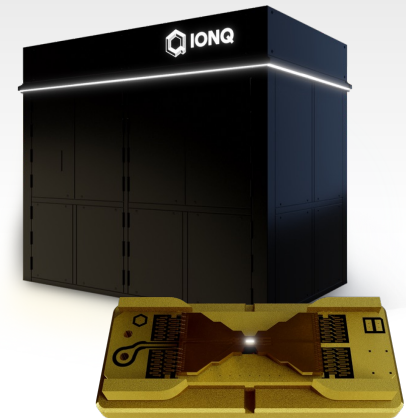- General-purpose transmon systems provide up to 20 qubits.

Quantinuum

- General-purpose ion trap systems provide up to 56 qubits.

IonQ

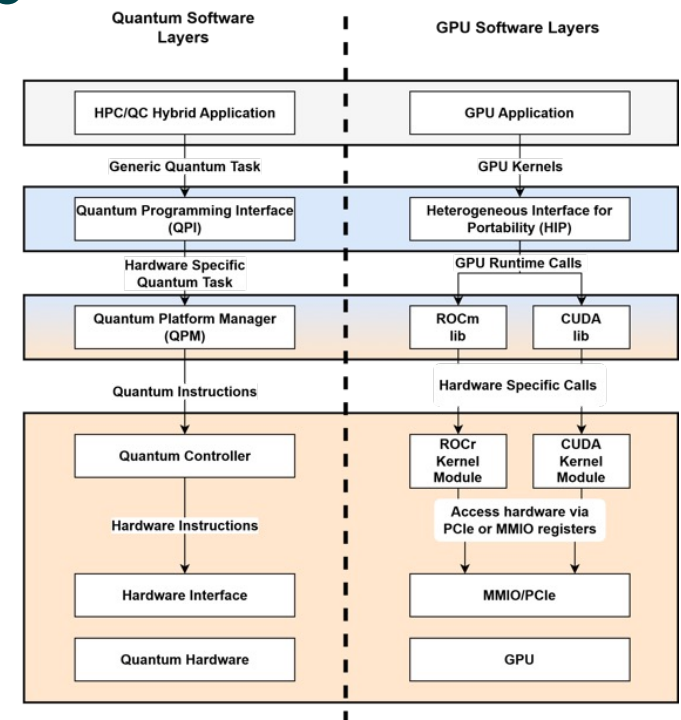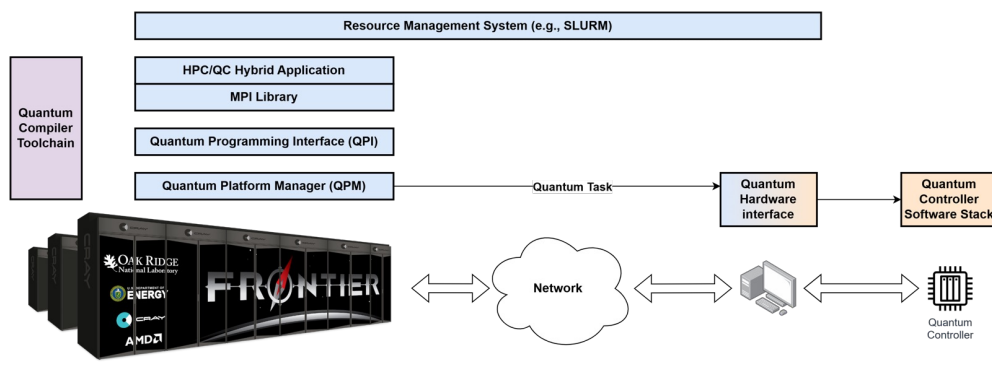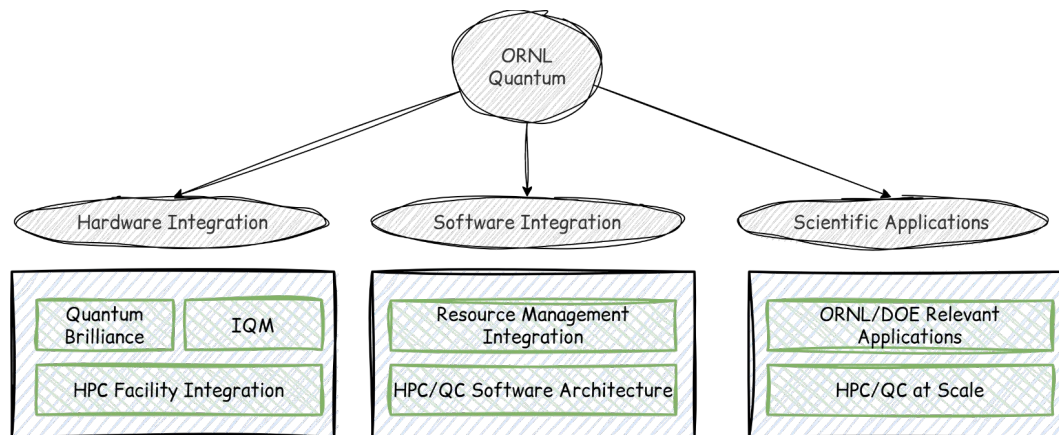- General-purpose ion trap systems provide up to 25 qubits.

Publication count by fiscal year (as of October 2024)

| FY2020 | FY2021 | FY2022 | FY2023 | FY2024 |

Selection of services is based on technical value, user needs, and budget availability.

Current system count is 18

ORNL is Driving Towards QHPC Convergence

A. Shehata et al., Bridging paradigms: Designing for HPC-Quantum convergence
*https://doi.org/10.1016/j.future.2025.107980*

Discovery (OLCF-6): Leadership Science Connecting HPC, AI, Quantum, and Integrated Research Infrastructures

Design choices for Discovery help support these connected efforts

OLCF-6

- **The Mod/Sim User Community will Persist and Grow**
  - Bandwidth needs to catch up with FLOPS in Leadership computing.
  - Support for FP-64 and mixed precision mod/sim

- **AI for Science will need a system with:**
  - High performance lower precision FLOPS
  - Support AI storage needs and priorities
  - Need for overall improved bandwidth

- **Hybrid Quantum/HPC computations**
  - Discovery will also connect to quantum computers for hybrid computations

- **New Integrated Research Ecosystem Use Cases**
  - Discovery will support Workflows for real time compute; data movement, storage & curation

Smart Exascale Ecosystem: Testbeds to Production
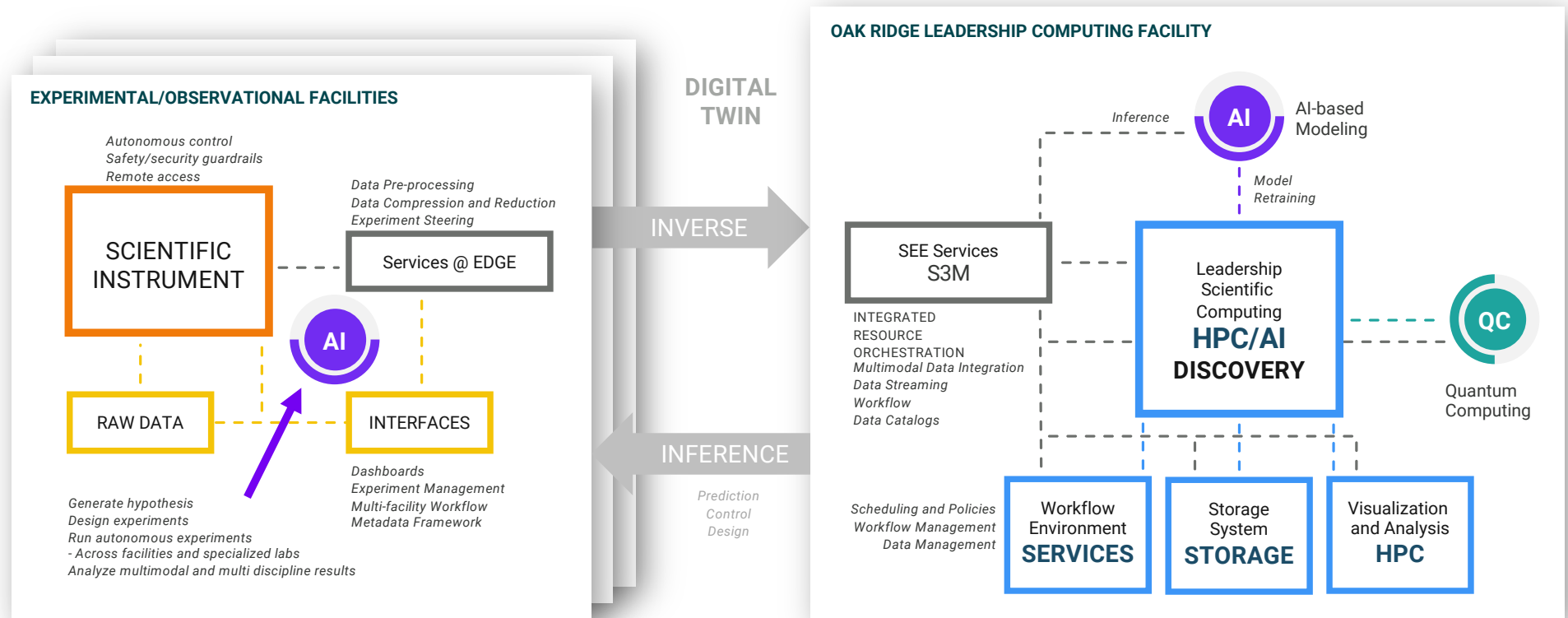
OLCF Brings Together Expert Users and Collaborative Teams

Leadership scale compute and data infrastructure is critical for accelerated innovation and global competitiveness.

Leadership scale HPC is a core capability for DOE nurtured for several decades.

Dedicated & **experienced workforce** is one of our greatest assets.

The OLCF invests effort in **developing the current and next generation** of HPC staff and users.

Sustainable Research Pathways

Winter Classic

Crash Course

Pathways to Supercomputing

AI Summer School

PCIP Internship Program

Next Gen Pathways to Computing

Co-Op Programs

Postdoc Programs

Quantum Summer School

Thank you!

Enjoy your time at the OLCF User Meeting 2025!