Personnel

Arizona State University (ASU) is served by both the central University Technology Office (UTO) and the Research Technology Office (RTO). UTO is the central IT organization with over 540 FTEs across multiple service areas including desktop support, wired and wireless networking, public and private cloud, identity management, information security, and web application development. UTO oversees core campus IT services such as payroll, email, instant messaging, user file storage, and document creation/collaboration. UTO also handles ASU policies regarding IT services, data governance, and information security. RTO focuses on IT services directly supporting research and researchers. Specifically, RTO comprises 85 FTEs covering Research Computing, Research Software Engineering, Research Data Management, Business Intelligence, and Web Services. RTO is overseen by the Chief Research Information Officer who reports to the University's Executive Vice President of Research. The Research Computing staff consists of computational scientists, programmers, engineers, and database administrators with expertise in all areas of computing, including scientific and parallel computing, big data analytics (in memory), custom software development, database engineering, and scientific visualization.

Advanced Computing

Research Computing is an academic supercomputing facility providing high performance computing (HPC) environments, a data intensive ecosystem, connectivity to the Internet2 research and education network, and large-scale data storage with elastic capacity to the public cloud. Research Computing provides a variety of HPC (both physical and virtual), cloud, storage, development, implementation, and consulting services. Research Computing consulting services and support for computational investigations, including data analysis, simulation, modeling, visualization, and other high-performance approaches include:

- Identifying optimal systems and software platforms
- Training in computational and/or graphics algorithms, tools, and packages
- Developing custom post-processing graphics tools
- Creating virtual environments for scientific research and fine arts
- Tuning applications for peak performance and implementing parallel algorithms and programs
- Purchase consultation for server, HPC, and storage acquisitions
- Virtual server provisioning (local, cloud)
- Physical and virtual server management
- Providing state-of-the-art interfaces to HPC systems
- Recharge of non-preemptable computing time and data storage solutions
- Accessing extensive external, government-funded compute resources (XSEDE, OSG)

<u>Advanced Computing Systems</u>

Through a strategic partnership with Dell Technologies, ASU launched Sol, the flagship supercomputing system at ASU, in spring 2022. Sol initially contained

- 18,000 AMD CPU Cores
- 224 NVIDIA 80GB A100 GPUs
- 5 Large Memory (2TB RAM) Nodes
- 4PB BeeGFS Scratch Data Storage
- 2PB Home Data Storage
- 200Gb/s HDR Infiniband network
- 25Gb/s Ethernet network

Sol has added additional capacity through grants, and researcher purchases.The new capacity since launch consists of the following.

- 1,024 additional AMD CPU Cores
- 38 additional NVIDIA 80GB A100 GPUs
- 18 NVIDIA 40GB A100 GPUs
- 21 NVIDIA A30 24GB GPUs
- 8 NVIDIA 80GB H100 GPUs
- 1 NVIDIA Grace Hopper Superchip
- 3 AMD MI250 GPUs
- 2 additional Large Memory (2TB RAM) Nodes

Each Sol compute node contains two 64-core AMD EPYC Milan 7713 CPUs and 512GB of DDR4 RAM.

ASU researchers also have access to the recently updated Phoenix supercomputer. Phoenix is a heterogeneous Intel-based HPC cluster containing over 17,200 CPU cores. Each node is stateless, and has system memory ranging from 128GB to 384GB of DDR4 2400 RAM, depending on the node. The cluster also includes three large memory application nodes with 1TB, 1.5TB, and 2TB of DDR4 2666 RAM. GPU computing capabilities include access to over 360 NVIDIA A100, V100, GTX 1080, and RTX 2080 GPU accelerators. Phoenix also has a 2PB scratch filesystem for computational storage. Compute nodes are accessible through two login nodes and two NSF-funded Open OnDemand web interface systems. Compute jobs are managed with the SchedMD Slurm scheduler. Phoenix is supported by a mixture of 100 Gbps Infiniband and Omni-Path networks. It is connected to the campus Science DMZ, Internet2, and Data Transfer Nodes by a 100GE core network.

A dedicated pool of 2PB high-performance BeeGFS fast scratch storage is presented to the Phoenix cluster via dual interconnected networks (InfiniBand and Omni-path), and a 2PB network attached storage array provides HPC home directory storage. For general purpose research data, a 10PB network attached storage array provides project storage.

Researchers may also purchase their own compute nodes and incorporate them into both the Sol, and Phoenix supercomputers, with Research Computing supplying all necessary rack space, power, cooling, networking, and software maintenance. Researchers and their delegates have priority access to their purchased nodes, and any idle capacity is made available to computing jobs for the general ASU research computing community. Such jobs will be guaranteed to run without preemption for at least four hours, after which jobs submitted by the node's owner will preempt them. The owner may also reserve their nodes exclusively for up to three one-week periods per year. Purchasing computing capacity in this manner allows researchers guaranteed access to the necessary computing power without needing to operate and maintain their own servers.

Research Computing will support researcher-purchased nodes for as long as feasible. However, beyond the hardware warranty period, the faculty is responsible for any hardware and labor costs necessary to maintain the hardware. Once the warranty period has expired, Research Computing may remove the node from the supercomputer if it is no longer technically feasible to support it.

Dell Center of Excellence for HPC and Artificial Intelligence

ASU has been designated a Dell Center of Excellence for high-performance computing (HPC) and Artificial Intelligence, the third such center in the United States and the sixth globally. This distinction has grown out of a close collaboration with Dell HPC experts on system architecture, design, and innovation.

Open Science Grid

Research Computing supports the Open Science Grid (OSG) and dedicates both CPU and GPU capacity for the research community at large.

Data Center

In 2022 ASU Research Computing launched a new data center at the Iron Mountain Phoenix facility, with more than four times the capacity of the older, on campus data center, ISTB1. The space is housed in a commercial Tier III+ data center with advanced power, cooling, and network capabilities. ASU Research Computing is a core tenant of the facility and has the capability to support regulated research security requirements (up to FISMA[1] High). A private fiber ring seamlessly connects the facility to the ASU Tempe Campus. Internet2 and Commodity Internet circuits are also available at the facility as secondary connectivity, as well as private point-to-point circuits.

Network

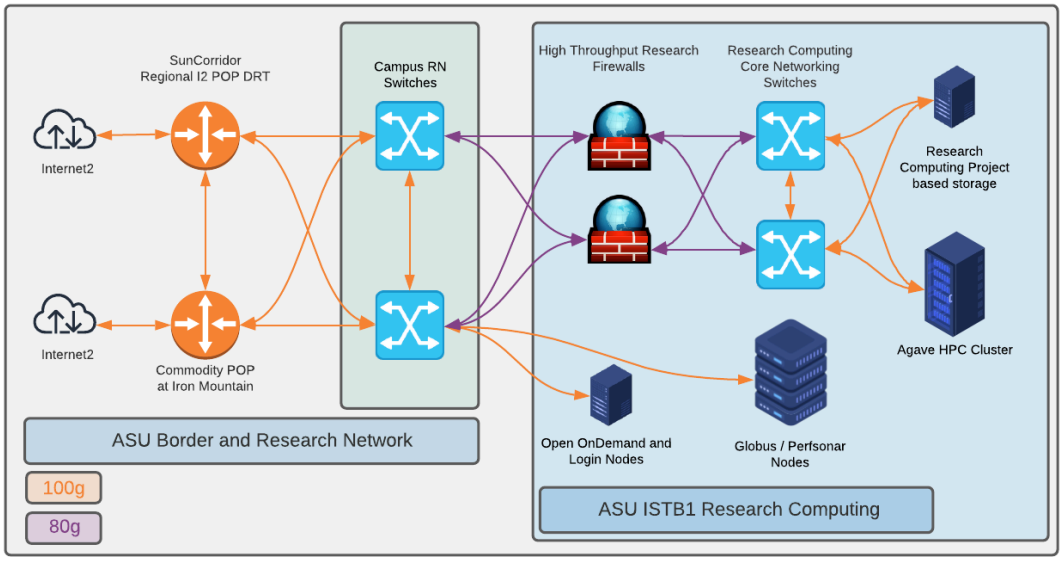

Figure 1: Research Computing Network Connectivity

Figure 1 illustrates the current ASU network border topology. Primary network access is via a 100 Gb Internet2 circuit to the Tempe campus. Secondary 100 Gb commodity Internet circuits provide additional and partially redundant network access directly from the Tempe campus. The ASU Polytechnic campus (25 miles southeast of Tempe), the ASU West campus (25 miles northwest of Tempe), and the ASU Downtown campus (10 miles west of Tempe) connect to the Tempe campus via redundant 100Gb circuits on a commodity fiber ring. The ASU network is monitored 24x7x365 by a commercial network provider as well as by the University Technology Office.

Buildings on all ASU campuses are connected in a hub-and-spoke model, with most buildings served by redundant 10Gb links and 1Gb to end users. The campus network employs an advanced security complex

[1] https://www.dhs.gov/cisa/federal-information-security-modernization-act

consisting of a layered defense-in-depth deployment of security controls that include DDoS and IP reputation, a variety of specialized network firewalls, and anti-phishing protections. The ASU cybersecurity program also includes mandatory security education and awareness training, and the UTO Governance, Risk, and Compliance Team conducts continuous assessments evaluating risk and vulnerabilities.

Science DMZ

The ASU Science DMZ is a network enclave that bypasses the network security complex. The Science DMZ is explicitly designed for high-throughput data movement, incorporating 100 Gigabit Ethernet, virtual circuits, and software-defined networking capabilities as well as dedicated systems for large data movement requiring a friction-free path, with security policies and enforcement mechanisms tailored for high performance science environments.

Data Storage

The ASU Enterprise Technology (ET) supports cloud storage using a variety of cloud-based storage offerings, including Enterprise Dropbox (for Staff/Faculty, 1TB limit), Microsoft OneDrive (available to all Staff, Faculty, and Students via Office 365, 1TB limit), and Google Drive (available to all Staff, Faculty, and Students via G Suite for Education, no storage limit). ET provides storage to Business Units via SMB/CIFS on Enterprise NetApp Network Appliances.

ASU Research Computing provides 100GB of home directory storage for users on each of the two supercomputers, as well as access to a combined 6PB of high-speed short-duration scratch environment for cluster computing jobs. Research Computing also operates 10PB of network-attached project term storage. This storage is accessible to the Phoenix HPC cluster and individual researcher workstations via traditional network shares. The Globus data movement platform provides resilient high-speed access to data stored on Research Computing systems and allows for transfer to user's University provided Google Drive accounts.

Quantum Computing and Simulation Systems

The Quantum Collaborative offers premium access to IBM's Quantum Innovation Center (QIC) quantum simulation and quantum computing resources. ASU is the founding member of the Collaborative, and all users of HPC systems at ASU may request this level of access to the QIC. The QIC quantum computing machines are 'utility scale' noisy intermediate-scale quantum (NISQ) era systems, comprised of 127 qubits or more, and kept current with IBM's most recent technology. Up-to-date and comprehensive information about the QIC quantum systems is detailed on the IBM QIC website.

Quantum simulation resources are also provisioned on Sol (ASU's flagship HPC system). Sol supports current versions of IBM's quantum simulation environment, Qiskit, and NVIDIA's CUDA-Quantum package. Both software instances use NVIDIA's cuquantum library to handle GPU implementations of quantum computing simulation routines, ensuring optimized performance of these applications. Additional programming frameworks, such as Google's Cirq, and Amazon's SDK Braket, can be made available via Sol upon request.