**Virginia Tech Cyberinfrastructure Strategy
Office of the Vice President for Information Technology**Revised 2021-11-30

# Mission

Consistent with the mission of the university, Virginia Tech will provide cyberinfrastructure resources, tools, and services to enable the university community to create, convey, and apply knowledge to expand personal growth and opportunity, advance social and community development, foster research competitiveness, and improve quality of life.

# Vision

Virginia Tech will create, deploy, and evolve a comprehensive portfolio of cyberinfrastructure resources and programs to enable computational and data-intensive science and engineering, research, and learning across all disciplines of the university.

The term “cyberinfrastructure” refers to technology-based resources, tools, and services essential to the conduct of 21st century science and engineering research and education. Examples include high performance computing, storage systems, visualization tools, high performance networks, data repositories, and software tools among other resources. As a STEM-focused research university, strategic investment in advanced cyberinfrastructure is crucial to Virginia Tech.

Virginia Tech’s long range plan recognizes that advanced computing – data-intensive, high-performance, and highly networked – is “crucial to facilitating advanced research” in areas of priority for Virginia Tech. The university Information Technology Strategic Plan identifies the objective of “Poviding Competitive Advantage through Sustainable Advanced Cyberinfrastructure and Collaboration” as one of the four focus areas for investment and development.

University investments in high performance computing and related infrastructure and support are guided by strategic evaluation and recommendations of a presidentially appointed High Performance Computing Investment Committee. The committee is comprised of senior level academic stakeholders chaired by the Vice President for Information Technology.

#  Strategies

Virginia Tech cyberinfrastructure strategy is organized around four foundational elements:

1. Integration of computational science into the process of inquiry.
2. Meeting the changing needs of our major research institutes and the university community.
3. Organizing the deployment of the cyberinfrastructure assets.
4. Financing the required significant investment on the part of the university.

## Integration of computational science into the process of inquiry

Virginia Tech must position itself to achieve the empowering paradigm shift that incorporates computational science and cyberinfrastructure into the strategic level of research methodologies.

* The university’s long range plan is infused with the recognition that computational thinking and informatics/digital fluency are needed in all disciplines. The integration of computational science in our learning and discovery domains must be established as a university goal, becoming part of faculty development and students’ education—at all levels.
* Many notable computer science and engineering projects require deep collaboration among engineers and scientists, and traditional computer scientists. We must look for ways to build and expand these efforts. Some of the activities at the Fralin Life Sciences Institute (FLSI), the Virginia Tech Transportation Institute (VTTI), the Virginia Tech Carilion Research Institute (VTC), the National Security Institute (NSI), and the Institute for Critical Technology and Applied Science (ICTAS) are in this class.
* We must invest in additional projects with the potential to take full advantage of the integration of computational science and cyberinfrastructure into our research programs.
* We must leverage the significant opportunities for integrating computational science into our research and learning domains to enhance our research enterprise and prepare our students for solving complex problems of the future.

## Meeting the changing needs of our major research institutes **and** the university community

Virginia Tech must build a collaborative atmosphere of cyberinfrastructure excellence and access, developing capabilities based on demonstrated strengths, redressing weaknesses, and improving support structures, including:

* Virginia Tech must establish a coherent cyberinfrastructure acquisition and development strategy.
* New governance and support structures must engage stakeholders from the research community in decision-making for acquisition and support strategy.
* The funding model must draw from an array of internal as well as external public and private sources.

## Organizing the deployment of the cyberinfrastructure assets

Virginia Tech must maintain and develop:

* **High Performance Computing**
	+ One or more continually upgraded, centrally provided data center facilities, providing the space, power and cooling that are necessary to run a world-class university research computing effort—central, and in special cases distributed, as well as a backup location for high-value data.
	+ State-of-the-art, large capability cluster systems—central, and in special cases distributed.
	+ Large shared-memory computer systems—central.
	+ Smaller clusters, project funded and acquired for specific needs not met by general, shared systems — distributed and central.
	+ Commodity-based compute systems that are network grid accessible to handle general research and capacity computing—centralized.
	+ Condominium-style clusters in the central data center.
	+ Computing and storage resources to support Controlled Unclassified Information (CUI) and protected Public Health (PHI) data research programs.
	+ On- and off-premise virtualization and containerization capability for reduced capital and operational expenditures, rapid depolyment, and high flexibility for researchers.
* **Storage** - Multi-tiered, large-scale storage facilities to provide seamless access to user data and to meet the increasing demands for data centric computing—central, and in special cases distributed.
* **Cybersecurity** - resources and capabilities required to ensure security and performance of university systems, to meet and exceed contract requirements and compliance, and to build on university core strengths in the field.
* **Visualization** tools and venues—central and distributed.
* **Technology-enhanced Learning** programs enabling the university community to envision and grasp opportunities to lead innovation for the creation and use of emerging technologies for research, teaching, and learning.
* **Networking** - Internal and external network connectivity of sufficient capacity, bandwidth, and control to enable user applications and data to be transported easily across the campus, the nation, and internationally—centrally managed and provided.

Virginia Tech must engage support personnel to build and support a broad-based program leveraging cyberinfrastructure and computational science-based research and inquiry. Generally, these personnel resources would be distributed across the research enterprise with economies of scale in clustering such personnel within specific research domains.

* Systems engineers housed in close proximity to hardware resources and dedicated to supporting the hardware and software for research computing.
* Application specialists housed as a group with easy access by the entire community of domain specialists and researchers.
* Domain specialists with deep expertise in the specific science/engineering research subject matter and close working relationships with, and close proximity to, researchers.
* Software engineers who build robust cyber-infrastructure systems that provide services to a group of researchers in a specific science domain.

Virginia Tech must maintain a commitment to leverage cyberinfrastructure to promote data security, physical security, and personal safety.

## Financing this significant investment on the part of the university

To achieve university goals, Virginia Tech must invest annually through central funding, in cyberinfrastructure to meet growth in scale and to address evolving cyberinfrastructure requirements. Current strategies include:

* The university currently utilizes a central funding model for core research computing using funds from all available sources, seeking to significantly expand computational science-based research with coordinated governance, management and control.
* The university seeks economies of scale in large-scale facility development projects, in access to distributed facilities, and in 24/7 operations and management.
* For both central and distributed resources, Virginia Tech requires that sustained operational, software, and personnel funding is factored into the life cycle estimate of any proposed investment in cyberinfrastructure.

The university iimplements shared contribututions to cyberinfrastructure through its Investment Computing program and a cost-center model.

#  Supplement:Immediate and Near-Term Efforts with Commitments as of Fall 2020

Following is a selected list of key programs geared toward realization of the cyberinfrastructure strategic plan which are underway or planned for the near term with commitments from the university, partners, and funding sources.

## High Performance Computing

Virginia Tech’s Advanced Research Computing (ARC) team operates several HPC systems available to the VT research community. The flagship TinkerCliffs installed in 2020, is primarily composed of AMD Rome II processors with Intel Cascade Lake processors and has a total of 41,984 cores, 93.2 TB of memory, 184.1 TB SSD/NVMe local storage, connected by HDR Infiniband. Recently, four large GPU nodes were added to TinkerCliffs. Each node has 128 AMD cores, 2 TB of memory, and eight Nvidia A100-80G GPUS. Other resources include a CUI cluster (12 compute nodes with 64 cores and 3 large GPU nodes with eight NVIDIA A100, 1.5 TB of memory ,and 650 TB flash storage), Cascades (7,312 Intel Broadwell and Skylake cores, 48.9 TB memory, 16.2 TB storage in a mix of SSD, NVMe, and SAS hard disks, 6 Nvidia GPUs, EDR Infiniband), Huckleberry (24 cores/192 threads IBM Minsky Power8, 512 GB memory, 8 Nvidia P100 GPUs with 16 GB each and Nvlink, EDR Infiniband), DragonsTooth (1,152 Haswell cores, 12 TB memory, 92 TB fast solid state drives (SSD), 10 Gbps Ethernet).

## Storage

Ongoing, substantial investments in research data analysis and storage systems support Virginia Tech's data intensive science. These systems include a 600 TB BeeGFS high performance parallel file system, a newly installed 3 PB GPFS storage system for TinkerCliffs, a 3.1 PB GPFS high performance file system, a 250 TB Vast NAS system for fast scratch, a 650 TB VAST flash NAS for CUI research, a 281 TB Qumulo storage system for home files, and a 9 PB research data archive based on SGI's Data Migration Facility .

## Virtualization and Containerization

Virtualization and Containerization are modern tools used to create reproducible, scalable and secure compute environments. Both technologies are state of the art and in demand by VT researchers. ARC, through NIS, housed an on-premise OpenStack system for several years. Lessons learned in the previous system are assisting in the design of a new on-premise system geared more to supporting research. The new Advanced Research Computing on-premise cloud system is in the design phase. A platform for deploying containers under Kubernetes is also in development.

Virginia Tech has three active contracts for access to cloud services. These include Amazon AWS, Microsoft Azure, and Google GCP. These solutions are brokered to support consultation, onboarding, and billing for flexible and nimble cloud service access. Policies are being put in place to institutionalize the use of commercial cloud services. The policies will likely advocate a “best fit” approach, meaning evaluate each use for where it would be best accommodated. For some uses, a commercial cloud deployment will make the most sense. For others, deployment to on-premise resources may make more sense.

## Cybersecurity

**InCommon Federation** - Virginia Tech participates in the InCommon Federation as an Identity Provider, allowing individuals to use their Virginia Tech credentials to securely authenticate to services provided by InCommon Service Providers. Since InCommon is a federal Trust Framework Provider, Virginia Tech is an approved Credential Service Provider under the FICAM TFS Program.

**IT Security Lab** - The Information Technology Security Lab (ITSL) is a component of the Information Technology Security Office (ITSO). It functions as the development lab for ITSO projects such as the ones listed in this section. It also functions as a teaching hospital allowing graduate and undergraduate students to gain live, hands-on experience in dealing and solving cybersecurity problems under the supervision of ITSO faculty and staff. The ITSL provides a real-world capability for researchers to test out their theories.

**Intrusion Detection Sensor (IDS) Deployment** - The ITSO's mission is to protect the University IT infrastructure from cyber-attacks. The ITSO deploys freeware and commercial intrusion detection sensors to monitor attacks against University computers. The data collected by these sensors provides a rich source of data for ITSO staff and researchers. Data mining and data analysis techniques becomes a critical component in responding to cyber-attacks. The tools and sensors deployed allow us to do malware analysis as well. VA Tech is continuing to implement its Continuous Monitoring IT Security strategy. This strategy allows the ITSO to "hunt" for compromised machines and remediate the event. Continuous Monitoring is a component of the Center for Internet Security’s (CIS) Controls architecture. The CIS Controls are a subset of the NIST 800-53 Priority 1 controls, NIST CSF and NIST 800-171.

**Visualization** - The data generated by the IDS sensors is difficult to show in a meaningful and timely manner. The ITSO works with the GIS group to merge IDS data with GIS maps and building floor plans of the campus. The ITSO and Network Infrastructure and Services has tools that can locate wired and wireless computers on campus. These tools in combination with GIS visualization tools provides the ITSO with a quick and timely way to determine the scope of cyber-attacks against University computers.

**IPv6** - Virginia Tech has been running a full production IPv6 network since 2006 and has been a leader with active participation on the Internet2 IPv6 working group and multiple federally funded programs including development of a number of IPv6 cyber defense techniques. The ITSO obtained a US patent for an IPv6 Moving Target Defense scheme

**Development of A Cyber Security Operations Center** - In parallel to expanding intrusion detection capabilities, the IT Security Office is also developing a Cyber Security Operations Center (SOC). This convergence of tools, data, and personnel into the SOC will allow IT Security personnel to unite data from network sensors, provide analysis, and coordinate needed responses to further protect Virginia Tech’s IT assets.

## Visualization

**High Performance Visualization.** As data sets from sensors and simulations become increasingly large and onerous to move, ARC is expanding services for visualization and interactive rendering on our HPC clusters. With fast I/O and clusters of computing hardware, users can scale up to visualize bigger data faster. Both interactive (GUI) and batch (scripted) sessions across multiple nodes are supported by ARC on our TinkerCliffs and Cascades clusters (hybrid CPU/GPU). Access to hardware-accelerated rendering is available through the Web interface of OpenOnDemand for tools like Matlab, R-Studio, Paraview, and Visit so that researchers can work with their results from thin clients.

**Immersive and Mobile Graphics.** the Web is the interface to access and author integrated data, notebooks, multimedia, and visualizations. Using ISO and WWW standards such as X3D and HTML5, ARC provides 3D graphics, 3D content management, and 3D publishing assistance for research, courseware, and simulation results to the Web. Such cross-platform visualizations are increasingly displayed on Virtual and Mixed -Reality devices; the Visionarium Lab provides an array of expertise, hardware, and software for researchers to develop and evaluate novel delivery of their data.

**Campus Mirror World.** With research partners across the University, the cross-cutting nature of spatial data infrastructure serves many stakeholders around and off campus. A Geo-referenced 3D multimedia model of the campus enables diverse applications; interoperability and institutional access supports design and review, onsite information analytics, and remote or virtual experiences and collaboration. Through our leadership in and adoption of open standards, we support researchers in moving their critical GIS and BIM data across proprietary applications.

## Technology-enhanced Learning

**Supporting the design of learning experiences, learning environments, and pedagogy.** TLOS puts in place the programs, services and supporting infrastructure to enable and encourage technology-enhanced learning across Virginia Tech. This includes support of both residential and distance education in multiple modalities, including asynchronous and synchronous online courses, hybrid classes, traditional classroom activities, and personal learning platforms. This support is made tangible through a TLOS’s DRIVE (Develop, Redesign, Innovate, Vitalize, and Enhance) grant program that provides faculty with training and direct production assistance with course design and development. Through this work we strive to position the university to effectively leverage technology to enhance and transform both classroom and online education, and to prepare our faculty and students to be successful in rapidly changing digital environments.

**Developing a Technology-enhanced Learning innovation pipeline.** TLOS provides support for innovative proposals through the Innovation in Learning (IL) grant program, as well as working with institutes and other partners to support cutting edge research in digital pedagogy, physical and online learning environments, and learning data analytics. Results of funded projects are shared with faculty through TLOS’s Professional Development Network, white papers, and showcase events. Projects will include not only those focused on the development of innovative content and strategies, but also a constant exploration of more effective ways for the university to support faculty and students in improving their digital fluency.

**Support of, and exploration within, the university’s digital learning environment.** In 2015 TLOS initiated the Next Generation LMS program, which resulted in the transition from our previous learning management system (built on Sakai) to Canvas. The transition to Canvas was completed in 2017, and it was followed in 2018 by the Video for Instruction program, which replaced outdated video conferencing and video storage platforms with Zoom and Kaltura, respectively. These three platforms (Canvas, Zoom, and Kaltura) form the core of Virgina Tech’s digital learning environment, and they are now in widespread use across all disciplines and all teaching modalities. In addition to providing enterprise-level support for these tools, TLOS is also undertaking new projects to expand our use of learning activity data generated by the platforms to inform teaching and learning activities at the university. These learning data analytics efforts will help instructors and students better understand their use of the LMS and help identify opportunities for ongoing refinement of the broader digital learning environment at Virginia Tech.

**Collaborative technology expansion**. Several enterprise-level technologies are deployed to enhance learning and collaboration. Collaborative technologies, in terms of SaaS (software as a service), include the Google Workspace and Microsoft 365 software suites. Both solutions support internal and external partnership for collaboration and communications.

**Digital learning solutions development**. In support of its programs for course design, faculty digital fluency, and technology-enhanced learning environments, TLOS provides design services that facilitate the creation of digital learning solutions, such as instructional video recordings, reusable learning objects, and custom application development within the LMS.

**4-VA, a statewide collaborative to benefit technology-enhanced learning and research**. 4-VA is a consortium of eight Virginia universities working together to promote collaboration and resource sharing to define new instructional models, expand access, increase research competitiveness, and increase opportunities for students in STEM courses and programs. Programs are underway in course redesign, course sharing, assessment, and research initiatives.

## Networking

**Mid-Atlantic Research and Education Network Exchange (MREX)** – VT operates a Regional Optical Network with core facilities in the Washington DC (MREX-IAD) and Atlanta GA (MREX-ATL) areas providing access to and commodity services for research universities who are members of MARIA, Inc. The MREX gateway to Internet2 at IAD is currently 100Gbps. At ATL, MARIA currently connects to Internet2 at 10Gbps with a planned upgrade to 100 Gbps in 2022. Both MREX nodes have gateways in place to ESnet and direct fiber links to numerous transit, content, and cloud service providers.

**Campus Connectivity to the MREX** – Virginia Tech has in place a fault-tolerant, diverse 100Gbps connection from the main campus in Blacksburg to the MREX-IAD in Ashburn VA. An upgrade for the link to MREX-ATL in Atlanta is planned for the first half of 2022 to bring that link to 100Gbps.

**IPv6** - Virginia tech supports IPv6 on all major network segments (academic, administrative, data center, wireless, and residence halls). Virginia Tech's network was one of the top seven networks for IPv6 volume and percent of working traffic in Google's 2010 paper "Evaluating IPv6 Adoption in the Internet" and is consistently in the top network measures by IPv6 deployment on the World IPv6 Launch website.

**Campus Network** – Virginia Tech was an early adopter of the Internet2 Innovation Platform with a 100G backbone that supports a high degree of virtualization and eventually SDN at large across campus. ASCED, our campus Science DMZ, was a primary design component of the upgraded backbone. These services are complimentary to broad-based wired and wireless connectivity provided directly to the university’s faculty, staff, students, and guests. Virginia Tech plans to upgrade the campus core to 400Gbps in 2023.

**Spectrum** – Wireless communication research is a core strength at Virginia Tech. The university Division of Information Technology provides unique assets and services in support of wireless research. We have two FCC Program Experimental Licenses in place covering our main campus and a large research center at Kentland Farm. In 2020, Virginia Tech acquired eight Priority Access Licenses in the CBRS band with a priority to use the spectrum to enable research and innovation.