ENVISIONING VIRGINIA TECH

BEYOND BOUNDARIES

ENVISIONING THE CAMPUS OF THE FUTURE

THEMATIC AREA GROUP REPORT

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VirginiaTech

The Beyond Boundaries visioning initiative identified the “campus of the future” as one of four thematic areas of inquiry central to Virginia Tech responding to a changing landscape and advancing as a global land-grant university. The initial topics assigned to the group to address included determining future facilities and infrastructure needs for the ways in which students, faculty, and staff learn and work, and exploring the role of technology in tomorrow’s university. This report documents the educational trends that the group identified as influencing the campuses of the future and the principles and visioning ideals guiding this direction. Participants propose three transformative platforms to organize and support the campuses of the future.

Trends Driving Change

The higher education landscape has undergone significant shifts in the past decade that will influence the future success of higher education institutions. This report highlights three of these trends as they relate to the campus of the future: changing student populations, technology, and transportation.

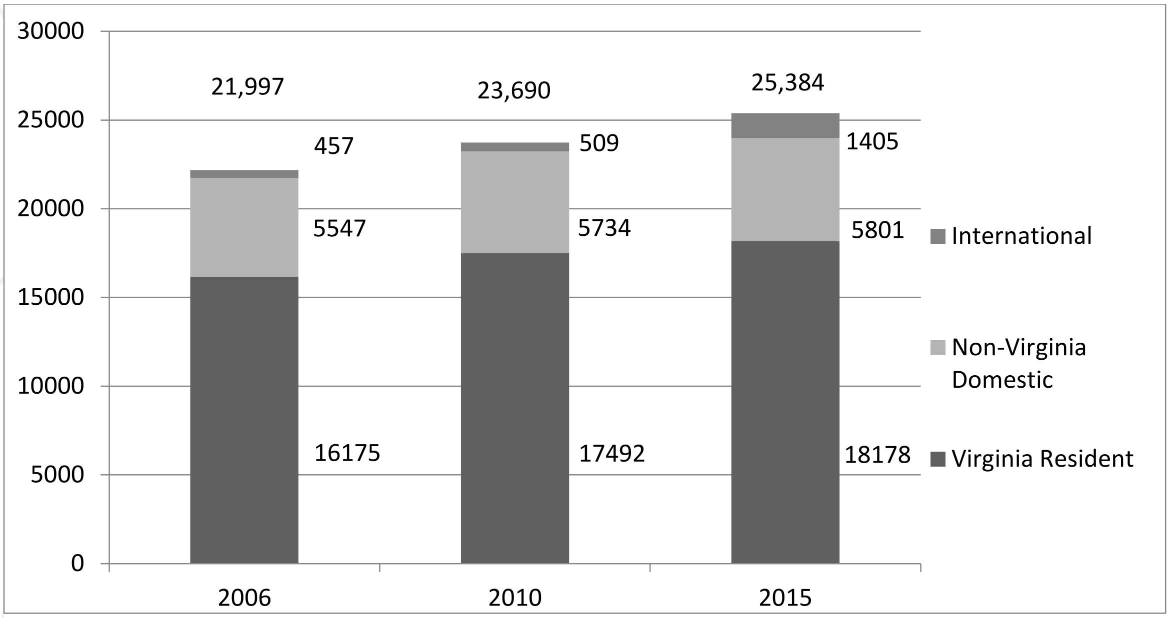
Student Populations in a Global Setting

As Virginia Tech looks towards its 175th anniversary, some of the decisions and priorities for the university will be based on changing student populations at Virginia Tech. Understanding these changes will be important as different types of students will require different forms of support. At present, the university serves a predominantly “traditional” undergraduate population of full-time students aged 18-24, which is typical of Virginia Tech’s peer institutions and many residential colleges. Only 2.1 percent of the undergraduate student body is enrolled part-time, and only three percent of Virginia Tech’s undergraduate population is over the age of 24 (IPEDS, 2015). At the graduate level, 31 percent of students are enrolled part-time (IPEDS, 2015). The US Census Bureau (2014) predicts that the traditional college student population of individuals aged 18-24 will grow by an additional 1.3 million potential students by 2050 from its present 31.2 million.

The more dramatic growth over the next 30 years, however, is predicted to be in the overall 18- to 64-year old population age group. This population is projected to grow from approximately 200 million to 230 million by 2050 (U.S. Census, 2014). In addition to efforts designed to anticipate the needs of a traditional undergraduate student population, universities preparing for the future should also consider the potential for a significant non-traditional student population of part-time and adult learners at both the undergraduate and graduate levels. This has been a largely untapped population for both Virginia Tech and its SCHEV peers; less than three percent of current Virginia Tech undergraduates are over the age of 25 (IPEDS, 2015). As post-secondary credentials become more important in the job market, many individuals contemplate going or returning to college after having established their lives, both personally and professionally (Carnevale, Smith, & Strohl, 2013). As such, there are increasing numbers of adult learners entering or re-entering the higher education environment.

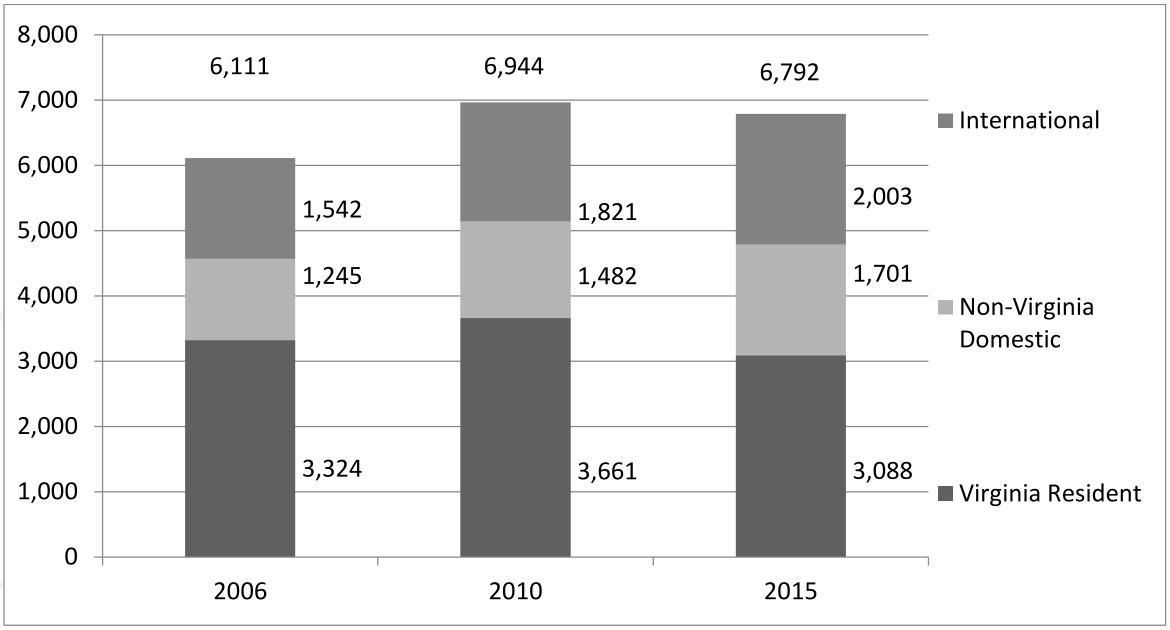
In addition to age and full-time status shifts that may occur in the student body of the future, a growing number of international students are seeking an education at American universities. This increase poses challenges related to the evaluation of candidates, the preparation of newly admitted students, and ways to integrate international students into campus life. Figures 1 and 2 highlight shifting trends in the composition of the Virginia Tech student population over the past decade. The shifts in student body composition reflect larger societal changes, both domestically and internationally, that point to the growing mobility and interdependence of global populations caused in part by technological and transportation innovations.

Figure 1. Virginia Tech Undergraduate Student Headcount Enrollments by Residence, 2006, 2010, and 2015



Source: Virginia Tech Office of Institutional Research and Effectiveness (2016)

Figure 2. Virginia Tech Graduate Student Headcount Enrollments by Residence, 2006, 2010, and 2015



Source: Virginia Tech Office of Institutional Research and Effectiveness (2016)

Technology

Over the past ten years, the development and growing use of new applications and devices have led to increasing demands for high-quality, ubiquitous connectivity. University communities have been particularly affected by increasing demands for computing power for their research enterprises. High-definition data visualization and video applications, the rise of "big data" and data science, and the proliferation of personal mobile devices all necessitate high-quality internet connectivity. Advancements in data visualization, telepresence, and related areas are highlighted in the Human-Centered Smart Environments section of this report.

In order to remain relevant as even campuses of today, much less of tomorrow, institutions of higher education must make investments in their telecommunications infrastructure, computing systems, and other forms of technologies. Institutions seeking to be leaders in technology innovation and utilization will need to be prepared to allocate significant financial resources for an infrastructure with capacity beyond current need that can adapt to new circumstances. Virginia Tech has not been immune to this push for faster speeds and greater capacity and has been involved in local, regional, and national efforts, including Internet2 and the University Community Next Generation Innovation Project (Gig.U), intended to facilitate and innovate in the deployment of high-speed, high-capacity infrastructure systems geared towards improving connectivity at all levels.

The need for high-speed, high-capacity data processing is only likely to increase in the future as researchers generate, and increase their use of, data across an increasing variety of fields. The prominence of big data collection, storage, analysis, and utilization will continue to increase with real-time processing of big data shaping how and where we move and a growing “Internet of Things” in which sensors are found in increasing numbers in what we wear and where we live. The demands for high-performance computing systems will continue to grow alongside increases in the amount of data generated and improvements in our abilities to analyze said data.

Technology considered at the “cutting-edge” for facilitating this analysis becomes middle of the pack five years later and commonplace or even obsolete after ten years. For example, Virginia Tech’s System X supercomputer was ranked #3 in the world when it debuted in 2003 but decommissioned and replaced with more powerful computing systems by 2012 (TOP500, 2015). Since 2009, Virginia Tech has added five high-performance computing systems (supercomputers) to its Advanced Research Computing program to support big data processing: Ithaca (2009), HokieSpeed and HokieOne (2012), Blue Ridge (2013), and NewRiver (August 2015).

Transportation

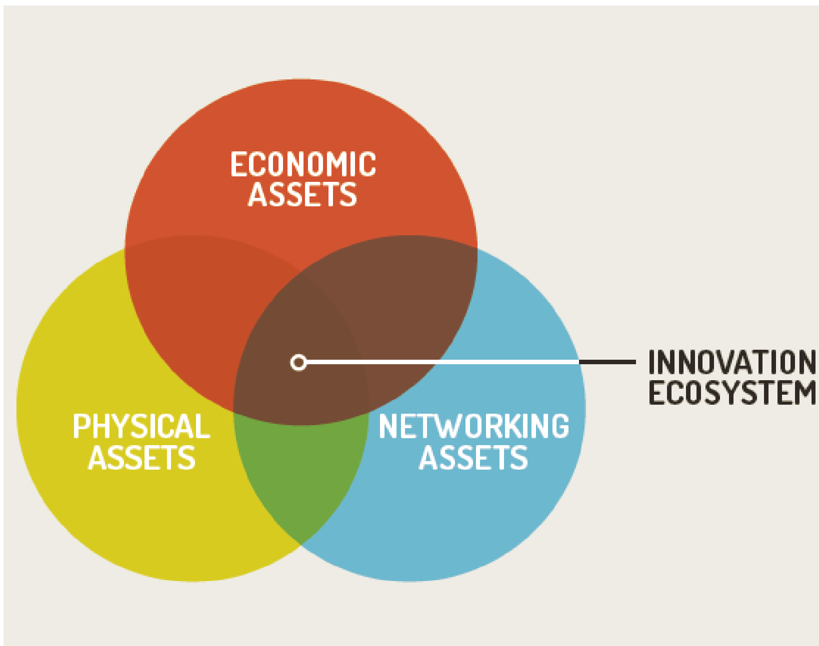
Transportation needs are another important component of planning the campuses of the future—both on our campuses and in the broader region. These needs will vary depending on where students, faculty and staff live in relation to our campuses and where their research takes them. In both instances, the university’s continued presence in Blacksburg and the broader New River and Roanoke Valleys will require careful planning of local, regional, and broader transportation. Of the top five friction points identified in Brailsford & Dunlavey’s 2013 nationwide “town-gown” survey, three of the five were directly related to the use of personal automobiles (parking space shortage, traffic congestion, and parking traffic violations). Coordinating public transportation infrastructure with university needs and major housing and retail/office development would be one way to reduce the strain on parking and road infrastructure.

Beyond local transportation needs, convenient and affordable mechanisms for connecting the Blacksburg campus with the larger region including our National Capital Region (NCR) campus, Commonwealth Campus Centers around Virginia, and locations across the globe need to be created and supported. The European Union Regional Policy’s “Connecting Universities to Regional Growth” noted there are many benefits of a globally-connected university in a region. The presence of a globally-connected university can attract investments in the region that would both support the development of new firms and strengthen a region’s existing firms (Goddard & Kempton, 2011, p. 22). However, when a region or its university is geographically isolated from the broader world, then these investments are less likely to occur. Additionally, the firms that do develop in such a region will likely relocate to more globally-connected regions as their needs for interconnection with individuals and markets, among others, grow. Technologies including telepresence may ameliorate some of this pressure but will not completely eliminate the demand for easy local, regional, and global mobility.

Innovation Ecosystems

In 2014, the Brookings Institution documented in its report, *The Rise of Innovation Districts: A New Geography of Innovation in America,* a growing economic development trend to integrate physical, economic, and networking assets in a community to create maximum benefit. Figure 3 demonstrates how these assets can work together at a nexus point to form an innovation ecosystem in which so-called "innovation districts" can emerge.

Figure 3 Innovation Ecosystem Assets



Source: *The Rise of Innovation Districts: A New Geography of Innovation in America* (p. 3)

Innovation districts can take a variety of forms depending on their location, including urbanizing industrial and researching parks or transforming former factories and warehouses in downtown areas. The anchor-plus innovation district model detailed in the Brookings report is of particular relevance for Virginia Tech's purposes. In this model, districts comprising tightly-integrated research, residential, commercial, and recreational spaces emerge around one or more central anchor institutions. The foundation for one planned anchor-plus innovation district in Roanoke will be a new $67 million building doubling the current Virginia Tech Carilion Research Institute (VTCRI) and funded through investments by the Commonwealth, Virginia Tech, and Carilion (Virginia Tech News, 2016).

University Principles

The Campus of the Future thematic group identified a set of university principles to guide university priorities and investments. These principles emerged from group discussions over five months and inform the vision and transformative platforms that will structure and support

Virginia Tech's future campuses. Principles include its land-grant legacy, linking non-collocated campuses, structural variety, and the development of VT-shaped individuals.

In the future, Virginia Tech will combine its land-grant legacy with 21st-century opportunities through hands-on, minds-on experiential learning and cutting-edge research. Upholding its motto of *Ut Prosim* (*That I may serve*), the university will translate research into innovative solutions to global problems.

The university will maintain both a global and local presence and focus with urban and rural footprints to form a tightly-coupled system of non-collocated campuses, or "binary stars." The university of the future will be made up of multiple binary star systems. Virginia Tech will use those centers of mass to continue connecting with other individuals and entities.

Some aspects of the university community, infrastructure, and environment will stay quite the same while others will change dramatically. A variety of forms of infrastructure will accommodate these aspects of campus life in some cases and, in other cases, drive them.

The campuses of the future will be designed to encourage the development of VT-shaped individuals. The university will achieve this goal by emphasizing "purpose-driven" learning to address complex, societal problems/applications in addition to the disciplinary depth and broad-based critical thinking and interpersonal skills for T-shaped learning. The university and its campuses will holistically incorporate both diversity and inclusivity with an emphasis on equity of access.

Therefore, We Envision that the Campus of the Future Will Emphasize

- **Flexibility** to change using a continuum of spaces that foster collaboration, both in person and through the use of technology, as well as spaces that offer quiet, focus, and privacy. The university's approach to curriculum, infrastructure, and technology will be flexible to promote individuality while encouraging community through multidisciplinary, multigenerational, and multicultural engagement.

- **Adaptability** for the future through iterative reflections of activities and outcomes. Spaces will be designed to respond to new situations through autonomous systems and smart rooms that adapt to users. We believe that design is fundamentally iterative.

- **Creative spaces** with the freedom to experiment, discover, learn, and "fail safely."

- **Connectivity**, both physically (inter- and intra-site/campus) and with an improved virtual presence for a distributed campus and global environment. This connectivity will support human-to-human interaction across a spectrum of environments—natural, built, and virtual—to promote innovation.

- **Community** through cross-cutting groups with a common set of interests and objectives that fuse intellectual and co-curricular life. The campuses will be comprised of complex heterogeneous networks and innovation districts facilitated by technology.

- **Sustainability** from both internal financial and broader environmental perspectives.

- **A global perspective**. The university will organize in such a way that maximizes the flow of information, individuals, and resources to solve complex societal problems. It will provide valuable educational experiences for students to prepare them for the interconnected world in which they will work and live.

Transformative Platforms

The Campus of the Future working group proposes three transformative platforms that will be being part of the global land-grant university in 2047: Integrative Innovation Hubs, Global Engagement Hubs, and Human-Centered Smart Environments. All three align with the university principles and vision and are structured according to the design characteristics articulated by the group members.

Integrative Innovation Hubs are geographic locations on campuses where individuals, spaces, and technology are organized around crosscutting areas of global and societal importance. Global Engagement Hubs are external to the core university locations, established to solve complex problems of societal importance while remaining intimately interconnected to on-campus hubs. Finally, Human-Centered Smart Environments are physical, virtual, and augmented spaces facilitated by digital technologies that support learning, research, and communication, with an emphasis on a hands-on, minds-on learning approach.

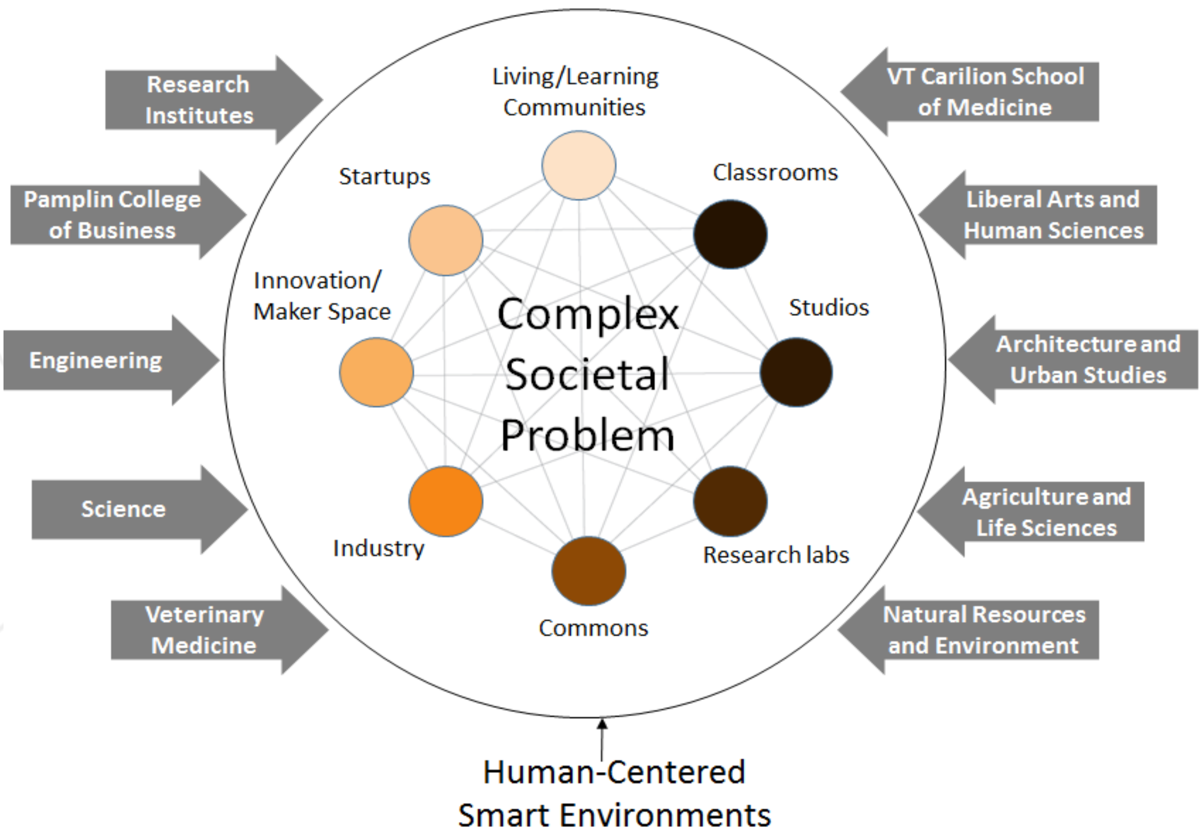
Integrative Innovation Hubs

We reimagine the infrastructure and design of the campuses of the future as integrating the currently-segregated academic, living, recreation, and business and industry (e.g. the university's Corporate Research Center) zones into Integrative Innovation Hubs (IIHs). IIHs are formed around thematic areas of global or societal importance.

Thematic group members believe that shared spaces and physical proximity increase the likelihood of serendipitous and productive intellectual collisions across disciplines and between colleagues. IIHs are intended to: (1) interconnect discrete, disciplinary campus units; (2) experiment with novel collaborations, perspectives and expertise; (3) address the most pressing social, economic, and environmental challenges from local to global scales; (4) be innovative; (5) be modular; (6) be continually self-reflective and adaptive; and (7) evolve as focus areas change over time.

IIHs establish relatively distinct spatial arrangements comprised of living/learning communities, dining and recreation, classrooms and teaching labs, research labs, studios, innovation and maker spaces, businesses and start-ups, and a commons area, as shown in Figure 4. In conjunction with traditional and emerging core disciplines, they form our future "VT-shaped" university. IIHs will exist in, and connect between, the various university campuses and locations, including the main campus in Blacksburg, the new Health Sciences Innovation District in Roanoke, and the NCR.

Figure 4. Integrative Innovation Hubs



Hub members will include students, faculty, staff, entrepreneurs, and community residents. These groups will bring disciplinary depth in the natural, physical, and social sciences, the humanities, engineering, art and design, policy, business, health, and wellbeing. Direct interactions with business and industry will afford new opportunities for experiential learning, co-creation, and new funding streams.

Integrative Innovation hubs will serve as experiments and will vary from each other in form and method based on location, strengths and needs of its members, and lessons learned from the implementation of other hubs. In addition to members focused on a hub's topical area, each hub will have dedicated assessment personnel that will monitor and evaluate their mission, strategy, and efficacy. These hubs would be part of a reflexive effort to understand the raw and advanced components of innovation that lead to actual impact and problem solving.

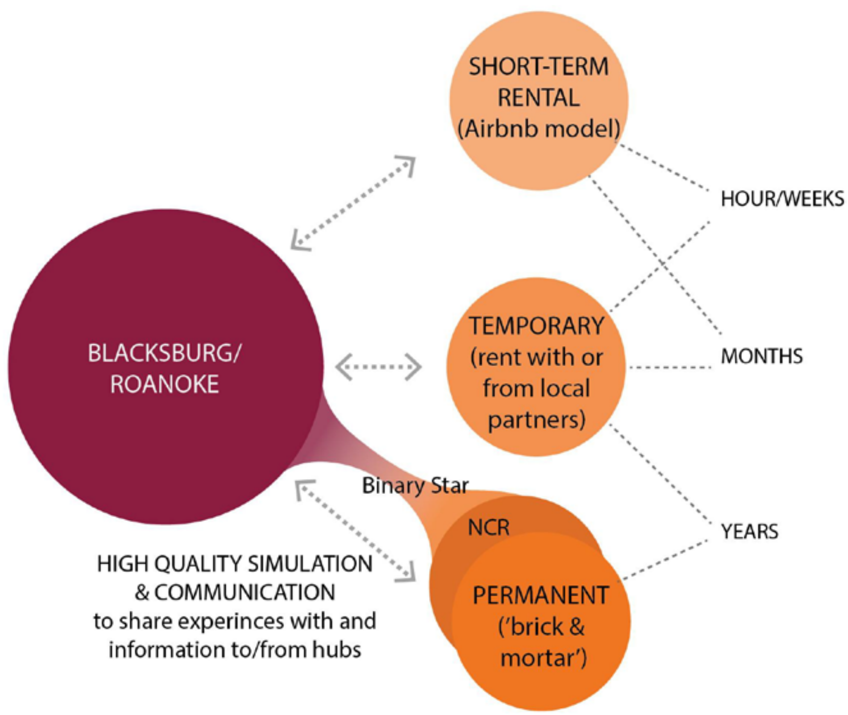
Aspects of this vision are already taking shape at Virginia Tech and elsewhere. The Institute for Creativity, Arts, and Technology (ICAT), Living and Learning communities, research institutes, incubators, and other organizations are beginning to bring the components of innovation hubs together. These spaces provide a foundation upon which the future innovation hubs can learn and grow.

Global Engagement Hubs

The campuses of the future will not be place-bound to Blacksburg, or even Virginia; instead, Virginia Tech will be projected globally through a network of Global Engagement Hubs (GEHs). Using this approach, experiences and information gained beyond local and regional campuses will be projected back to the university community on campuses.

The university will structure GEHs based on a range of options to suit the needs of any particular global engagement, as is shown in Figure 5, rather than following a "one size fits all" model to ensure uniformity across GEHs. On the time scale, GEHs will be designed to support engagements that range from weeks, a few years, to permanent time spans. GEHs designed for short time spans will support short-term research engagements, for example in the wake of a natural or man-made disaster. This concept requires a flexible infrastructure, perhaps based on modular mobile laboratories. Such an approach will allow Virginia Tech to be on the forefront of research support for complex problems around the world.

Figure 5. Global Engagement Hubs: Time and Space Scales



On the other end of this continuum, permanent "brick-and-mortar" hubs may be required to support highly reputed programs for education, research, development of faculty talent, and economic development in key global locations. Temporary GEHs would be deployed as an initial testing phase ahead of the establishment of a "brick-and-mortar" location. Temporary and permanent GEHs would likewise have a carefully-designed physical presence that can convey Virginia Tech's identity, culture, and values. The Shandong University - Virginia Tech

International Laboratory in China is an example of a joint venture that has started from a research collaboration, established a small but highly-recognizable physical presence and a collaborative education program, and is now on the verge of expanding into a comprehensive joint venture on a new university campus under construction in China (College of Engineering, 2010).

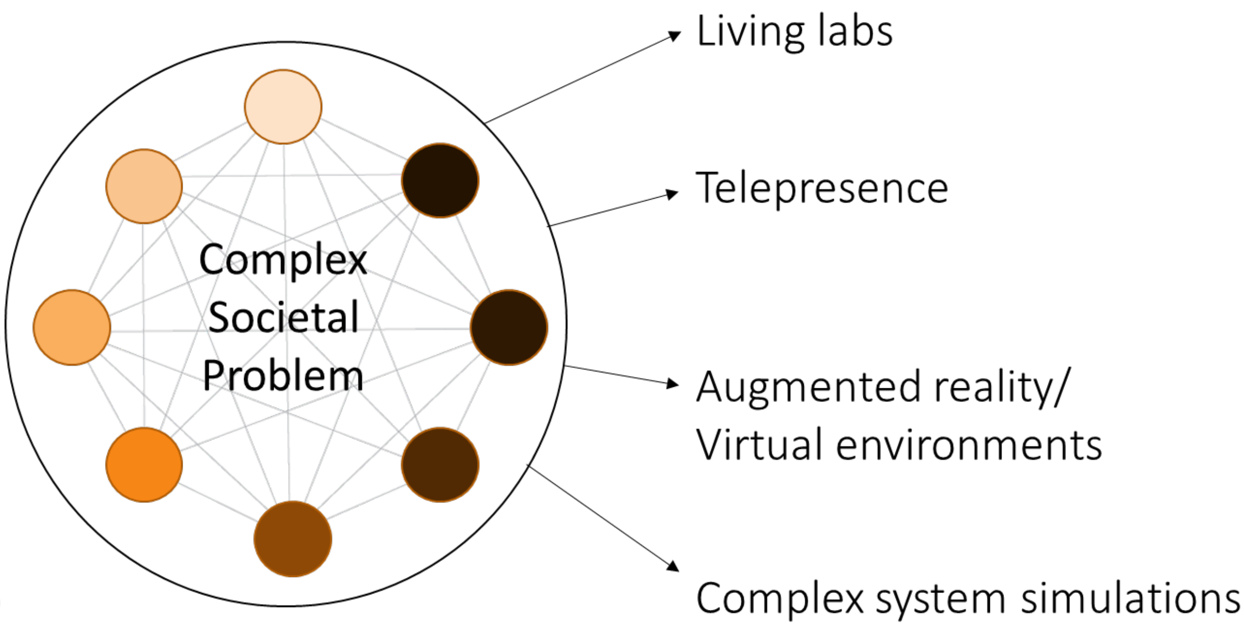
GEHs require a local network of financial, social, and political support in addition to a physical infrastructure that may be mobile or permanent. The larger the scale of the GEH in time and in size, the more critical this network will be. Each GEH will be supported by a local business case; for example, local partners that see value in Virginia Tech's presence and are willing to provide the resources for its operation. To build this partner network, the campuses of the future will reach out to Virginia Tech alumni around the world. These local connections will help the university to establish GEHs, and in turn, international alumni will be engaged in their operations. The architecture department's Chicago Studio is an existing program that uses alumni connections for instruction, professional office experience, classrooms, and housing for students studying and working in Chicago.

Improved telepresence solutions as part of Human-Centered Smart Environments are discussed in the next section and will link GEHs to one another and to the Blacksburg campus. However, to be successful, the GEH network and the campuses of the future also should be set up to facilitate and encourage the physical mobility of students, faculty and staff by providing operational support for personnel on short-term assignments or internships.

Human-Centered Smart Environments

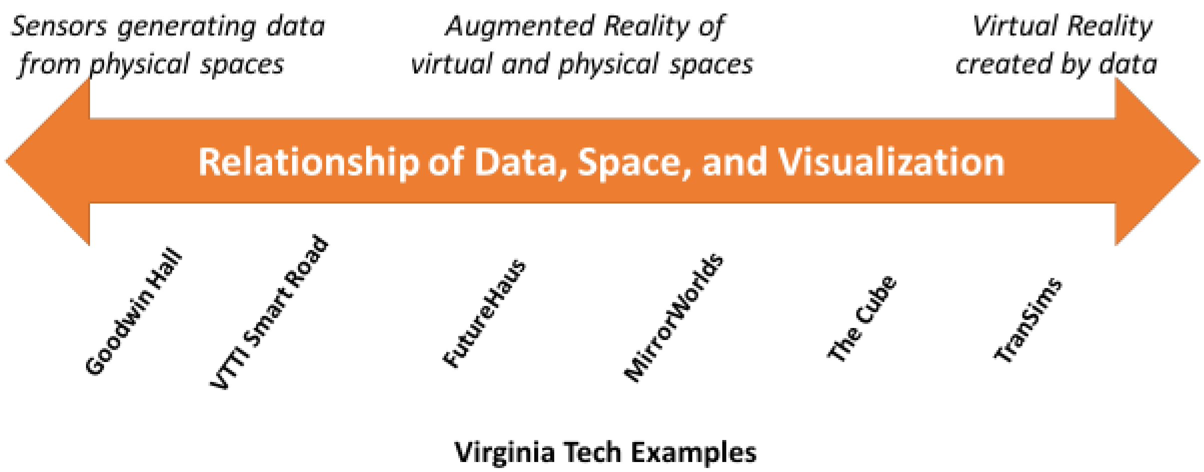
The campuses of the future will emphasize hands-on, minds-on learning and discovery through digitally-enabled Human-Centered Smart Environments (HCSEs). Living laboratories, augmented reality technologies and virtual environments, telepresence, and complex system simulations are some types of HCSEs the group foresees as being critical components in the campuses of the future. A key HCSE element is the immersive integration of human users and simulated human communities within a smart environment. The group imagines individuals interacting seamlessly with their colleagues on campuses around the world using these environments.

Figure 6. Types of Human-Centered Smart Environments



Human-Centered Smart Environments depend heavily on the generation and utilization of large amounts of data. Figure 7 demonstrates the interactive relationship of physical spaces generating data, virtual spaces offering the visualization of large amounts of data, and augmented realities in between the two that are hybrid spaces incorporating both physical and virtual elements. Sensors in the physical environment can lead to virtual realities, but there is also a relationship formed by information flowing from the virtual realities that influence decision making and the design of the physical spaces. At the forefront of the physical/virtual spaces interaction are immersive augmented and virtual realities. The Cube is a current example of such a space and is a cooperative arrangement between the Center for the Arts and ICAT at Virginia Tech.

Figure 7. Relationship of Data, Space, and Visualization



HCSEs have immense but under-explored potential applications in the humanities fields. They could be used to enable richer remote historical site exploration, interactive and engaging visualization of textual analysis, more immersive language experience for students, and incorporating sensors into the creation of various art forms. Virtual reality and digital representation technologies will be at the center of "global perspective windows" both on campuses and as part of the GEHs. Data streams, including audio, video, 3D, and other forms yet to be discovered, will flow across the GEH network and displayed (time-shifted as needed) at each location in highly-frequented public spaces. This approach gives students, faculty, staff, and visitors a global awareness and allows for them to interact with participants working around the world.

The university library of the future will play a role in managing knowledge generated through the use of HCSEs and in both IIHs and GEHs, and it will use HCSEs to help disseminate the information. The challenges, processes, progress, and conclusions of research projects will be widely and openly communicated and broadcast through the university library which will publish and market it in new ways so that timely developments can be known and built upon by anyone who chooses. HCSEs will enable new opportunities for individuals to interact with and respond to research findings in more meaningful ways both as projects are in progress and after they have concluded.

Living Laboratories. Living Laboratories are experiential environments wherein students and researchers can engage in learning, discovery, and innovation through interactions with real-world systems and communities. Living labs incorporate "smart" autonomous systems that range from furniture and wearable technology to buildings and the surrounding landscape. These systems will assist humans in multiple ways that include supporting wellness, collaboration, solitude, inspiration, and disruption. The design and implementation of these living laboratories will inform and be informed by the latest research in neuroscience, organizational psychology, architecture, and human/computer interactions.

Current examples at Virginia Tech include the VTTI Smart Road in Blacksburg and Connected Vehicle Testbeds in the NCR, and the College of Architecture and Urban Studies Lumenhaus and Futurehaus demonstrations. Additionally, the new Goodwin Hall on Virginia Tech's Blacksburg campus is its signature engineering building and also a 160,000 square foot living laboratory for the Smart Infrastructure Laboratory (VT-SIL). It is touted as the most-instrumented building in the world for capturing vibrations that can be used to detect migration patterns, climate, seismic activity, and any number of other activities taking place in and around the building (VT-SIL, 2016). Data generated from the sensors in the laboratory are being used in schools and institutes across the university including the School of Performing Arts, ICAT, and the geography and education departments.

Augmented Reality and Virtual Environments. Researchers are just beginning to fully explore the potential for hybrid reality spaces that allow users to interact with both a virtual and physical world. Immersive virtual reality (VR) technologies have a rich history at Virginia Tech dating back to the 1990s. Augmented Reality (AR) technologies, as shown in Figure 7, provide digital information and imagery superimposed on the user's physical environment.

With the growing availability of consumer-grade VR headsets and interest by companies such as Google, Facebook, and Snapchat, AR and VR technologies and their applications are only likely to increase in both use and utility over the coming decades. The possibilities are countless for their application in disciplines across the university and in exploring solutions to complex societal problems. Virginia Tech should be at the forefront of using these technologies and in creating new ones. ICAT's NSF-funded Mirror Worlds is a current AR research project at Virginia Tech that breaks down the boundaries between physical and virtual spaces (ICAT, 2016). Researchers at the Center for Human-Computer Interaction and its affiliated labs at Virginia Tech are exploring other similar advancements.

Telepresence. The vision of a fully-integrated but geographically-distributed global land-grant university requires sophisticated telepresence infrastructure and applications. Next-generation telepresence will move significantly beyond today's video teleconference (VTC) and WebEx-style technologies. For example, AR technologies could allow geographically-dispersed users to seemingly exist and interact in each other's physical environments. By comparison, current telepresence technologies do not enable seamless interaction between remote participants. Our researchers must continue to innovate new ways to bring people together across vast distances.

Complex System Simulations. Our world and the problems it faces grow increasingly complex as we progress through the 21st century. As a result, the tools needed to understand and solve these problems must also become more sophisticated and complex. The Network Dynamics and Simulation Science Laboratory (NDSSL), a part of the Biocomplexity Institute of Virginia Tech, is one example of how Virginia Tech uses high-performance computing to explore complex multi-domain problems and systems ranging from interconnected infrastructures and social networks to the development of epidemics. Complete simulated cities and regions with millions of synthetic inhabitants have been created to model and predict their behavior under various stresses or policy implementations. Efforts within the Discovery Analytics Center and the Social and Decision Analytics Laboratory (SDAL) attempt to quantify human behaviors and sentiments, which will make these complex system simulations even more realistic and accurate in the future. The models are developed and validated based on information in large-scale data sets.

Conclusion

The Campus of the Future working group has articulated a set of core principles that Virginia Tech should adhere to in planning for this changing landscape. The group believes that our future campuses must support and create opportunities for human-to-human interaction in a variety of environments that includes natural, built, and virtual spaces. Complex heterogeneous networks that are facilitated by technology will both inhabit and define these spaces.

Group members proposed three transformative platforms upon which these principles could be realized: Integrative Innovation Hubs, Global Engagement Hubs, and Human-Centered Smart Environments. The two types of hubs will provide the spaces and connections, both on Virginia Tech campuses and distributed globally, to cultivate multidisciplinary responses to complex societal problems. Human-Centered Smart Environments will be the technologically-enhanced means by which individuals will interact with the problems and each other in a seamless way regardless of geographical distance.

The Virginia Tech of the future will be built upon its current strong foundation and spirit of *Ut Prosim*. Moving forward, the university must carefully reflect on its choices and activities to ensure that the most beneficial components are carried forward and expanded while sunsetting others that are no longer relevant or have failed to achieve their goals. By doing so, the university will be nimbler and better able to respond to the increasingly global and complex world in which we live.

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