VirginiaTech

Institute for Critical Technology and Applied Science

Strategic Plan

2012 – 2018

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I. INTRODUCTION

In 1997, Virginia Tech celebrated 125 years as a land-grant university and research institution. During that same year, forward-thinking leaders for Virginia Tech decided to establish the *Institute for Critical Technology and Applied Science (ICTAS)* as a vital vehicle for accelerating Virginia Tech's growth in scholarship, sponsored research, and national ranking, thereby advancing the university's stature into the ranks of the nation's foremost universities.

Following years of conceptual development, rallying of resources, and early-stage steering by two interim directors from the College of Engineering, Dr. Roop Mahajan, the first permanent institute director, was hired in 2006. Guided by a stakeholder board and a faculty advisory board (see Appendix I, page 33, for the governance structure), and by the feedback gained through countless meetings, conversations, and encounters with respected thinkers of the day, the following compelling vision for ICTAS was formulated by the ICTAS leadership team.

Vision:

To be a premier institute to advance transformative, interdisciplinary research for a sustainable future.

This vision recognized the following major concepts:

> One of the greatest challenges facing the world in the 21st century is to continue to provide better living conditions to all people while minimizing the impact of human activities on the global environment. In creating such a sustainable future, we face a daunting set of complex, challenging, and interconnected problems affecting water, energy, environment, health, poverty, terrorism, and war, to name a few. Meeting these challenges will require a healthy dose of innovation, multiple perspectives, teamwork, and a culture of nimbleness to change course midstream, if needed.
>
> Interdisciplinary research as a mode of discovery and learning is a powerful paradigm for meeting the above challenges. It allows us to break down and restructure our knowledge about a subject in order to gain new insights into its nature and to use our imagination to invent and innovate. The report Facilitating Interdisciplinary Research from the National Academies Press, 2005, considers interdisciplinary research to be "one of the most productive and inspiring of human pursuits - one that provides a format for conversations and connections that lead to new knowledge."

Mission:

Motivated by our vision, the following *mission* was adopted:

To serve Virginia Tech, the Commonwealth of Virginia, the nation and the world through high-impact research and scholarship at the intersections of engineering, the sciences--physical, life, and social--and the humanities. To this end, ICTAS will

- *advance the frontiers of knowledge and learning,*
- *enhance the educational experience of undergraduate, graduate, and professional students, and,*
- *promote economic development through the creation and application of innovative research that enhances the quality of life and preserves our natural resources.*

Fulfilling the Mission:

In the discovery domain, our first step was to select strategic areas of interdisciplinary research for investment and growth. In an NSF/DOC-sponsored report, *Converging Technologies for Improving Human Performance*, Roco and Bainbridge (2002) presented a consensus view among leading experts from government, academia, and the private sector that a set of four powerful technologies--nanotechnology, biotechnology, information technology, and cognitive science (NBIC)--is poised to unleash new understanding of matter at the atomic scale and within the complex working of the human brain that will create opportunities for new industries, robust job growth, and enhanced human capabilities. After careful deliberations, we concluded that these four converging technologies, anchored by the principles of sustainability, as depicted in the Venn diagram in Figure 1, would serve to guide ICTAS research. Further discussions among key faculty and ICTAS leadership eventually led to the formation of the following thrust areas: nanoscale science and engineering, nano-bio interface, cognition and communication, sustainable energy, sustainable water, renewable materials, and national security. Finally, another thrust area "emerging technologies" was added to focus on emerging and disruptive technologies. See Section V for a detailed description of the Core Research.

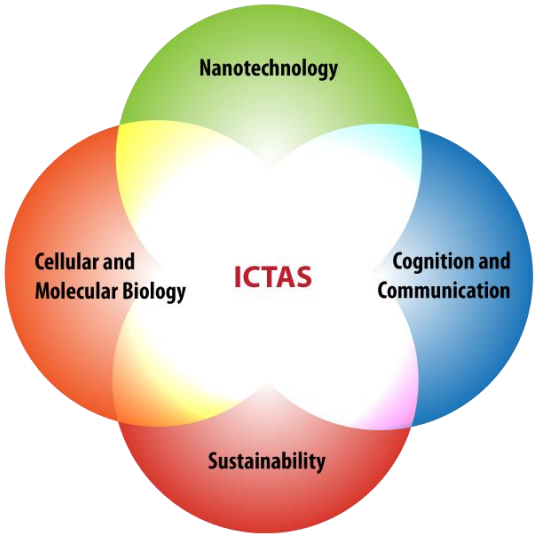


Figure 1. ICTAS view of transformative technologies.

Next, we adopted an upward spiral strategy for growing collaboration among researchers from across Virginia Tech colleges and institutes, as depicted in Figure 2. This growth strategy starts with an investment of seed monies through our yearly Request for Proposals (described in Appendix IV) which seeks collaborative research for investment

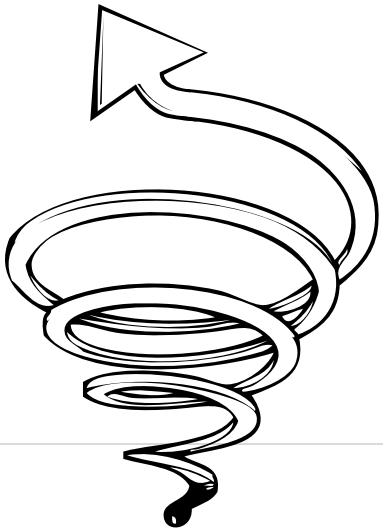


Figure 2. ICTAS model of spiral research growth.

and growth in the selected areas of interdisciplinary research aligned with our mission. Research conducted with these seed monies provides preliminary data/proof of hypothesis and constitutes the narrow first turn of the spiral. Building on this preliminary data/research, researchers are more likely to be successful in securing funds from external agencies (NIH, NSF, etc.) which allows them to expand their research up to the next broader turn of the spiral, where their research becomes larger in scope and richer in content. At this point in the upward spiral journey, ICTAS offers resources to assess the possibility of bringing faculty together under the umbrella of an ICTAS center or Interdisciplinary Research Group (IRG), typically composed of an interdisciplinary roster of twelve or more faculty members engaged in a multifaceted research effort with a significant potential for scholarship and large external funds. To ensure the sustainable growth of these centers, ICTAS can commit additional investment on a long-term basis.

We realized early on that for our research strategy to succeed, ICTAS needed to provide state-of-the-art collaborative laboratories in support of teams engaged in cutting-edge interdisciplinary research. From a small administration space in the Virginia Tech Corporate Research Center (CRC) in 2006**,** we have grown to 173,097 square feet of laboratories and research support space spread over three buildings in Blacksburg and 6,700 square feet of space in the Virginia Tech Research Center at Arlington (VTRC-A).

The first building, ICTAS-A, encompassing 32,000 square feet, is located at the CRC and was officially inaugurated on September 21, 2007. It houses the **Nanoscale Characterization and Fabrication Laboratory** (NCFL) as well as other research laboratories, associated staff offices, and conference space. The NCFL offers more than $10M in highly specialized equipment for observing materials at the nanoscale, modifying the materials, and characterizing new products.

The first of two central campus buildings, ICTAS-I opened in the spring of 2009 and offers 99,411 square feet of laboratory, office, and meeting space for interdisciplinary research. Located at the corner of Turner and Stanger Streets, it serves as headquarters for institute operations and home to collaborative research activity including targeted delivery of nanomedicine, tissue engineering, cognitive radio, environmental nanoscience and technology, sustainable energy, biobased materials, and advanced multifunctional materials. This building is also home to the **School of Biomedical Engineering and Sciences** (SBES).

The second central campus building, ICTAS II, located on Washington Street in the Life Sciences District of the Virginia Tech campus, opened in January 2011 and offers 42,190 square feet of research laboratories, office space, and conference rooms in support of research activities that include applied environmental biochemistry, fluvial processes, a global laboratory for bioinspired science and technology, nanobiology, nonlinear imaging and spectroscopy, organic nanostructures, pathogen ecology, pipeline corrosion, sustainable water, and advanced medical training research (humanoid hospital).

The approximately 7,000 square feet of space at VTRC-A, provides laboratory, office and conference room space in support of three research areas: energy, cyber security, and discovery

analytics. We anticipate additional space needs in this building as our research grows and expands from the current areas of focus to other fields.

In the **learning domain**, the ICTAS Doctoral Scholars Program was launched in the fall of 2007 to enhance recruitment of exceptional Ph.D. candidates through Graduate Research Assistantships. Initially focused on five colleges represented on the ICTAS Stakeholder Board (College of Engineering, College of Science, College of Agriculture & Life Sciences, College of Natural Resources and Environment, Veterinary Medicine), this program is a cooperative effort supported and coordinated by ICTAS, with significant contributions from participating departments, colleges, and the graduate school. Other activities include support of Integrative Graduate Education and Research Traineeships (IGERTs) and Research Experience for Undergraduates (REUs), research proposals that include graduate student participation as a central component, and sponsorship of student-initiated activities related to interdisciplinary research.

In **outreach**, we collaborated with the Office of the Vice President for Outreach and International Affairs to establish robust research activities in targeted international regions, specifically and initially with VT, India and the Technical University of Munich, Germany. We also strengthened our collaborative activities with national labs, mostly with the Naval Surface Warfare Center Dahlgren Division, the National Institute of Standards and Technology (NIST) and Oak Ridge National Laboratory (ORNL).

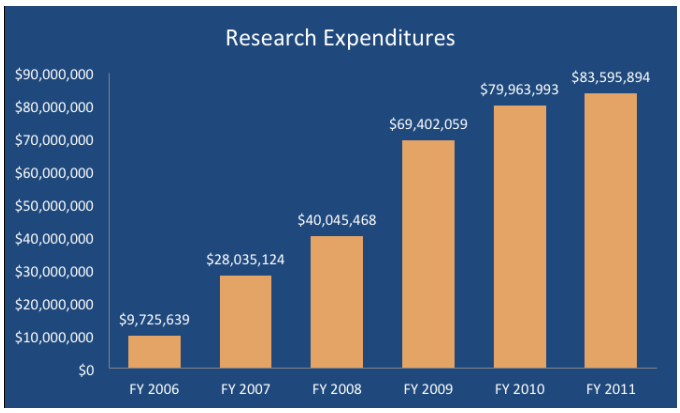
Fiscally Speaking:

ICTAS operates as an *investment institute*, *i.e.*, it receives a majority of its funds in an annual budget from the university. Historically, ICTAS funding has been provided by the university administration through a combination of General Funds and Commonwealth of Virginia Research Initiative Funds. However, starting with fiscal year 2011, most of the funds have been provided through General Funds (see Section VI). ICTAS collects no overhead funds for the research that it sponsors and develops, except for research conducted by faculty directly employed by ICTAS.

Record of Growth:

Building on the basics established in its first few years, ICTAS has grown significantly since 2006. Growth in the number of faculty and graduate students engaged in ICTAS-supported research, ICTAS Doctoral Scholars, ICTAS-funded seed projects, ICTAS-supported centers and IRGs, and related research expenditures symbolize the success of the institute's ongoing efforts. A few of these statistics are shown in Figure 3 below. This growth has been made possible by an increase in our budget from $3.9M in FY 2007 to $8.3M in FY 2011. These initial years of expansion and growth are characterized by many organizational refinements including enhanced communication and visibility, transition of the research structure from *Focus* and *Theme* research areas to eight *Thrust* areas, matriculation of the first class of ICTAS Doctoral Scholars, and expansion of the institute's local, regional, national, and international outreach.

The steps ICTAS has taken to invest in faculty capacity for success and the advancement of research have transitioned over the initial 5-year period from building relationships and gaining faculty ownership to establishing intellectual and physical infrastructure, providing a clear path to meaningful involvement in research, making prudent investments, developing capacity for submission of large proposals, and contributing to the enhancement of the reputation and capacity of the university's research enterprise, and--in the broadest sense--establishing a strong foundation for the institute as part of the university's strategic plan.



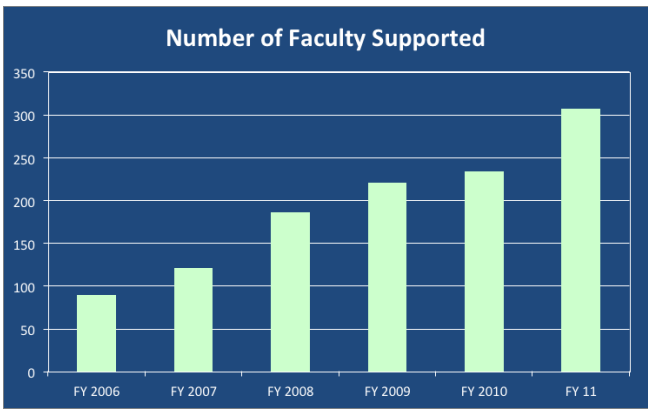


Figure 3. Growth in Research Expenditures and Faculty Supported

II. LOOKING AHEAD: STRATEGIC PLAN 2012-18

Preamble

We live in exponential times when a few converging and emerging technologies are poised to spur inventions and knowledge at a very fast pace. It is our belief that the four converging NBIC technologies mentioned in Section I will continue to serve as platform technologies, at least for the next few decades. However, these technologies will give rise to or will be supplemented by contemporary cutting-edge developments in various fields of technology, i.e., the emerging technologies. In an op-ed, "The coming Tech-led Boom" (*Wall Street Journal*, January 30, 2012), Mark P. Mills and Julio M. Ottino list three grand technological transformations--big data, smart manufacturing, and the wireless revolution--poised to transform this century as much as telephony and electricity did in the 20th century. Not fortuitously, ICTAS has a strong presence in all these areas. However, this list is by no means comprehensive and most likely misses a few that are not yet recognized, but may still carry an extreme impact. These are the so-called Black Swan technologies. In his book *The Black Swan*, the *New York Times* bestselling author Nassim Nicholas Taleb cites the example of the three recently implemented technologies that most impact our world today--the Internet, the computer, and the laser--and notes that all three were unplanned, unpredicted, and unappreciated upon their discovery, and remained unappreciated well after their initial use. Wikipedia defines Black Swans as "The disproportionate role of high-impact, hard to predict, and *rare* events that are beyond the realm of normal expectations in history, science, finance, and technology." While these events may be rare and hard to predict, our contention is that we can create an environment in wwhich engineers, scientists and humanists from different disciplines can come together to move beyond the predictable and incremental advances in current technologies to the transformative science and technology of the future.

Moving forward, our focus will be on the confluence of converging and emerging technologies and on foundational transformative tools for a sustainable future. We will expand our current thrust areas to include agriculture and environment, will seek to establish a dominant position in research and scholarship in these areas, and we will put into place mechanisms that enable ICTAS to become a breeding ground for the next set of positive Black Swan(s). We also must be able to respond swiftly to changing societal needs or technological breakthroughs. While we recognize the transformative power of these potentially revolutionary technologies, we also are cognizant of the fact that they have attendant unexamined and sometimes controversial ethical issues. To this end, in our research and operations, we will give due weight to societal and ethical considerations.

In the learning domain, we will build on our successful ICTAS Doctoral Scholars Program and extend it to include undergraduate and K-12 students. We will become active partners with Virginia Tech's academic units in recruiting high-quality students and developing forward-looking curricula beyond 2018.

In support of Virginia Tech's *Economic Development and International Outreach* goals, we will focus on economic development through the commercialization of intellectual property generated by ICTAS investments and will actively support international efforts such as VT-India and initiatives in other regions of the world. A new area of emphasis will be on helping urban and rural communities to become self-reliant through sustainable design, technologies and practices.

In executing our strategic plan, we will be guided by the following principles:

- **EXCELLENCE:** This principle underpins everything that we do. Our objective is to be among the top three research institutions in all our efforts.
- **FACULTY-FOCUS:** Our strength as an institute depends on the quality of Virginia Tech's faculty and on our ability to support them in their transformational interdisciplinary research efforts.
- **NIMBLENESS:** We must be constantly on the lookout for the "next big thing" and must be ready to position the institute to exploit the opportunities offered. We must be proactive in identifying and creating these opportunities and responsive to changing circumstances.
- **VALUES:** Our actions must be guided by our core values and governed by unwavering ethical standards.
- **METRICS:** Our decisions will be informed and guided by measures of scholarly, societal, and financial impact.

III. STRATEGIC GOALS, OBJECTIVES, and IMPLEMENTATION STRATEGIES

GOAL 1: Increase Virginia Tech's capacity in transformative, interdisciplinary, and collaborative research that transcends traditional boundaries

Objective 1.1: Enhance the *intellectual capacity* for research at Virginia Tech.

- attract and retain the best (world-class) faculty in areas of strategic need
- increase the number of high-quality Ph.D. graduates in our strategic areas
- enhance opportunities for postdoctoral associates
- provide undergraduates with opportunities in interdisciplinary research
- act as a catalyst for Big Science and Engineering

Implementation Strategies:

- Partner with academic units to identify, attract, recruit, and retain world-class faculty in areas of strategic need within the ICTAS thrust areas. ICTAS will double its contributions to start-up packages/retention packages from the 2011 baseline year by 2018.
- ICTAS Program Managers will actively engage faculty in ICTAS-supported thrusts, assist in identifying funding opportunities, and facilitate in connecting faculty with federal agency program managers. ICTAS will develop targeted programs to support Junior Faculty.

- ICTAS Doctoral Scholars Program
  - Enhance the impact of the successful ICTAS Doctoral Scholars program by emphasizing supporting students in areas of strategic need to ICTAS.
  - Resources permitting expand the Doctoral Scholars program to strive to serve all eight colleges of Virginia Tech in a manner that complements the broader mission of ICTAS.
  - Refine the program to emphasize interdisciplinary research as one of the criteria for selecting these scholars.
  - Advertise ICTAS Doctoral Scholars *outside* Virginia Tech; current announcements primarily target Virginia Tech departments
- ICTAS will encourage the support of a larger number of graduate student researchers (doubled by 2018) in ICTAS-related research projects by engaging a broader spectrum of Virginia Tech faculty.
- Develop an ICTAS post-doctoral fellowship program to buy out a small portion of select post-doctoral associates time to focus on proposal writing.
- ICTAS will support and encourage participation in undergraduate research programs that have been established and administered by other offices and organizations at Virginia Tech. ICTAS Program Managers will encourage ICTAS-affiliated faculty to participate in these programs on an annual basis.
- Set aside up to 10% of investments for unencumbered, blue sky research. Use Black Swan Seminars and targeted requests for proposals for high-risk, high-impact research.

Objective 1.2: Promote the development of *interdisciplinary research teams*.

Implementation Strategies:

- ICTAS will establish a new construct and supporting policies for interdisciplinary research teams (3 or more faculty members), interdisciplinary research groups (10 or more faculty members), and interdisciplinary research centers (similar in size to an IRG, but with a formal structure, longer expected endurance and additional resources—for additional information on the distinctions of interdisciplinary teams, groups and centers see Appendix).
- Expand ICTAS Junior/Senior Faculty funding model as a means to increase the number of mentor/mentee relationships with the objective of catalyzing innovation and big ideas.
- ICTAS leadership will provide advice, assistance, and, where appropriate, advocacy for junior faculty involved in interdisciplinary research for promotion and tenure decisions.
- Emphasize interdisciplinarity as a consideration for ICTAS Doctoral Scholar selection.
- Emphasize interdisciplinarity as a consideration for ICTAS RFP awards.

Objective 1.3: Enhance the *physical infrastructure* for research at Virginia Tech.

Implementation Strategies:

- Identify and develop plans to acquire additional laboratory/office space for the expanding needs of the research thrusts.

- Target annual ICTAS support toward sustaining well-equipped labs and collaborative space with state-of-the-art equipment and instrumentation within the ICTAS facilities in Blacksburg and the ICTAS space in the VTRC-Arlington facility.
- Develop and execute an NCFL Equipment modernization plan.

Objective 1.4: Develop *inter-campus and inter-institute partnerships* to leverage resources in areas of strategic interest to Virginia Tech.

Implementation Strategies:

- Work with the leadership of Institute for Society, Culture and Environment (ISCE) and Institute for Creativity, Arts, and Technology (ICAT) to set aside targeted funds in ICTAS seed research RFPs for investment in the social sciences, humanities, and arts in collaboration with researchers in engineering and the physical sciences with an enduring emphasis on societal and ethical aspects.
- Play a catalytic role in forming strategic partnerships with VBI and Virginia Tech Carilion Research Institute (VTCRI) in recruiting, developing infrastructural capabilities, and conducting cutting-edge research at the intersection of engineering, the physical sciences, and the life sciences.
- Engage VTTI in exploring joint research opportunities common to ICTAS and Virginia Tech Transportation Institute (VTTI).
- Increase collaboration opportunities with Virginia Tech Research Center (VTRC)-Arlington and other research centers in the Commonwealth of Virginia.

GOAL 2: Increase the reputation of Virginia Tech in transformative, interdisciplinary, and collaborative research

Objective 2.1: Increase the *scholarly impact* of ICTAS' interdisciplinary research.

Implementation Strategies:

- Emphasize scholarship and impact in ICTAS thrust areas, IRG's, centers, seed investments, as measured by quantitative indices such as "h-index," number of citations, and significant Intellectual Property.
- Continue to assist in multi-million dollar proposal development in ICTAS thrust areas as a means of promoting high-impact, interdisciplinary research proposals.
- Improve connection between ICTAS funding and impact; decisions on seed funding proposals should be tied clearly to performance on previous seed grants.

Objective 2.2: Achieve *national and international recognition* as one of the premier academic research institutes focused on transformative, interdisciplinary research (IDR).

Implementation Strategies:

- Increase presence at VTRC-Arlington and use the unique location to provide recognition for ICTAS through seminars/increased visibility with NSF and other funding agencies.
- Host/sponsor national and international seminars/workshops/conferences on interdisciplinary research in areas of strategic interest to ICTAS.

- Collaborate with the Graduate School on IDR initiatives such as the Interdisciplinary Graduate Education Program (IGEP).
- Develop national and international strategic partners focused on IDR.
- Develop a detailed communications plan focusing on ICTAS' IDR successes.
- Establish ICTAS Doctoral Scholar Alumni Program and engage them to broadcast ICTAS' significant strength in interdisciplinary research.

Objective 2.3: Increase research expenditures (3–year moving average) by a factor of 2 in 6 years.

Implementation Strategies:

- Develop and implement a plan to have at least one award per thrust area in excess of $10M by 2018.
- Develop and implement a plan to have at least one award in ICTAS in excess of $100M by 2018.
- Increase the number of faculty associated with ICTAS.
- Use metrics/methods for evaluating all initiatives, including external evaluation to allocate/reallocate resources to meet goals in scholarship and research expenditures.

GOAL 3: Establish and promote a research culture geared toward meeting society's most challenging needs for a sustainable future

Objective 3.1: Develop a broad-based research portfolio that specifically addresses our society's most challenging needs--with an initial focus on security, resilience and sustainability in the critical areas of energy, water, environment, and disease.

Implementation Strategies

- Establish a metric for sustainability to be used in allocating future financial and space resources.
- Establish the contribution to holistic sustainability as a selection criterion for ICTAS seed research and thrust requests for proposals.
- Engage the ICTAS Program Managers and thrust leaders to identify large-scale funding opportunities in the area of sustainability and build teams among Virginia Tech's researchers that are capable of capitalizing on these opportunities.
- Conduct an assessment of the ICTAS operation with respect to sustainability and revise processes to make ICTAS a campus leader in the practice of sustainability.

Objective 3.2: Achieve international recognition as a leading interdisciplinary research institute focused on sustainable science and technology.

Implementation Strategies

- Develop national and international strategic partners focused on sustainability.
- Conduct a future ICTAS Research Day that highlights our sustainability focus.

- Sponsor seminars and workshops on sustainability and invite internationally renowned experts in the fields of sustainable science and technology (S&T) with the objective of enhancing recognition and developing collaborative partnerships.
- Develop a plan for conducting research toward developing self-reliant urban and rural communities.

GOAL 4: Reach out regionally, nationally and internationally to expand research capabilities and to enhance opportunities for economic development.

Objective 4.1: Develop strategic partnerships with national labs, government agencies, other national/international universities, research organizations, institutes, and industry.

Implementation Strategies:

- Working with the Virginia Tech Office of Outreach and International Relations, cultivate connections with government officials, university and national laboratory researchers by attending and organizing networking and research discipline-specific events.
- Focus on industrial partnerships.
- Increase engagement with national and international "think tanks

Objective 4.2: Identify and capitalize upon prospects for research commercialization.

Implementation Strategies:

- Choose commercialization prospects toward licensing or spin-off companies and work with Center for Innovation Based Manufacturing to create business plans for the most promising prospects of faculty research with the intention of creating at least one spin-off company by 2018.
- Identify and obtain initial funding (e.g., SBIR/STTR, industry) for research commercialization, with the intention of identifying at least one SBIR/STTR or industry funded research commercialization per thrust area by 2018.
- Work with VTIP and VT Knowledge Works to establish licensing agreements or spin-off companies from faculty research.
- Initiate and develop a network of angel investors and venture capitalists for commercialization.

Objective 4.3: Globally establish co-located ICTAS Innovation Research Centers with partner institutions with an initial focus on VT, India campus near Chennai, India.

Implementation Strategies:

- Identify and approach key contacts (e.g., foreign university partners, local lead individuals) for establishing global ICTAS Innovation Research Centers. To this end, define initial research areas for global ICTAS Innovation Research Centers.

Objective 4.4: Develop capacity for transferring sustainable technologies and educational programs to developing communities.

Implementation Strategies:

- Working with OIRED, identify funding mechanisms such as the USAID, World Bank, and Bill & Melinda Gates Foundation.
- Engage with foreign partners (both in federal governments and in local communities) to stage for technology transfers to developing communities.

GOAL 5: Develop an organization that exemplifies and prides itself on

- nimbleness,
- a "can-do" attitude,
- teamwork,
- a culture of service to our faculty, our students, our staff, Virginia Tech, the Commonwealth of Virginia, our nation, and our world.

Objective 5.1: Take positive actions to inculcate the desired organizational culture.

Implementation Strategies:

- All ELT members will lead by example and make concerted efforts to promote this culture.
- Discuss the vision, mission, and guiding principles in some manner at the commencement of each ICTAS staff meeting. Display prominently the mission, vision, and guiding principles throughout all ICTAS laboratories, offices and collaborative spaces.
- Develop processes that reward performance that exemplifies the desired organizational culture.
- Refer to the mission, vision, and guiding principles as the foundation for all decisions.

Objective 5.2: Establish and refine the organization and processes to achieve a focus on nimbleness.

Implementation Strategies:

- All ELT members will set the example and seek to inculcate nimbleness into all organizational processes and policies.
- Identify metrics/methods for evaluating all initiatives, including external evaluation.
- Conduct rigorous benchmarking of ICTAS compared to peer institutes.
- Conduct an after-action review of opportunities (those seized and those missed). Based on this review, develop a list of strengths, weakness, opportunities and threats and develop an action plan to create and revise processes in response. Review and, if appropriate, refine the organizational structure, duties and responsibilities, and reporting relationships at least annually.

IV. RELEVANCY TO VIRGINIA TECH'S STRATEGIC PLAN

Virginia Tech's 2012-18 strategic plan "A Plan for a New Horizon" was published in September 2012. As you can see from the figure below, the ICTAS Strategic Plan for the same period is clearly supportive of the University's plan.

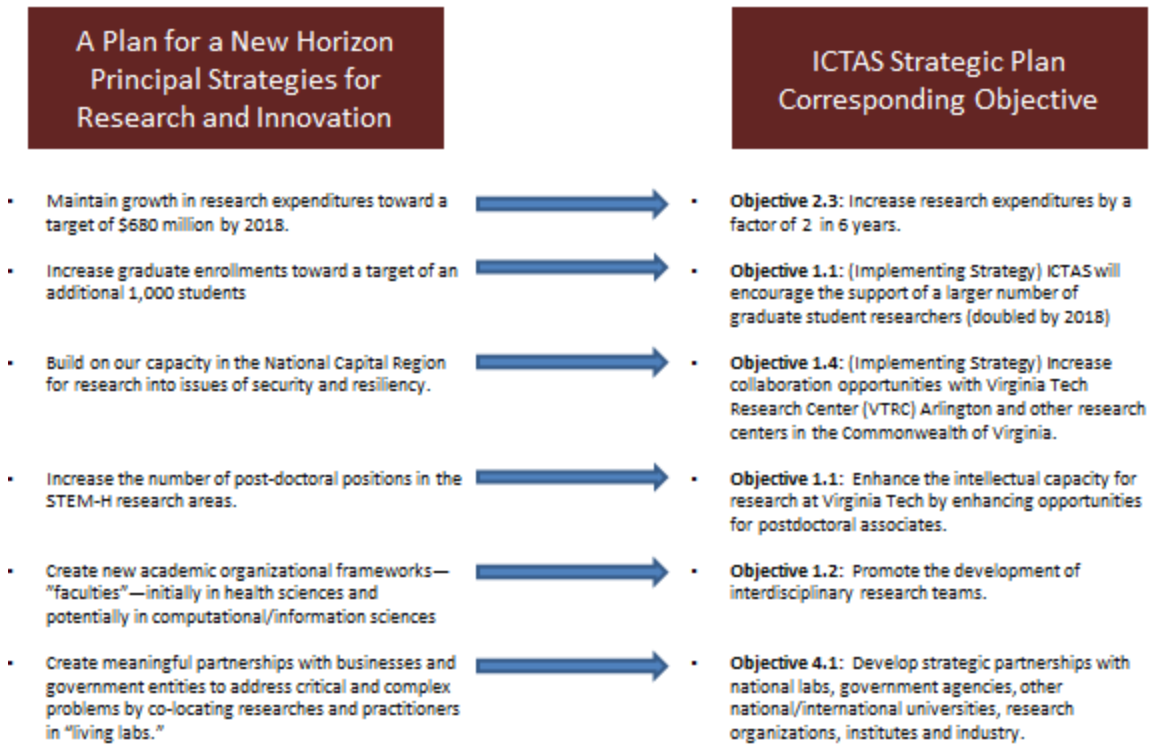


Figure 4. Mapping of ICTAS Strategic Plan to "A Plan for a New Horizon"

With one exception all of the Principal Strategies for the Research and Innovation section of "A Plan for a New Horizon" are addressed directly in this plan. The remaining strategy will be addressed in the first annual review of the plan.

V. CORE RESEARCH – THRUST AREAS

Eight thrust areas have been identified to serve as the core for ICTAS research (see Figure 4). Each thrust area, in turn, is populated by Research Centers and Interdisciplinary Research Groups in established areas of research and by smaller team efforts to incubate new research. The Centers/IRG's are typically comprised of 10-16 faculty members and are primed to gain national prominence. A brief description of these thrust areas follows.

Nanoscale Science and Engineering	**Nano-bio Interface**	**Sustainable Energy**	**Renewable Materials**
• Environmental Nanoscience and Technology • Nanomaterials • Nanosensors • Sustainable	• Targeted Delivery of Nanomedicine • Cellular Engineering Microsystems • Noninvasive Sensing and	• Fuel Cells • Solar: Organic Photovoltaics • Biofuels • Energy Harvesting • Wind Power	• Biobased Materials: Design and Processing

Nanotechnology	Diagnosis • Inflammation • Bioimaging		
Sustainable Water • Water Infrastructure Management • Wastewater Treatment • Watershed Management • Water and Health • Outreach • Platform Technologies	**Cognition and Communication** • Cognitive Radio Networks • Autonomous Secure Communications • Human Computer Interface	**National Security** • Applied Autonomy • Data to Decision • Cyber • Energy • Advanced Weapon Systems	**Emerging Research** • Innovation-based Manufacturing (IbM) • Discovery Analytics • Advanced medical training research • Micro/Nano-Satellite Systems • Additive Manufacturing • Bio-Inspired Science and Technology (BIST) • Nuclear Science and Engineering (NSE)

Figure 4. ICTAS Thrust Areas with respective major initiatives.

1. Nanoscale Science and Engineering

The Nanoscale Science & Engineering (NSE) thrust advances nanoscale-related research and education with an emphasis on sustainability, the latter a vital portion of the strategic plan of ICTAS. Sustainability is at the core of everything we do, from the development and manufacturing of nanoscale technologies to leveraging these technologies to help remedy global sustainability challenges in areas such as clean air and water, waste minimization, and environmental remediation. We have shown that state-of-the-art materials science, molecular- and microbiology, environmental engineering and geochemistry, nanoscience and nanotechnology, and even social science can all work together in a truly interdisciplinary fashion to generate unique and societally important results. Currently, most faculty within the NSE Thrust Area are organized within VT SuN—the Center for Sustainable Nanotechnology. The NSE strategy for expansion has been to focus initially on the success and growth of VT SuN. Looking ahead to 2018, the NSE Thrust plans to nucleate and grow new IRGs and Centers focused on 'New Horizons' in nanoscale science and engineering, described below. As summarized below, VT SuN has been nucleated within the NSE Thrust – over the next six years, we expect significant growth within the NSE thrust as we focus on executing our 'New Horizons' strategy:

- **Virginia Tech Center for Sustainable Nanotechnology (VT SuN).** VT SuN was created to address the need for nanotechnologies that are sustainable throughout their life cycle, to educate and train a new generation of researchers skilled at the interfaces between nanoscience and environmental systems, and to disseminate cutting-edge research on sustainable nanotechnologies, globally. Currently, most faculty within the NSE Thrust Area are organized within VT SuN—the Center for Sustainable Nanotechnology. This highly interdisciplinary core group of 11 faculty members from five departments has been incredibly active and productive.

Looking ahead to 2018, we have identified four NSE Thrust Platforms that stem from our recent discoveries, university core strengths, and an international agenda for research occurring at the interfaces of nanoscale science and engineering. A summary of each platform is provided:

- **Platform 1 – Earth Nanosystems.** Earth Nanosystems research is focused on applying nanoscience to environmental geochemistry, biogeochemistry, and mineralogy. Currently, NSE researchers aligned with this research platform are core members of the national Center for the Environmental Implications of Nanotechnology (CEINT). In addition, research is focused on investigating other complex environmental systems including mineral-microbe interactions and mineral surface science.

- **Platform 2 – Engineered Nanosystems.** Engineered Nanosystems research is focused on applying fundamental engineering and chemistry principles to assess the fate and transport, and toxicity of engineered nanomaterials released to environmental systems. In addition to evaluating the implications of engineered nanomaterials, Engineered Nano Systems research is also focused on applying nanoscale technologies to address global environmental health challenges.

- **Platform 3 – Sustainable Nanomanufacturing.** Our research in sustainable nanomanufacturing is focused on applying basic principles of green engineering, life cycle assessment, and various others disciplines to establish sustainable manufacturing processes for engineered nanomaterials.

- **Platform 4 – New Horizons in Nanoscale Science & Engineering.** Looking ahead, we will seek to expand the reach of the NSE thrust into new domains of nanoscale science and engineering. We call these new domains 'New Horizons' in nanoscale science and engineering, and they will be focused on nanotechnologies for sustainable energy (in coordination with the ICTAS Sustainable Energy Thrust Area), sustainable bionanomaterials (in coordination with the ICTAS Renewable Materials Thrust), nanoinformatics for sustainable materials design (in coordination with the ICTAS Cognition and Communication Thrust), and nanotechnologies to sustain the warfighter (in coordination with the ICTAS National Security Thrust Area).

For the 2012-2018 period, we will prioritize investment and energy as follows:

1. Earth nanosystems (Major emphasis)

2. Engineered nanosystems (Major emphasis)
3. Sustainable nanomanufacturing (Major emphasis)
4. New horizons in nanoscale science & engineering (Major emphasis)

2. Nano-Bio Interface

Nano-Bio Interface

The Nano-Bio Interface thrust aims to establish Virginia Tech as a leader in research frontiers emerging at the interfaces of nanoscale science and engineering and molecular and cellular biology. Our Thrust currently supports an intellectually diverse group of interdisciplinary faculty devoted to an exciting array of research topics ranging from nanoscale scaffolds for tissue regeneration to targeted delivery of therapeutics. This breadth of research activities serves as our strength and enables our Thrust to identify emerging research frontiers and broadly disseminate scholarship in *complex biomolecular nanosystems*. As summarized below, multiple IRGs, inter-institute collaborations, and other teaming arrangements focused on transformative interdisciplinary research at the intersections between nanoscale science and engineering and biotechnology have been nucleated within the Nano-Bio Interface Thrust:

- **Center for Veterinary Regenerative Medicine (CVRM).** The CVRM, which is jointly supported by the ICTAS Nano-Bio Interface Thrust and the Fralin Life Sciences Institute, provides new medical alternatives for animals, while generating scientific knowledge that can help save and transform human lives. Refer to Vet Med website for details. You may want to mention that it is jointly supported by Fralin and ICTAS.
- **Targeted Delivery of Nanomedicines (TDN).** The TDN is an emerging interdisciplinary research group (IRG) within the Nano-Bio Interface Thrust that is focused on using tailored nanocrystals for immune-targeting, performing microinjection of nanoparticles, using real-time spectroscopy in biological systems, and engineering nanoconstructs for targeted regulation of intracellular free radical concentration. Many strong research collaborations exist between the TDN IRG and the recently established Virginia Tech Center for Drug Discovery (VTCDD), which is an interdisciplinary group within the Fralin Life Sciences Institute, that is committed to advancing existing drug discovery and development programs at Virginia Tech. Through these collaborations, the TDN IRG and the VTCDD can work together to pursue research focused on improving the effectiveness of existing drugs, as well as developing new classes of nanoscale therapeutics with enhanced targeting and transport capabilities.
- **Center for Inflammation.** A joint collaboration with the Fralin Life Sciences Institute, the Center for Inflammation is structured to leverage unique research expertise in immunity and bioluminescence to identify key molecular targets for effective therapeutic intervention of chronic human inflammatory diseases that include infectious disease, cardiovascular disease, obesity and diabetes, and neurological disorders.
- **ICTAS-Supported Center for Systems Biology of Engineered Tissues (ISBET).** ISBET seamlessly intertwines computational and experimental models to drive the next generation of advances in tissue engineering and systems biology. Systems biology approaches will underlie predictive computational models of engineered tissues and drive

novel experimental analysis of engineered tissues, while the demands of tissue engineering will inspire new methodologies and analysis frameworks in systems biology.

- **Multiscale Bio-Engineered Devices and Systems (MBEDS).** MBEDS combines micro electrical mechanical systems (MEMS) and cellular biology to monitor, transform, manipulate, and genetically engineer cells in new ways with unprecedented precision and sensitivity. The mission of MBEDS is to develop fundamentally innovative techniques for the diagnosis and treatment of diseases by exploiting phenomena that dominate at the micro- and nano-scales.

Looking ahead to 2018, we have identified four Nano-Bio Interface Thrust Platforms that stem from our recent discoveries, university core strengths, and a rapidly evolving common international agenda for research occurring at the interfaces of nanoscale science and engineering and biotechnology. A summary of each platform is provided below:

- **Platform 1 – Target delivery and transport of nanoscale therapeutics in the emerging field of nanomedicine.** The Nano-Bio thrust has initiated a core competency in targeted delivery and transport of nanoscale therapeutics in the emerging field of nanomedicine.
- **Platform 2 – Wound healing and tissue/organ regeneration with a focus on skin biology and health.** We propose continued research efforts in tissue/organ regeneration in historical collaboration with Wake Forest Institute of Regenerative Medicine (WFIRM) with a new focus on skin biology and wound healing.
- **Platform 3 - Formation and transport of charged aqueous nanostructures across targeted cellular and nuclear membranes.** A new focus on Platform 3 stems from our growing competency in nucleic acid delivery, where a cationic synthetic vector efficiently condenses a negatively charged nucleic acid or protein into a nanoparticle (20-200 nm in diameter).
- **Platform 4 - Entry into the rapidly growing discipline of food nanotechnology for global food availability and security.** Platform 4 will position the Nano-Bio thrust to understand the role of nanostructure in food systems for many emerging challenges including food safety, nutrition, and bio-availability

For the 2012-2018 period, we will prioritize investment and energy as follows:

5. Targeted delivery and transport of nanoscale therapeutics (Major emphasis)
6. Wound healing and tissue/organ regeneration (Major emphasis)
7. Formation and transport of charged aqueous nanostructures across targeted cellular and nuclear membranes (Moderate emphasis)
8. Entry into the rapidly growing discipline of food nanotechnology (Minor emphasis)

3. *Sustainable Energy*

Research in Sustainable Energy Thrust is dedicated to discovering alternative energy resources and improved energy conversion systems in order to sustain and improve the quality of life as our global population increases from 6.7 to almost 10 billion over the next 50 years. In order to address these global energy challenges, basic to applied research is being conducted for developing more economical and efficient means for producing electricity from solar energy; improved biomass feedstocks and conversion processes; and more effective and durable fuel cell systems.

Center for Energy Harvesting Materials and Systems: The National Science Foundation (NSF) Industry/University Cooperative Research Centers (I/UCRC) Center for Energy Harvesting Materials and Systems (CEHMS) is addressing the urgent need for developing renewable energy based power sources for multiple civilian and defense platforms. CEHMS researchers are leading the global research in development of energy technologies covering mechanical, thermal and chemical energy harvesting, wind energy, solar cells, supercapacitors, Li-air batteries, and high efficiency electronics.

Self-sustaining Living Module (SLiM): A highly interdisciplinary team of faculty from the College of Engineering (ME, EE, ESM, CS) and the College of Architecture and Urban Studies (Architecture, Industrial Design) will create sustainable energy systems for rapidly deployable military shelters for the Department of Defense. The team will use a systematic design approach to the development of an integrated SLiM system that offers dramatic improvements over state-of-the-art expeditionary force facilities by providing: occupant protection, quality of life enhancement, utility in a wide range of deployments, and sustainability.

Center for Clean Coal Energy (IC3E): The ICTAS Center for Clean Coal Energy (IC3E) Grand Challenge research project is focused on the development of tools for predicting the behavior of reacting fluidized beds to support the design of more efficient biomass and coal gasification processes for energy production. This multidisciplinary, collaborative research project couples the use of experiments and computational fluid dynamics (CFD) to increase the fundamental understanding of particle mixing behavior and reactions in a fluidized bed gasifier used for solid fuel conversion to SYNGAS.

Sustainable Energy Laboratory: Research in this lab is aimed at addressing current and future energy challenges facing our global society. With a focus on sustainability, basic and applied research is being conducted to achieve breakthroughs in materials for efficient automotive and stationary fuel cells using renewable energy sources. Researchers are also engaged in emerging areas ranging from materials for energy storage and energy harvesting.

Key research accomplishments 2006-2011

- SLiM – In 2012, The SLiM Team awarded Phase I ($200k) with Phase II ($1M) pending.
- Robert B. Moore, Louis A. Madsen published “Linear coupling of alignment with transport in a polymer electrolyte membrane” in Nature Materials, 2011. The article described the utilization of multi-axis pulsed-field-gradient NMR to study how PEM structure and morphology relate to mobile species transport which is important in technologies such as solid-state batteries, ‘artificial muscle’ actuators and reverse-osmosis water purifiers.

- CEHMS – Awarded an NSF I/UCRC in 2011. NSF I/UCRCs are leading the way to a new era of partnership between universities and industry, featuring high-quality, industrially relevant fundamental research, strong industrial support of and collaboration in research and education, and direct transfer of university developed ideas, research results, and technology to U.S. industry to improve its competitive posture in world markets. Through innovative education of talented graduate and undergraduate students, the I/UCRCs are providing the next generation of scientists and engineers with a broad, industrially oriented perspective on engineering research and practice.
- Researchers in the Sustainable Energy Laboratory collaborated with GM in a 5 year project (2007-2012) on the testing and development of Proton Exchange Membrane (PEM) fuel cell materials.
- In 2008, Biomethodes, a French biotechnology company, licensed Percival Zhang's technology for converting biomass to ethanol and other products.

Over the next few years, we plan to focus on three areas that seem to offer significant prospects for interdisciplinary collaboration and growth in research activity: photovoltaic materials, combustion and gasification of biomass, and electrochemical energy conversion and storage. We have researchers who are active in dye sensitized solar cells, organic PV, and multi-junction PV, and we have recently added the capability to characterize these materials in our shared laboratory facilities. In addition, we have developed materials that show promise for improving Li battery performance and have recently added the capability to fabricate and characterize these materials and devices in our shared laboratory facilities. Finally, we have begun to connect researchers from horticulture who are interested in tailoring biomass properties for energy applications with researchers in the combustion and gasification area who can characterize the performance of biomass in energy conversion operations. We look forward to strong growth in these areas over the next few years. In addition, we hope to connect on-going work in energy grid sustainability with work in the national security thrust.

Investment priorities for 2012-2018

a. Energy Harvesting (Major Emphasis)
b. Energy Storage (Major Emphasis)
c. Smart Grid (Moderate emphasis)
d. Solar Energy (Minor Emphasis)
e. BioFuels (Minor Emphasis)

4. Sustainable Water

To meet our nation’s current and future water needs, ICTAS research in sustainable water technologies is focused upon improving water infrastructure and distribution, water remediation, water conservation, water and health, and creating new sources of water for our world. The Sustainable Water Research Thrust will enable Virginia Tech to be a world leader in research that advances water sustainability in the 21st Century and place Virginia Tech faculty at the leading-edge in water sustainability research. The center will catalyze research at interfaces between water infrastructure, health and the environment, by providing seed resources and

infrastructure for multi-disciplinary efforts that characterize the complex water sustainability problems confronting society.

Although not exclusive to our mission, we have selected three key Focus Areas for emphasis in strategic planning: 1) Sustainable Water Infrastructure Management (SWIM) will develop the understanding necessary to repair, replace and rehabilitate the nations decaying water infrastructure; 2) Water and Health is developing sound science to combat childhood obesity, childhood lead poisoning, human disease from pathogens that grow in building plumbing systems (e.g., Legionnaires disease and non-Tuberculosis Mycobacterial (NTM) infection), food safety and fetal development; and 3) Sustainable Watersheds/Ecosystems explores a diversity of topics including impacts of climate change on water quality and water supply, design of water supplies in green buildings, stream ecosystem health, water recycling/reuse, and interfaces between land use such as agriculture, grazing and stream ecosystems The ICTAS Sustainable Water thrust area has a goal of becoming amongst the foremost research institutions in the world in each Focus Area.

Cross-cutting Initiatives have been pursued with substantial success. In addition to the successful NSF REU on campus ($380K Lohani), ICTAS seeded a successful grant to NSF on teaching graduate ethics in a collaboration between Civil Engineering and Science Technology and Society ("Learning to Listen" PIs Lambrinidou/Edwards; $300K). Thirteen members of the ICTAS Water and Health Focus Area also developed a successful interdisciplinary research program on campus entitled "Water INTERface: INTERdisciplinary Research Transcending Boundaries of Engineering, Science and Human Health that was funded in 2011. This leveraged into a $3 million dollar NSF IGERT submitted in 2012. The current level of external support for cross-cutting initiatives is about $140K per year.

Key areas of emphasis within the thrust include:

Sustainable Water Infrastructure Management (SWIM) will develop the understanding necessary to repair, replace and rehabilitate the nations decaying water infrastructure. Over the next 20-30 years nearly a trillion dollars must be spent to upgrade water and wastewater pipelines and related infrastructure in the United States. Much of this expenditure is non-discretionary as pipeline failures create catastrophic damages and threaten public health (e.g., http://www.ictas.vt.edu/downloads/SWIM.pdf). Virginia Tech is well-positioned to educate the next generation of students and to conduct research necessary to meet this grand challenge.

Water and Health is developing sound science to combat childhood obesity, childhood lead poisoning, human disease from pathogens that grow in building plumbing systems (e.g., Legionnaires disease and non-Tuberculosis Mycobacterial (NTM) infection), food safety and fetal development. All of these problems are at the forefront of public health concerns and Virginia Tech's research is considered cutting edge.

Sustainable Watersheds/Ecosystems explores a diversity of topics including impacts of climate change on water quality and water supply, design of water supplies in green buildings, stream ecosystem health, water recycling and reuse. The diversity of faculty and resources at Virginia Tech in this Focus Area presents unique opportunities and challenges in executing of large scale interdisciplinary projects. Specifically, key faculty are located at three Virginia Tech campuses (Blacksburg, Falls Church, Manasass) and faculty are concentrated in numerous departments

(Civil and Environmental Engineering, Biological Systems Engineering, Forest Resources and Environmental Conservation, Crop and Soil Environmental Sciences, Biology, Geosciences, Urban Affairs and Planning, Urban Affairs and Planning, and Fisheries and Wildlife Sciences). There are also two on-campus centers with a long and productive history: Virginia Water Resources Research Center (VWRRC) and the Center for Watershed Studies (CWS). Existing external research funding for this area is approximately $180K per year.

Investment priorities for 2012-2018

- **Seed money for leadership on large ($2 million+) multi-investigator grants with potential to for 100:1 return on investments.** Funding in the range of $15-30K will be used for PI buy-outs to free up time for leadership on large efforts, sometimes with a small development or travel budget.
- **Seed grants for high impact, multidisciplinary, and/or multi-investigator research.** This is exemplified by the $64K 2011 investment in the Stroubles Creek Place-Based Laboratory for Research, Education, and Outreach.
- **Strategic Equipment/Younger faculty development.** If the need arises for small equipment grants that are potentially limiting breakthrough research, or seed money for early career faculty, the possibility for investments will be considered on a case by case basis.

5. *Renewable Materials*

Increased understanding and manipulation of materials that are naturally occurring and can be replenished are critical to replacing fossil-based fuels and resources. The ICTAS Renewable Materials Thrust supports interdisciplinary education and research in the synthesis, characterization, structure-property relationships, and applications of bio-based materials such as proteins and cellulose, and innovative projects in sustainable agriculture.

Sustainable Agriculture – A group led by Joseph Gabbard and Jerzy Nowak that lays the groundwork for transdisciplinary research that marries emerging engineering technology, agriculture, and sustainable natural resource management practices.

Bio-Based Materials Center (BBMC) - The BBMC comprises 15 faculty members from 9 departments and 5 colleges focused on glycoscience, and on the crucially biologically important interactions between proteins and polysaccharides.

Some key accomplishments :

In 2009, the BBMC received a $500K USDA Educational grant, “Bio-based Sustainable Materials as Resources for Tomorrow (BSMART)”. The project goal is to train students for graduate degrees in activities to strengthen US agricultural, food, and fiber competitiveness and expand economic opportunities in rural communities. BSMART offers a curriculum to prepare students for the biorefinery and the flexibility to satisfy degree options from almost any science or engineering discipline at VT. BSMART actively recruits a diverse student body with three primary goals for educating and training graduate students: 1) engage students in stimulating multidisciplinary research through carefully designed, co-advised projects, 2) educate them on core principles of biomaterials and bioprocessing while simultaneously enhancing their ability to

function within a team, 3) provide experiential learning opportunities including undergraduate-student mentoring, internships, and extension activities/K-12 outreach, along with opportunities to learn about small business development and technology transfer.

- In 2011, Somali Bantu refugees in Roanoke used the Sustainable Agriculture technology platform to grow crops, later sold to generate additional income for their community.
- BBMC-led Graduate Certificate in Bio-Based Materials approved, 2011.
- Thrust Leader Kevin Edgar filed 2 patents with ICTAS support, "Novel Amphiphilic Pullulan Derivatives" and "Bioavailability Enhancement of Rifampicin via Amorphous Solid Dispersion".

BMC faculty have emphasized the broad fields of polysaccharide and protein science in their research to date. These efforts include the synthesis of novel polysaccharide derivatives, the development of methods to analyze, prepare, and determine the properties of selectively substituted polysaccharides of controlled monomer sequence, the physical chemistry of polysaccharide surfaces and nanoparticles, and the utilization of lignocellulosic materials in applications ranging from drug delivery to adhesion. The chemistry of polypeptides, with emphasis on the control of polypeptide tertiary structure, the processing of polypeptides, the interaction of polypeptides with the human body, and the utilization of polypeptides for applications ranging from plastics to human implants is also key.

A third focal area was recently added to the research plan that brings together the research efforts of BBMC faculty to solve one of the key, complex, impactful issues of contemporary science, the field of polysaccharide-protein interactions, or glycoscience. This difficult area is important because such complex interactions drive crucial biological processes including CNS development, cell adhesion and recognition, and pathogen recognition of target cells.

The Sustainable Agriculture team established and integrated a technology platform that employs in-ground sensor suites that communicate with handheld devices to report real-time soil conditions that are indicators of a crop's stress status and drivers for sustainable agriculture management decisions. Water, air, nutrients, pH correction and other compounds can be delivered precisely in the stress zone (s) using a subsurface microirrigation system. This platform was fielded in a real-world production agriculture setting at the Catawba Sustainability Center.

Going forward, this team will examine how microbial communities assemble and function in soil ecosystems and root-zone habitats – with implications for human health (for food crops). They will also work to physically and conceptually extend the technology platform to leverage other ongoing interdisciplinary efforts at Virginia Tech. Additionally, a team of undergraduate ME students will engage in a capstone course to design an autonomous robot, that will "work in the field" and facilitate the goal of sustainable agriculture through precision delivery of inputs. The autonomous robot will plug in to the technology platform, and provide additional communication, sensor and digital image capabilities

Investment priorities for 2012-2018

f. BBMC (Major Emphasis)

g. Exploring new Renewable Material topics (Major Emphasis)

h. Sustainable Agriculture (Moderate Emphasis)

6. Cognition and Communication

Rich in content and potential, *Cognition and Communication* refers to the nexus of computation, communication and human cognition. This is perhaps the most inherently interdisciplinary of the eight thrusts with clear opportunities for collaboration between engineers, physical, life, and social scientists, humanists and artists.

As the name suggests, the **Wireless@VT** faculty perform leading-edge research in wireless communications with strong effort in the development of new and more efficient designs for antennas in wireless applications, merging of hardware and software to create better environments for interpersonal connection, and developing innovative low-power VLSI (Very Large Scale Integration) designs. In Cognitive Radio Networks, researchers are developing techniques for more efficient use of spectrum for the purpose of enabling higher data rates and more wireless devices and developing automated ways for deploying and maintaining wireless infrastructure with minimal human interaction. Another research effort--Autonomous Secure Communications—is centered on building an autonomous and secure communication system that dynamically evolves the architecture design of a network according to its environment so that the survivability, availability, manageability, capacity, integrity, and confidentiality of the communication system can stay at its optimal level.

The Center for Human-Computer Interaction brings the human element and the computational components together through technologies that connect the human sensory, perceptual, cognitive, and motor capabilities to access information, control processes, manipulate data, and improve the quality of human experience through the interaction with computation. It encompasses both human interaction with computers and interaction with other humans through computation. The center faculty work to address both the facilitation and the foundational understanding of such interaction.

In addition to these two centers, the **Discovery Analytics Center**, while still considered in the Emerging Research Thrust will play a critical role in the Cognition and Communication Thrust. Additionally, it is anticipated that there are tremendous opportunities for collaboration with the Institute for Society Culture and Environment, the Institute for Creativity, Arts and Technology and the Virginia Tech Carilion Research Institute in this thrust.

Key research accomplishments in this thrust during the period 2006-2011 include significant developments in the field of cognitive radio, culminating in the development of the CORNET cognitive radio testbed integrated into the ICTAS I building. The Center for Human Computer Interaction can boast significant results in the development of high resolution displays and innovative methods for interface with computational aspects. An excellent demonstration of both of these is the development of the intelligence analysts workstation, that includes a number of high resolution displays and tools to maximize their utility.

Key areas of emphasis and investment priorities for 2012-2018 include:

1. The use of the CORNET testbed as the foundation of a next generation wireless testbed.
2. Research into the hospital room of the future.
3. Visual analytics.

7. *National Security*

Drawing on a wealth of diverse resources, this thrust area is dedicated to meeting the growing needs of national security. While there are several areas of emphasis, National Security Research in effect draws from researchers from across the eight ICTAS thrusts and from various other disciplines from throughout the university.

The **Virginia Center for Autonomous Systems (VaCAS)** facilitates interdisciplinary research in autonomous systems technology. VaCAS hosts research activities spanning every application domain: water, land, air, and space. VaCAS member research activities range from fundamental control theory to vehicle development to applications for science, security, and commerce.

Second, The **Ted and Karyn Hume Center for National Security and Technology** seeks to be the country's leader in holistically developing the elite science and technology human capital for the Intelligence Community through sustainable and flexible research programs that engage faculty and students to solve the needs of the National Security community. The Hume Center's research programs focus on national security applications of wireless communications, cybersecurity, and data analytics. Our educational programs seek to engage students and expand curriculum in key areas of interest to national security sector employers.

Finally, the **Center for Naval Systems (CNavS)**, provides leadership within Virginia Tech's efforts to create strategic relationships with the DoD and other National Security agencies. The mission of CNavS is to enable contract research to address the science and technology needs of the armed forces with a special emphasis on the U.S. Navy and Marine Corps in order to:

- Bridge early research and development concepts to enable the creation of unique solutions for current military technical challenges.
- Provide research opportunities to develop the next generation of scientists and technologists to meet our nation's national security needs.

A strategic goal of this group is to enhance the Virginia Tech relationship and technical reputation with the Naval Surface Warfare Centers (NSWC) Dahlgren Division (NSWCDD). In collaboration with NSWCDD, CNavS will expand our relationships to encompass other Navy and DoD organizations working to solve the multitude of science and engineering challenges for our nation.

Key research accomplishments in this period include a broad range of success in underwater, surface, ground and aerial autonomous vehicles and humanoid robots. This period also saw the standup and rapid periods of growth for the Hume Center and CNavS.

Areas of emphasis and investment priorities for 2012-2018 include:

1. Autonomy and Robotics
2. Cybersecurity
3. Data to Decision
4. Tactical Energy
5. Advanced Weapon Systems

8. *Emerging Research Areas*

Emerging Technologies Thrust Area covers high risk/high pay-off developments in the emerging and 'disruptive' technologies that are in the early stages of development, yet have potential to become either a significant component of one of the established thrust areas or gain status as a

new thrust area. Emerging Technologies catalyzes and promotes transformative, interdisciplinary/transdisciplinary cutting-edge research at the intersection of engineering, science, and medicine by providing a collaborative atmosphere designed to stimulate and promote creativity, a place where intellectual capacity can be explored and challenged to reach areas previously explored in isolation. Key areas of emphasis within the thrust are:

Innovation-based Manufacturing (IbM). This research falls within the auspices of the Center (CIbM) which is collaborating with the Center for the Enhancement of Engineering Diversity to create an Innovation and Entrepreneurship Residential Community for undergraduates. Planning is underway for a VT Catalyst program bridging the gap between university-developed product concepts and proof-of-concept prototypes. Focus areas include Manufacturing Innovation; Manufacturing Scale-up; Local Industry Applied Research; Student-driven Initiative Support; Continuing Education & Cross-functional Problem Solving.

Discovery Analytics (DA). DA has identified three initial verticals: intelligence analysis, sustainability, and health informatics. The ICTAS Discovery Analytics Center fosters a university-wide emphasis in knowledge discovery & data mining (KDD), bridges traditional departmental and college boundaries, and helps form concerted teams to attack key data mining problems of national interest. These research activities are pursued under the umbrella of ICTAS- supported Discovery Analytics Center. The center spans faculty from computer science (CS), statistics (STAT), mathematics (MATH), and electrical and computer engineering (ECE). Faculty in the center constitute the "horizontals", i.e., the core ingredients of data mining such as discrete algorithms, numerical optimization, image processing, information retrieval, and Bayesian statistics. They come together in different combinations to address challenging application problems in "vertical" areas.

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Overall mission of the center is to position Virginia Tech as the country's preeminent leader in the interdisciplinary practice of KDD, the science of extracting interesting and actionable knowledge from massive datasets.

Humanoid Hospital. The development of an interactive humanoid patient that will mimic a range of common clinical problems and provide a broad spectrum of clinical variables ideal for training purposes is the goal. This will facilitate discovery-based medical education and enhance the quality of healthcare services.

Micro/Nano-Satellite Systems. This group is poised to become the preeminent program for the development of CubeSat technology for geospace exploration focusing where science and platform technology development is most needed: sensor development & design, fabrication, testing of remote and in situ science instrumentation, and precision navigation and control capabilities.

Additive Manufacturing (AM). The AM interdisciplinary research group has on-going research in fabricating geometrically complex objects in a layer-by-layer fashion from novel materials

including metals, ceramics, biomaterials and nanomaterials. AM with nanomaterials has been a core focus, resulting in the production of novel quantum dot nanocomposites.

Bioinspired Science & Technology (BIST). BIST is envisioned to provide leadership in ideas for bioinspiration and to define directions for turning it into a mature science and engineering discipline. One of the laboratories in this ememrging area- the Global Laboratory on Bio-inspired Science and Engineering (GLOBES) has already established operational partnerships with Shandong University in China and the Smithsonian Institution. GLOBES will leverage these assets and act as a crystallization seed for bioinspired engineering research at Virginia Tech; and make qualitative data from diverse sets of biological species available to bioinspired engineering research.

Nuclear Science and Engineering Lab (NSEL). In coordination with the Nuclear Engineering Program, NSEL draws the expertise of faculty members from different disciplines, and promotes nuclear education by offering workshops, courses, and seminars. NSEL's activities include: Innovating new tools and devices, and advanced computational and visualization tools for application in nuclear power, nuclear security, nonproliferation and safeguards, and radiation diagnosis and therapy; Engaging in science-based analysis for formulation of nuclear policy; and facilitating international collaborations with academic institutions and industrial organizations.

Key research accomplishments 2006-2011

Innovation-based Manufacturing (IbM).

- Collaboration with VBI in monitoring of DNA manufacturing
- Self-healing Assembly Systems

Discovery Analytics.

- The center has received several key grants, from NSF (TUES CRP), NEH ("Digging into Data"), and NEC Labs.
- In the process of contract negotiations to receive a $13.M contract from IARPA with VT as the lead institution with several other key partners, including UMD College Park, Cornell University, Children's Hospital, Boston (a division of Harvard Medical School), UCSD, Indiana University, San Diego State University, along with a top-100 federal contractor (CACI, Inc.) and a small business (Basis Technology).

Micro/Nano-Satellite Systems.

With ICTAS support, submitted the following major NASA proposals with Virginia Tech as the lead:

- Heliophysical Pathways to Atmospheric Coupling (HPAC)
- Coupled Heliosphere Atmospheric Research Mission (CHARM)
- Solar Occultation Constellation for Retrieving Aerosols and Trace Element Species (SOCRATES)

Additive Manufacturing (AM).

- 2 Provisional Patents, 8 Invention Disclosures, 1 Book Chapter, 6 Refereed Publications, 9 Conference Proceedings and Other Publications, 18 Presentations, 2 Conferences & Workshops Organized.

Bioinspired Science & Technology (BIST).

- First quantitative analysis of biodiversity in bat pinna shapes acting as biosonar antennas
- First analysis of sub-second dynamics in bat biosonar sensing
- Optimal design of morphology & gait of biomimetic flight vehicles using geometric control & averaging theory

Nuclear Science and Engineering Lab (NSEL).

- Developed the TITAN code which allows for hybrid Sn and Characteristic algorithms
- Publications and presentations in fracture resistance of austenitic stainless steels and irradiation resistance of nano-porous materials

ICTAS Core Research - Other Initiatives

The **Occupational Safety and Health Research Center** (OSHRC) is devoted to discovering and disseminating innovative ways to separate humans from hazards in the occupational environment, though research and training, and focusing on applications that reduce fatalities, injuries, illnesses, and accidents. OSHRC provides leadership in large-scale, work-related accident, injury, illness, and fatality reduction in the U.S. and beyond; in support of its mission to design, develop, implement, and translate innovative, integrated, and multidisciplinary projects for significant safety and health improvements in the occupational domain. OSHRC accomplishments include 15 pilot projects funded, several of which have led to subsequent external funding, more than $10M in externally sponsored research, and over 100 publications in peer-reviewed archival journals. Specific recent/ongoing accomplishments:

- Development and evaluation of fall arrest systems for construction applications
- Simulation to improve efficiency and reduce injury risks during residential construction
- Interventions to enhance dust control technology for control of respiratory illness (e.g. silicosis)
- New technologies (rock mechanics, laser scanning, and microseismic tomography) for identifying and understanding ground stability hazards in mining
- Novel optical systems for real time monitoring of welding fumes
- Identifying risk factors for occupational falls, and evaluation of existing guidelines

Research objectives for 2012-2018 include:

- Obtain continued funding from NIOSH for a National Center for Construction Safety and Health
- Facilitating and enhancing researchers across disciplines at Virginia Tech, partner institutions, sponsors, and practitioners for effective collaborations.
- Developing effective, human-centered approaches.

- Seeking the best safety and health practices from diverse sectors for technology and knowledge transfer.
- Promoting research that is innovative, translatable, and usable to companies and workers.
- Sectors of current major emphasis are: Construction, Healthcare, Manufacturing, and Mining.

Disciplinary areas of emphasis are: Industrial Hygiene, Musculoskeletal Disorders, Safety, Slip/Trips/Falls, and Work Organization.

ICTAS Research in the National Capital Region (NCR)

Background:

Acquiring federal research funding requires nimbleness and new creative and effective strategies to maintain a bead on untapped opportunities. Virginia Tech's new NCR facility will be a key component to maintaining its leading role in research. In particular, the growing trend toward more contracts-related research funding has been noted. In 2008, 17% of research funding was in the form of grants, whereas 83% was in the form of mission-specific contracts. Of that 83%, more than 89% were contracts for a million dollars or more. Virginia Tech's limited presence in the greater DC area has hampered its efforts toward solidifying the base of relationships critical to obtaining these contracts; this will change with the new NCR facility in Arlington. Virginia Tech will be able to establish its brand more visibly, be more proactive in working with agencies, and follow the funding sources with this new physical presence, a state-of-the-art facility for research.

The Role of ICTAS in the NCR

ICTAS will be strongly engaged in the NCR facility and integrated with the College of Engineering (COE) and College of Science (COS) through the mutual sharing of ~35,000 square feet of lab and office space (ICTAS allocation of 3,000 square feet of useable space with 6,705 square feet of total space). This presence will allow ICTAS, COE, and COS to fully leverage the local ecology within the greater DC area. Toward this end, a core group of research faculty will be hired to identify, secure, and execute contract research. ICTAS and its partners will continue to expand efforts with already well-established organizations such as Georgetown University, Johns-Hopkins University, and others for our mutual benefit in securing contracts. In addition to this research role, the facility will act as ICTAS' gateway to funding agencies and will serve a significant business development role for all ICTAS research areas.

After careful deliberations, the following research thrust areas have been selected for ICTAS investment and growth.

(i) Discovery Analytics: Modeling and Simulation

Lead Faculty: Professor Naren Ramakrishnan (Computer Science)

(ii) Cybersecurity

Lead Faculty: Professor Charles Clancy (Electrical & Computer Engineering)

(iii) Nuclear Science and Engineering

Lead Faculty: Professor Alireza Haghighat (Mechanical Engineering)

VI. RESOURCES

1. Funding Sources

ICTAS operates as an *investment institute*, *i.e.*, it receives a majority of its funds from the university and takes no overhead funds from research it sponsors and develops (except in the case of faculty that are directly employed by ICTAS). Other sources include funds from federal (for example, Major Research Instrumentation grants), state (for example, Commonwealth Research Initiative), local, and private donor sources. Historically, ICTAS funding has been provided by the university administration through a combination of General Funds and Commonwealth of Virginia Research Initiative Funds. However, starting with fiscal year 2011, most of the funds have been provided through General Funds.

Funding history for ICTAS from FY2003 to FY2011 is as follows.

FY	Original Budget	Actual Budget	Research Expenditures: FY 2006-11
2003	$ 260,000	$ 260,000	-
2004	$ 600, 000	$ 600,000	$ 5,723,688
2005	$2,200,000	$2,200,000	$13,970,688
2006	$2,800,000	$2,800,000	$16,040,722
2007	$4,000,000	$4,000,000	$33,187,633
2008	$6,000,000	$5,700,000	$48,084,510
2009	$8,500,000	$8,100,000	$67,591,039
2010	$9,300,000	$7,800,000*	$79,693, 993
2011	$9,300,000	$8,300,000*	$83,555,894

*includes fringe benefits

In FY 2007, ICTAS received an additional $5.383 million in CRI (Commonwealth Research Initiative) funds for the purchase of sophisticated equipment for nanoscale characterization and fabrication.

2. ICTAS Investments

A majority of ICTAS investment is focused on providing seed monies, collaborative laboratory space, and specialized equipment in the thrust areas. Funds are also provided as start-up funds for faculty hires in strategic areas and as matching funds in support of large external research proposals. Funds are primarily allocated through an annual Request for Proposals (RFP) and directed investment, as dictated by the evolving needs in a core area of research. Another significant investment is through predetermined recurring awards, on the order of $75,000/year, to help ICTAS centers/IRGs grow their research portfolios. In each of these investments, ICTAS operates under a *spiral funding model*, explained earlier.

In addition to the ICTAS RFP, ICTAS has an evolving program for funding focused research in each of the thrust areas. The intent of this program is to permit the thrust leaders and program managers to guide and focus the research programs in key interest areas.

Approximately 25% of the available funds for investment in research projects will be set aside to support junior faculty and high-risk, high-reward proposals through the annual RFP process mentioned earlier.

Nanoscale Characterization and Fabrication Laboratory (NCFL) represents one of the major investments in equipment made by ICTAS. Approximately 16,000 square feet in laboratory space, NCFL is home to the state-of-the-art equipment (see the table below for a listing of the instruments) for characterizing and fabrication at the nanoscale. ICTAS Instrument Specialists supervise the instruments, provide user training, develop characterization techniques, and guide researchers in applying the equipment to specific research problems. NCFL is established as a service center and is available on a cost basis to members of the academic research community and to industry.

3. Resources for Future Growth

Assessing the resource implications of the implementing strategies in this plan, we estimate that additional resources will be required. The estimated additional space in square feet, personnel, and annual budget are provided below. In the current resource constrained environment, generating additional resources will be a challenge. We will need to explore innovative ways of raising resources, given that, as a policy matter, we do not receive any overhead on research ICTAS seeds and develops.

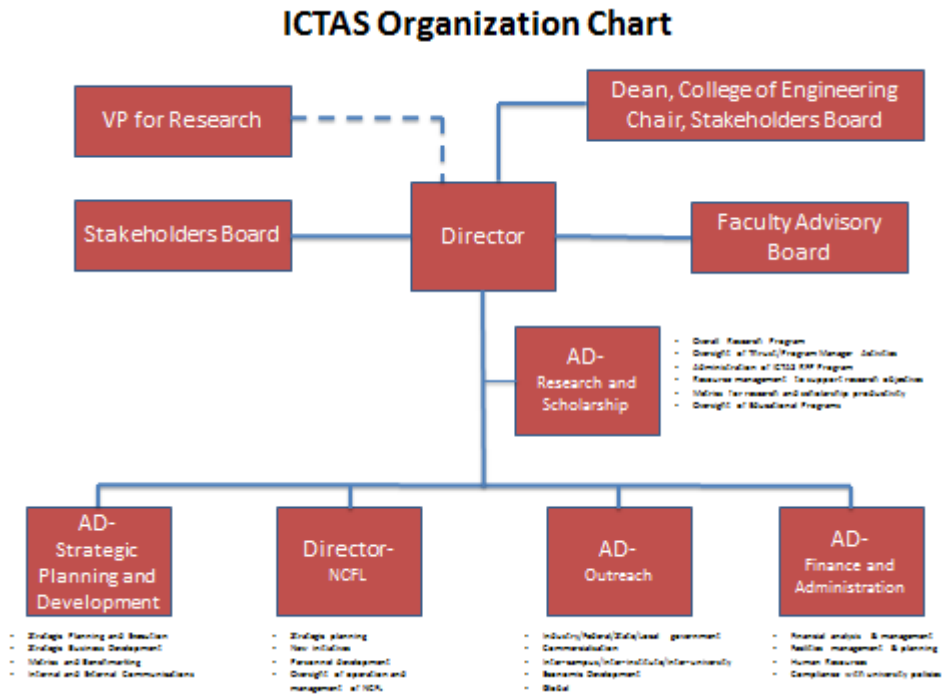
Additional Space Required (Sq. ft.)	**Additional Personnel Required**	**Additional Annual Budget Required**
54,000	20	$3 M/yr

In conclusion, ICTAS is excited to be on the forefront of numerous emerging fields in science and technology. The institute's dynamic and nimble structure, with focused thrust areas, will allow expansion through the duration of this strategic plan and beyond. The ICTAS team looks forward to growing existing areas and developing new ones across the targeted research areas in concert with Virginia Tech's overall strategic plan.

Appendix I

Governance

The organization chart 1a shown below captures the governance structure outlined in the ICTAS charter.



1. Administrator

The Administrator called for in Policy 3020 will be the Dean of Engineering. The Administrator will serve as the standing chair of the Stakeholders Board.

2. Stakeholders Board

The Institute's Stakeholders Board is comprised of the deans of five colleges (i.e., Engineering, Science, Natural Resources, Agriculture and Life Sciences, and Veterinary Medicine), the Dean of the Graduate School, the Vice President for Research, and the Vice President for Finance & Chief Financial Officer. Stakeholders may appoint designees to attend meetings in their absence. The Stakeholders or Director may invite guests to attend meetings as appropriate.

3. Faculty Advisory Board

An ICTAS Faculty Advisory Board (IFAB), comprised of faculty members appointed by the deans of each of the colleges represented on the Stakeholders Board, serves in an advisory role to the Director in defining and prioritizing the research areas and resources of the institute. It meets at least twice a year. The membership is reviewed every 3 years for changes/additions.

4. ICTAS Senior Administration

ICTAS is comprised of an Executive Leadership Team that is led by the Director and includes these members: Associate Director for Research and Scholarship, Associate Director for Finance and Administration, Associate Director for Outreach, Associate Director for Strategic Planning and Development and Director Nanoscale Characterization and Fabrication Laboratory. This team collectively has the responsibility of developing and implementing policies for advancing the ICTAS mission, as described in some detail below.

(i) Director, ICTAS

Major Responsibilities

Institutional Management

- The Director's major activity will be to work with the Virginia Tech administration and the ICTAS Stakeholders Board to set strategic directions and make resource investment decisions on behalf of the institute.
- The Director will work closely with the faculty and deans from the Colleges of Engineering and Science and other colleges/research institutes at Virginia Tech to support the growth of nationally and internationally recognized research programs, particularly in interdisciplinary areas.

ICTAS Personnel

- The Director is responsible for recruitment of staff and evaluation of their performance, for development of program plans of work and budgets, and for carrying out the institute's research program in collaboration with ICTAS staff.

Reporting and Metrics

- The Director reports to the Dean of the College of Engineering and is responsible for overall development and administration of ICTAS policies and procedures related to programs, budgets, personnel, and fund development.

(ii) Associate Director for Research and Scholarship

Major Responsibilities

Institutional Management

- The Associate Director for Research will work with the Director on the technical administration of the institute and will share responsibilities for setting strategic directions and allocating resources on behalf of the institute.

ICTAS Personnel

- The Associate Director for Research is responsible for the evaluation of key staff supporting the research infrastructure, their professional development, and integration into the institute's research program.

Facilities

- Work with the Director to allocate research space in ICTAS buildings in support of existing and future thrust areas.

ICTAS Research

- Provide technical and administrative support to thrust leaders to accelerate the advancement of funded activities and ICTAS initiatives.
    - Nano-bio Interface, Nanoscience and Engineering, Cognition and Communication, National Security, and Sustainable Materials, Energy, and Water.
- Continually improve and refocus the ICTAS strategic investments made on behalf of the university through a college-wide Request for Proposals.
- Critically evaluate all ICTAS-funded and -supported research to determine its impact and overall productivity in order to advance the university's strategic investments.
- Identify and promote new research areas for ICTAS to internal and external collaborators on behalf of the university.

ICTAS Learning Domain

- **Doctoral Scholar Program** – compose and disseminate program description, work with Associate Deans for Research to implement call for nominations, coordinate committee evaluation of nominations, announce awardees, establish and work channels of communication with awardees, advisors, departments, colleges, and alumni as well as document individual accomplishments and program outcomes. Lead event planning for the program.
- **Point of Contact for Student Program Support**– serve as point of contact to formalize ICTAS support for student-related activity, including facilitation of transfer of monetary support, coordinating setup of a physical presence for ICTAS or speaker participation, and other direct student interaction for a range of activities (e.g., Graduate Student Assembly Research Symposium, Conference on Higher Education Pedagogy, Student Internship and Work Opportunities in ICTAS).
- **New Horizons Seminar Series** – coordinate topic preferences and requests for speaker nominations, contact speakers, gather schedule and topic preferences, extract and edit hcontent for flyers to promote the series, and coordinate staff and facility support for speakers and events.

Reporting and Metrics

- Prepare a biannual report of ICTAS-supported research to document ICTAS-supported faculty via awards, proposals, and research expenditures.
- Support senior executive team in advancing all aspects of ICTAS via reporting of productivity to Stakeholders and Board of Visitors.

(iii) Associate Director for Administration and Finance

Major Responsibilities

Finance

- Supervise and manage financial aspects of the institute consistent with university policies and sound fiscal practices. This includes preparing and tracking overall budget and budgets for projects, managing and approving purchases, managing and tracking financial aspects of the NCFL service center, managing financial process for ICTAS Doctoral Scholars, and providing financial updates for Stakeholders' meetings.

Facilities

- Supervise Facilities Manager. Interface with Planning Design and Construction, designers, contractors, and Virginia Tech Corporate Research Center on three ICTAS buildings in Blacksburg and space for ICTAS in NCR to ensure that ICTAS interests are served. Interface with researchers and work with the Associate Director for Research and Scholarship in the allocation and modification of research space.

IT

- Supervise IT manager. Approve implementation plans for IT systems and IT purchases.

Reporting and Metrics

- Prepare university annual report. Use data warehouse to determine awards, proposals, and expenditures resulting from ICTAS PIs. Interface with OVPR on new metrics reporting.

HR

- Manage hiring process for all positions within ICTAS including research faculty, staff, and students. Manage performance plan and evaluation process for all ICTAS employees. Approve GRA appointments, funding changes, and wage appointments.

(iv) Associate Director for Outreach

Major Responsibilities

Institutional Management

- The Associate Director for Outreach will work with the Director on advancing commercialization of early-stage and disruptive research on behalf of ICTAS.

Outreach

- Work with Virginia Tech faculty and administration to lead economic and community development efforts in targeted regions such as Roanoke/New River Valleys, Southside, and Southwest Virginia.
- Promote the advancement and economic vitality of Virginia Tech faculty and students by increasing the scientific recognition of Virginia Tech research externally.
    - Actively advance Virginia Tech National Capital Region (NCR)
    - Increase external collaborations with organizations such as National Laboratories (ORNL, NIST) and industry
    - Work with Virginia Tech faculty and administration to increase businesses with commercial interests in Virginia emanating from faculty research.
    - Advance international collaborations in the areas of research, education, and outreach interactions with international organizations.
        - VT, India campus initiative
        - Virginia Tech collaborations with Germany (Technical University of Darmstadt, University of Munich, Institute, Alexander von Humboldt Foundation, DAAD, DFG)

(v) Associate Director for Strategic Planning and Development

Major Responsibilities

Strategic Planning and Execution

- Lead the effort to devise and revise the strategic plan.
- Lead execution of strategic plan.

Strategic Business Development

- Identify strategic research opportunities.
- Develop teams and capabilities to exploit these opportunities.
- Support proposal development.

Metrics and Benchmarking

- Develop, maintain, analyze and report on organizational metrics.
- Benchmark ICTAS against peer institutions.

Communications

- Develop and execute a communications strategy designed to support ICTAS organizational goals and objectives.
- Work with ICTAS faculty, staff, and students to develop and publish communications across the full range of media.

(vii) Director Nanoscale Characterization and Fabrication Laboratory (NCFL)

Major Responsibilities

- Perform strategic planning and development of new initiatives for NCFL.
- Provide general oversight of operation and management of NCFL.
- Oversee human resource development activities.

Appendix II

ICTAS Physical Infrastructure

Critical to the success of cutting-edge research are **state-of-the-art laboratories, collaborative space, and intellectual environment** where interdisciplinary research can flourish. To this end, ICTAS has four buildings in different stages of design and operation.

1. ICTAS I (Headquarters)

The ICTAS building on campus is a $45 million, 100,000-gross-square-foot building which serves as the home of the administrative offices of ICTAS. It also houses the School of Biomedical Engineering and Sciences, the Center for Injury Biomechanics, and focus areas of Targeted Delivery of Nanomedicine, Nanoscale Science and Engineering, including Nanotechnology and the Environment, Renewable Materials, and Fuel Cells. This building provides an active environment for intellectual activity and a test bed for new research ideas and educational paradigms.

2. ICTAS II (Life Sciences District)

Located on Washington Street in the Life Sciences District of the Virginia Tech campus, the $35 million, three-story 42,190-square-foot ICTAS II building was completed in January 2011 and has been recognized by the Green Building Certification Institute as LEED (Leadership in Energy and Environmental Design) certified to the Gold level. This building is home to research laboratories, office space, and conference rooms. Research activity includes applied environmental biochemistry, fluvial processes, a global laboratory for bioinspired science and technology, nanobiology, nonlinear imaging and spectroscopy, organic nanostructures, nanosensors, pathogen ecology, pipeline corrosion, sustainable water, and a humanoid hospital.

3. ICTAS-CRC (NCFL - Corporate Research Center)

A 32,000-square-foot building is home to a world-class Nanoscale Fabrication and Characterization Laboratory (NCFL) and related collaborative research space. The NCFL houses over $10 million worth of specialized equipment to fabricate, observe, and characterize material and devices at the nanoscale. Formally inaugurated on September 2007, the facility has proven to be an asset in enhancing research and attracting industry. Project teams with grants valued at $19 million used the NCFL in FY09. Fifteen companies routinely utilize the facility, and more than fifteen additional companies are occasional users.

4. Virginia Tech Research Center – Arlington (ICTAS - National Capital Region)

The Virginia Tech Research Center - Arlington facility in the NCR is a 140,000-square-foot facility with office and lab space shared among multiple institutes and colleges. ICTAS occupies approximately 7,000 square feet of space with core areas of research comprising discovery analytics, energy and cybersecurity.

Appendix III
Establishing an ICTAS Supported Center / IRG

1. Introduction

An ICTAS Supported Center of Interdisciplinary Research Group (IRG) presents an excellent opportunity to pool faculty and student expertise to create a larger, more recognizable entity than single Principal Investigator (PI) activities alone might accomplish. ICTAS has a vested interest in establishing ICTAS Supported Centers and IRGs to enhance interdisciplinary scholarship and funding across Virginia Tech. This document outlines a process for establishing an ICTAS Supported Center/IRG and the expectations for continued support of an established Center/IRG.

2. Criteria for Establishment of an ICTAS Supported Center or IRG

The initial proposal for the establishment of an ICTAS Supported Center will be reviewed based on the following criteria.

- Focused area of technology and/or science that is aligned with one or more of the ICTAS Thrust Areas and the overall ICTAS mission
- Critical mass of multidisciplinary researchers in the proposed area
- A record of collaborative activities among the proposed center researchers (e.g., joint publications and proposals)
- A record of external funding for projects related to the proposed Center/IRG activities
- Evidence of success stemming from prior ICTAS seed funding, if applicable

3. Establishing Center/IRG Support from ICTAS

To begin the process, a document addressing the following items will be submitted to the ICTAS Associate Director for Research and Scholarship for consideration and formal approval.

3.1 Motivation for establishing the center

3.2 Background

3.3 Vision

3.4 Mission

3.5 Current Resources

a. Faculty
b. Students
c. Equipment
d. Laboratory space
e. Staff

3.6 Accomplishments to-date

a. Technical Advances
b. Externally Sponsored Awards (Research and Teaching)

c. Peer-reviewed Publications
d. Industrial Collaborations, if any
e. Patents/Invention Disclosures

3.7 Goals and Strategies for growth (5+ Years, with specific details for first 2 years)
a. Research and Scholarship
b. Externally Sponsored Awards (Research and Teaching)
c. Peer-reviewed Publications
d. Industrial Collaborations
e. Patents/Invention Disclosures
f. Resources

3.8 Center Administration

3.9 Budget
Provide a brief description of how the ICTAS support (see Section 4 below) will be used to advance the mission of the center or IRG.

4. Funding

Each approved ICTAS Supported Center or IRG will nominally receive $75,000 in annual seed funding for a period of 5 years to further the center's mission. Under exceptional circumstances, requests for additional resources may be considered.

5. Review

Progress reports will be submitted to ICTAS by January 31 (Interim Report) and by July 31 (Annual Report) during the project and for 3 years after funding ends. Format for these reports will be provided. Any continued funding into the next FY will be contingent on satisfactory progress toward the goals of the project, based on review of the January 31 report. A formal Review of Center Advancement, including a presentation(s) from the center's administration, will be required in the third year. Center administration will be expected to demonstrate success toward fulfilling two basic criteria:

(i) Achievement of an internationally recognized record of research and scholarship.

(ii) Double externally sponsored research funding from the center's initial base within 5 years of the center's inception. (*For some centers, a goal of research funding in absolute dollars may be appropriate.)*

6. Other Obligations

- Each center/IRG will submit an Annual Report to ICTAS utilizing a template that will be provided by ICTAS.
- It is expected that Center/IRG faculty will acknowledge ICTAS support and/or involvement in all center-related materials including website, presentations, publications, releases, and posters.

7. Basis for Continuation or Termination of the Proposed ICTAS Supported Center

A center may be terminated when the following conditions exist:

- The center/IRG is unable to advance its research mission due to loss of critical faculty.
- The research mission of the center IRG becomes obsolete or incongruent with the research mission of ICTAS.

8. Memorandum of Understanding

The Center Director and the ICTAS Associate Director for Research or his/her designee will sign an agreement to abide by the obligations set forth in this document.

Appendix IV

RFP and Guidelines for ICTAS Seed Proposals

FY 2013 ICTAS Request for Seed Proposals

(Seed-RFP)

ICTAS is soliciting a white paper submission from Virginia Tech faculty for two funding opportunities with anticipated support beginning July 1st, 2013 (FY 2014). White paper submissions will be considered for an invitation to submit a full proposal. If selected, a 5-page proposal will be requested for panel review and subsequent consideration for funding. ICTAS has approximately $2.2M available for funding projects for FY 14 (This figure includes award of second year projects). New for this year: Limit of one white paper submission per PI in each of the two funding categories.

1) Junior Faculty Collaborative (JFC) Proposals

Responses in this category will demonstrate an **interdisciplinary**, collaborative research relationship between tenure-track junior (non-tenured) and senior (tenured) faculty members. Proposal topics must be aligned with one or more of the ICTAS research thrust areas. (For more information regarding the strategic initiatives of ICTAS, please refer to http://www.ictas.vt.edu/index.html). Awards in this category are limited to two years, and are not expected to exceed $60K/year. In addition, a minimum of 75% of the requested support must be designated for use by the junior faculty member.

Project duration: 1-2 years. (Funding in the second year is contingent on demonstration of Satisfactory technical performance and scholarship, and available resources).

2) ICTAS BAA Proposals

ICTAS is seeking **interdisciplinary**, *High Risk / High Impact* research efforts capable of promoting significant growth for the university and ICTAS. All technical thrust areas will be considered for this seed funding, including emerging technologies that are not currently addressed under the umbrella of ICTAS. Responses in this category will directly address how the proposed effort is unique and capable of establishing or transforming a field of science and technology research. This program is intended for the support of new, transformative ideas, as opposed to further development of ongoing research projects. This year, we have developed eight BAA topics in which we have particular interest. These are attached at the conclusion of this call. We selected these topics with the objective of building our capacity in areas that offer unique potential to improve our position in one or more of our research thrusts. While we encourage submissions in line with these targeted BAA topics, we recognize that there are likely other outstanding ideas outside of these BAA topics that are worthy of support. Thus, proposals in all areas of research that fit the mission of ICTAS will be considered. Awards in this category

are limited to two years; awards are anticipated to range between $75K and $150K per year depending on the quality of the submission. *Please note that these BAA topics effectively replace the TSTS program as a means to target research programs that are more closely aligned with the strategic missions of our existing thrust areas and federal investment priorities. The topics are intended to complement proposal requests issued through our annual thrust RFP.*

- White paper pre-proposals must be submitted using the online ICTAS Proposal and Reporting Portal and are due November 19, 2012 (8am). The portal (**ICTASPA**) may be found at https://ictaspa.stl.vt.edu/pages/login.php.
- All awards are subject to continuing availability of funds.

Questions/advice/courtesy reviews? Please Contact:

GENERAL QUESTIONS: Robert B. Moore, 540-231-6015, rbmoore3@vt.edu

NANOSCALE SCIENCE AND ENGINEERING: Matt Hull, (540) 231-5812, mahull@vt.edu

NANO-BIO INTERFACE: Matt Hull, (540) 231-5812, mahull@vt.edu

SUSTAINABLE ENERGY: Dennis Grove, (540) 231-3353, dgrove@vt.edu

RENEWABLE MATERIALS: Dennis Grove, (540) 231-3353, dgrove@vt.edu

COGNITION AND COMMUNICATION: Jon Greene, 540-231-8566, greenej@vt.edu

NATIONAL SECURITY: Jon Greene, 540-231-8566, greenej@vt.edu

SUSTAINABLE WATER: Jeff Beeby, (540) 231-2569, usnbb@vt.edu

EMERGING TECHNOLOGIES: Jeff Beeby, (540) 231-2569, usnbb@vt.edu

Expected Timeline for the FY 2013 Seed-RFP Program

White Paper Submission Deadline: ***November 19, 2012 at 5 p.m.***

Notification of Invitation for Full Proposal: December 7, 2012

Invited Proposal Deadline: January 7, 2013 at 5 p.m.

Panel Reviews: January 21 – February 1, 2013

FY 2013 Seed-RFP Review Process

White papers will be sorted by ICTAS Thrust Area (as designated by the PI on the ICTASPA whitepaper submission cover page…if more than one thrust is selected, all associated thrust areas will review). The white paper review will be a **Blind Review** (PI and co-PI names will be removed from the cover pages prior to distribution to the reviewers). White papers will be reviewed by ICTAS thrust leaders, program managers, and research faculty (see: http://www.ictas.vt.edu/research/index.html) with attention to the following criteria:

- ***Clear association with one or more ICTAS research thrust.***
- ***Interdisciplinarity (collaboration between diverse disciplines) is strongly encouraged.***
- ***Cutting edge science and technology.***
- ***Transformational potential.***
- ***Contribution to sustainability (in particular, proposals that seek to use existing space, facilities and processes at Virginia Tech as the test bed for sustainable solutions will be well received).***

Each white paper reviewer will submit a rank order of the pre-proposals to the ICTAS AD of Research and Scholarship for consideration of invitation for full proposal.

Full proposals will be grouped into topical areas for review by panels of experts (at least 5 reviewers per panel). Panels will include members of the ICTAS Faculty Advisory Board and other senior faculty of Virginia Tech. Panel reviews will pay attention to the same criteria as stated above for the white papers with the addition of the following criteria:

- Results and impact of previous ICTAS seed funding (if relevant)
- Reasonable link between requested funds (budget details) and proposed outcome
- For JFC proposals, the specific role of the senior faculty mentor must be clearly defined.
- Probability and impact of success
- Panel review process will emulate the standard NSF style with rankings of Excellent, Very Good, Good, Fair, and Poor.
- Rankings will be tabulated for each panel for consideration and recommendation for funding by the ICTAS AD for Research and Scholarship.

Programmatic Considerations for ICTAS Seed Funding

- Funds for faculty salary are not eligible for ICTAS Seed funding, and must not be included in the proposed budget.
- All funds should be budgeted as direct costs (Overhead – indirect costs – are not accepted for ICTAS Seed funding).

ICTAS BAA TOPICS

The following topics are of particular interest to the leadership of ICTAS and are targeted for the ICTAS BAA awards. Please note that, due to limited resources, we do not expect to fund all eight BAA topics in FY 2014.

We recognize that faculty may conceive transformative ideas beyond the specific topic areas defined here; therefore, any topic that fits within the mission of our ICTAS thrusts, is interdisciplinary, represents the cutting edge, is not already supported through existing thrust and center research, and has the potential for transformational contributions (especially with respect to sustainability) should be submitted and will be given due consideration.

For both the white papers and the full proposals, please indicate on the cover page, the BAA topic number addressed by your proposed project.

I. Exploring the Nexus of Computation and the Brain.

The human brain remains the most capable computer on the planet…*for some applications.* We also see applications where the brain is woefully slow or biased. Likewise, today's computational tools provide an incredible ability to perform some operations, but are extremely limited in others. How do we fully exploit the power of the human mind and the computer? We seek a ***BROAD DIVERSITY OF DISCIPLINES*** in this effort as we see elements of discovery analytics, psychology, human computer interaction, cognition, sociology, wireless communications, neurology, anthropology, artificial intelligence, control theory and a host of other disciplines and specialties providing critical input into the broader investigation.

II. Science-Based Risk Minimization and Policy Development.

The intent of this topic is to promote more participation of scientists and engineers in risk management and policy development. The topic explicitly targets the interface of the hard and social sciences and includes individual and societal risk perception. Potential topics include: (a) Managing risk and certification policy for autonomous vehicles operating together or with manned vehicles (for example, how would one certify a UAV is "safe" to fly in airspace with manned aircraft or an autonomous vehicle is safe to operate on public roadways); (b) Environmental nanotechnology policy; (c) Biosafety risk analysis; (d) Bio-threat risk analysis, (e) Energy policy; (f) Terrorist threat assessment.

III. Sustainable Communities.

From our coal-fired power plant, to our water purification and sewage systems, to our often congested roadways, how can we take advantage of the many research strengths at VT to make not only our campus, but communities, both local and world-wide, more sustainable? Inspiring communities to be wholly committed to sustainability requires a cohesive strategy merging large scale solutions for energy production and transportation with smaller scale ideas in architecture, informing consumers, and community action. We encourage multi-disciplinary proposals looking to improve both new and existing infrastructure. Examples could include, but are not limited to: (a) Energy Generation and Transmission; (b) Improving energy efficiency of new

and/or existing residential and commercial buildings; (c) Cultivating sustainable transportation; (d) Sustainable Living; and (e) Impoverished and remote community resiliency.

IV. Sustainable Agriculture and Food Security.

By 2050, more than 9 Billion people are expected to inhabit the planet. Increasing population and adapting to climate change will place extraordinary demands on agriculture and the security of global food resources. The nexus of energy and water will strain the adequacy of global food and water supplies. In response, transformative technologies across the entire food supply chain to improve efficiency of agricultural practices and to ensure the safety of food supplies throughout their production, distribution, and storage. Responsive proposals should advance the science and engineering of sustainable agricultural and food security practices and lead to innovative, cost-effective solutions. Additionally, practices that will address the increasing scarcity of fresh water are critical to providing truly sustainable solutions. Sub-topic areas listed below are considered to be of particular interest, but proposals for relevant sub-topics not specifically identified here are also encouraged.

V. Materials by Design.

A secure, sustainable future requires innovative materials for energy generation and storage, medical devices, drug delivery, defense systems, and myriad other applications. Currently, the process of developing these materials and transitioning them for use in society can take 20 years or more. Aligned with the US Materials Genome Initiative, this topic requests proposals that integrate computational tools with fundamental chemistry and materials science and engineering to streamline the process of discovering and developing advanced materials for a sustainable future. Sub-topic areas including: (a) Materials for energy; (b) Materials for defense; (c) Materials for Health; and (d) Computational material design tools, are considered to be of particular importance, but proposals for relevant sub-topics not specifically identified here are also encouraged.

References:

1) Materials Genome Initiative: A Renaissance of American Manufacturing. www.whitehouse.gov/blog/2011/06/24/materials-genome-initiative-renaissance-american-manufacturing. White House Office of Science and Technology Policy.

2) DOE Critical Materials Strategy. http://energy.gov/node/1939/office-policy-and-international-affairs/initiatives/department-energy-s-critical-materials

3) DOE and Nanotechnology: http://science.energy.gov/bes/news-and-resources/presentations/nanotechnology-energizing-our-future/

4) Miziolek AW, Karna SP, Maura JM, Vaia RA (eds). 2005. Defense Applications of Nanomaterials. Volume 891. American Chemical Society.

5) Nanoinformatics Roadmap: http://eprints.internano.org/607/

VI. Intersections of Biology and Technology.

Steve Jobs noted, "The biggest innovations of the twenty-first century will be [at] the intersection of biology and technology". Indeed, the convergence of fundamental biology with breakthroughs in nanoscale science and engineering, additive manufacturing, informatics, and engineered systems promises to wholly transform the way we manufacture devices, operate machines, treat disease, and meet many other critical societal needs. This topic requests proposals that bring together faculty teams at the intersections of biology and emerging technologies. Sub-topic areas including: (a) energy-efficient bio-inspired approaches to assemble or orient nanostructures that display novel and unexpected properties; (b) advancements in synthetic biology to develop biological processes that perform specific functions; and (c) bioinspired technologies for material or systems design, are considered to be of particular importance, but proposals for relevant sub-topics not specifically identified here are also encouraged. Applicants should contact the designated Program Manager to determine whether a specific sub-topic will be considered responsive.

References:

1) Auyeung E, Cutler JI, Macfarlane RJ, Jones MR, Wu J, Liu G, Zhang K, Osberg KD, and Mirkin CA. 2012. Synthetically programmable nanoparticle superlattices using a hollow three dimensional spacer approach. Nature Nanotechnology, 7: 24-28.

2) BIOFAB: International Open Facility Advancing Biotechnology (BIOFAB). www.biofab.org/

3) Capadonna JR, Shanmuganathan K, Tyler DJ, Rowan SJ, and Weder C. 2008. Stimuli-responsive polymer nanocomposites inspired by the sea cucumber dermis. Science, 319: 1370-1374.

VII. Science to Society.

Across Virginia Tech, new discoveries in materials, medicine, energy, and the environment promise new solutions to society's greatest challenges. ICTAS is committed to helping 'invent the future' by supporting transformative, interdisciplinary efforts that help bridge the gap between cutting-edge research discoveries and applications for unmet societal needs. We are particularly interested in proposals that link faculty researchers with experts in the fields of clinical medicine and industrial manufacturing. Sub-topic areas including (a) research that facilitates the translation of medical discoveries in the laboratory to clinical settings; and (b) sustainable, high-capacity manufacturing at the boundaries of conventional, additive, and nano-manufacturing, are considered to be of particular importance, but proposals for relevant sub-topics not specifically identified here are also encouraged. Applicants should contact the designated Program Manager to determine whether a specific sub-topic will be considered responsive.

References:

1) NIH Bedside-to-Bench Program: www.cc.nih.gov/ccc/btb/

2) NNI Nanotechnology Signature Initiative (NSI) White Paper: Sustainable Nanomanufacturing: creating the industries of the future. www.nano.gov/sites/default/files/pub_resource/nni_siginit_sustainable_mfr_revised_nov_2011.pdf

VIII. A vibrant, continuous, sequentially and progressively oriented k-12 STEM Program

A vibrant, continuous, well thought out STEM program that encourages broad participation and enthusiasm similar to what we see in k-12 rec center/school sports programs is urgently needed. Even during times of economic uncertainty, there maintains an ever increasing demand for people in STEM fields – from technicians to engineers to academic researchers. Despite a handful of well-respected STEM outreach efforts, a cohesive, all-inclusive, sequentially progressive program has yet to pervade k-12 education to the same degree as other similar programs offered to youth. Compiling the lessons of successful, smaller scale programs and identifying potential collaborators, funding sources, and mentors are key to implementing a model that can be emulated across the country. A unique local opportunity exists with the opening of the brand new Blacksburg High School in Fall 2013. ICTAS seeks innovative interdisciplinary approaches that will permit unique and measurable contributions to the effort and not "just another STEM program."

Appendix V

Process for Evaluating Requests for ICTAS Major Equipment Acquisitions

Evaluating Requests to ICTAS for Equipment

Purpose

One way in which the Institute for Critical Technology and Applied Science (ICTAS) promotes interdisciplinary research across campus is through the support of equipment purchases that further the research and education agenda of Virginia Tech. This document describes the procedure through which requests for financial support of equipment purchases are evaluated.

Procedure

Three categories of equipment requests are covered by this procedure:

a. Requests for equipment cost sharing on proposals to external agencies

b. Requests for equipment to support ongoing research activities under the ICTAS umbrella

c. Requests for equipment in response to specific calls for proposals from ICTAS

Equipment requests that fall under category (a) often require rapid decisions; decisions on these will be left to the discretion of the ICTAS Director, although he/she may choose to follow the following steps. Relevant factors that drive decisions in this category include: the amount being requested (i.e., how much does the equipment cost) and the size of the budget for new equipment.

For requests in categories (b) and (c), an ICTAS Equipment Committee consisting of ICTAS technical leadership personnel and possibly experts external to ICTAS will meet to evaluate the requests using a point system:

1. **How many researchers** will benefit from the equipment? Consider whether the equipment is a standard or a specialized tool. Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.5.
2. Will equipment **benefit an ICTAS thrust area**? Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.5.
3. Will equipment have **high impact on Virginia Tech research**? Consider whether its absence is preventing research, does Virginia Tech have the expertise to use it effectively, are there any similar capabilities available near Virginia Tech, and does it elevate the quality of research in a tangible way. Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.5.
4. Will equipment **improve grad student training?** Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.3.

5. Will equipment **help recruit new top-notch faculty?** Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.3.
6. Will equipment **help enhance external funding?** Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.3.
7. Will equipment have a **long useful service life?** Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.2.
8. Does equipment have **low operating costs (maintenance, operator costs)?** Consider the ongoing expense associated with the equipment purchase (space, maintenance contracts, technical staff). Score between 0 and 100 with 100 being most desirable. Weighting factor for this criterion is 0.2.

As general a guideline for this scoring system,

90-100: Merits immediate action (provide support to purchase)

80-90: Critical equipment (fund purchase within a year)

70-80: Important equipment (re-evaluate, purchase within 2 years)

< 70: Defer for later

Once the committee has evaluated the equipment request(s), it will tender recommendations to the ICTAS Director as to whether ICTAS should provide funds to purchase the equipment.