Resilient Earth Systems

Background: The human population is projected to increase from 7 billion to more than 9 billion over the next 35 years. An overarching challenge of our time is to meet accelerating needs for food, energy, water, and basic health, while maintaining stability between earth environments and society. This challenge is compounded by complexities between social and ecological systems, as exemplified by animal-human transmission of the Zika virus. In 1947, the first known case of Zika fever was reported in a Rhesus monkey in Uganda. After the first human outbreak in Micronesia (2007), Zika has spread through at least 59 countries and territories. This growing health crisis threatens billions of dollars in tourism for South America and has sparked an intense social debate regarding birth control in the region. Such time-critical challenges are most effectively addressed through collaborative research and partnerships with industry and government sectors focused on providing solutions. New educational models must also be developed to produce a workforce that understands already-strained ecological systems and earth resources, and complex social and environmental interconnections.

The Resilient Earth Systems Destination Area emerges from Virginia Tech's leading reputation for innovative research and education in food, water, and other natural resources. Social stability is critically dependent upon the human condition and perspectives from the social sciences and humanities are important in this Destination Area. Its mission is to educate students with expertise in ecological, earth, and social systems while fostering the ability to collaborate broadly, approach problems from interdisciplinary perspectives, and anticipate the consequences of system interconnectedness. Pulling together internationally recognized expertise at Virginia Tech and building upon programs for interdisciplinary research and student training, this cornerstone Destination Area is naturally coupled with other Destination Areas in data analytics, security, health, and civil infrastructure.

Current Virginia Tech Differentiators:

- Expertise in the development and management of water resources
- Emphasis on host-pathogen-environment interactions and microbiomes
- Advanced capabilities in remote sensing, modeling, and forecasting of global processes
- Innovations in agriculture in response to pollution, bio-invasions, and climate change
- Leading scholarship in ecosystem processes and biodiversity conservation
- Expertise in coastal processes and hazards in a changing climate
- Forward-looking Interdisciplinary Graduate Education Programs (IGEPs)

Experience and Assets: In addition to the examples of areas of strength noted above, multiple interdisciplinary research and education programs focus on the society-environment nexus. These programs combine expertise from the biophysical sciences, data analytics, engineering, and social sciences to prepare the next generation of scholars.

Four highlights: **1)** The Virginia Tech Global Change Center is a university-wide, faculty-led initiative that addresses major challenges to environment and society including disease, climate change, pollution, habitat and biodiversity loss, and invasive species. In its first year, the Global Change Center has already published 176 journal articles, with 72 more submitted or in review. Eighty-three new grants were

funded for a total exceeding $27 million, and 25 Ph.D. students and 120 undergraduate researchers were mentored. **2)** The Water INTERface program is united by a central focus of "Water for Health," spanning from "pipes to people." Accomplishments in the 2014-15 fiscal year include 56 journal articles, four book chapters, 13 Ph.D. students and seven new grants totaling more than $2.6 million. **3)** The Remote Sensing group and Space@VT collect big data using advanced instrumentation for monitoring the physics and biogeochemistry of water, forest, atmospheric, and the near-earth space environments. **4)** The Fralin Life Science Institute supports several additional critical areas that will support this DA, to include the Vector-Borne Disease program that focuses on diseases transmitted by mosquitoes.

Notably, Virginia Tech's existing Interdisciplinary Graduate Training Programs serve as a "trans-cutting" model that enables all of the above areas. A foundation provided by several problem-focused IGEPS in the areas of global ecological change, water, plant sciences, nanotechnology, health sciences, and remote sensing will support this Destination Area.

Examples of Targeted Hot Spots:

- **Water Security:** From food and energy security to human and environmental health, access to freshwater is vital to social well-being and economic growth, affecting the livelihoods of billions. Emerging needs include water quality and availability, water demands for food production, integrity and safety of drinking water, water systems that prevent the spread of disease and antibiotic resistance, and understanding effects of water pollution on biodiversity. This will require highly integrated water resource development and management that considers diverse issues ranging from ecological impacts to human rights.
- **Agriculture in a Changing Climate:** Human and ecological health are intimately reliant on sustainable agricultural practices. Agriculture requires 70 percent of all freshwater use, accounts for 65 percent of antibiotic applications, produces 30 percent of greenhouse gas emissions, is a significant contributor to environmental pollution, and is increasingly vulnerable to climate change. An urgent need exists to improve the resilience of crops and livestock to drought, disease, invasive pests, and other stressors and exploit technology for precision agriculture to improve production while reducing environmental, human, and animal health impacts.
- **Ecology of the Microbiome:** The microbiome revolution is revealing the instrumental role of microbes in critical ecological processes, ranging from biogeochemical cycling of nutrients to complex relationships within host organisms. Data analytics and emerging technologies allow us to finally answer long-standing questions regarding microbial interactions in natural and built environments. Examples include indoor plumbing pathogens, bio-transformations of environmental pollutants, plant-microbe-soil interactions, the microbiome's role in human and animal health, and engineered microbial solutions to wastewater treatment.