Overview of SEAS Research Strengths

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Biomechanics – Researchers at U.Va. apply mechanical principles to a wide range of biological systems, such as humans, animals, organs and cells. One application is the field of injury biomechanics, which has resulted in improved automobile designs, occupant restraints, child restraints, helmet designs and personal protective devices. In addition, active research is underway on movement disorders, musculoskeletal modeling and simulation and morphing functional structures that mimic animals.

Biomolecular Design – Research addresses a wide range of applications in which the understanding and use of biotechnology can assist in the creation of biorenewable fuels, improved batteries, water remediation and rational drug design and production, as well as protein and viral engineering.

Catalysis and Surface Reactivity – Research enables new relationships between catalyst structure and chemical reactivity to be discovered for a wide range of chemical reactions used in chemical synthesis, fuel cells, chemical conversion and magnetic materials for memory device fabrication. State-of-the-art computational methods and experimental probes are used.

Corrosion and Electrochemistry – Electrochemical science and engineering impacts public safety, next-generation energy systems and national defense. Most societal grand challenges in engineering require advances in electrochemical science and engineering. SEAS researchers are working on projects that address a range of issues including those that affect renewable energy, long-lived infrastructure and national security.

Cryptography – SEAS research seeks to create systems that can be trusted even in the presence of malicious attackers and that empower individuals to control how their data is used.

Dependable Systems – This research focuses on issues related to software and architectures in high-value systems – computing systems of extreme importance to society whose failure would have a severe negative impact whether measured in terms of time, money or loss of life. Dependability of a computing system is the ability to deliver reliable, available, safe services that can justifiably be trusted. Such systems include medical devices, avionics, weapons systems; critical infrastructures such as financial networks, transportation systems, and power systems; and grid computing systems that increasingly play a strategically vital role in such diverse industries as finance, health care, pharmaceuticals and aerospace.

Ethics in Emerging Technologies – Technology affects society, but society also affects technology. Advances in our technological capabilities bring with them new ethical questions that must be addressed. Examples of active interest at U.Va. include questions concerning the effects of climate change, nanotechnology risks and distribution of advanced health care.

Graphics – Computer graphics is used for data visualization and simulating the appearance of virtual scenes, all of which are important components in many software systems and a wide range of applications in which accurate rendering of 3D objects is critical such architecture, manufacturing plants, security systems, entertainment and medicine

Human Computer Interaction – Human computer interaction research at U.Va. focuses on modeling human judgment and decision-making, data visualization, computer-based training, haptics and computational neuroscience in the domains of health care, air transportation, meteorology, bioinformatics, and process control to inform system requirements, procedures, display designs and training. One example is the design and analysis of medical simulators to ensure that health practitioners' hands-on skills are systematically trained, time-effective and highly accurate.

Medical Imaging – Biomedical imaging is a dominant approach for discovery, diagnosis and therapy in today's biological and medical world. At U.Va., an established biomedical imaging community has produced a remarkable string of innovations in magnetic resonance imaging, ultrasound imaging and cellular imaging – including the fastest MR pulse sequences for abdominal and cardiac imaging, the smallest ultrasound devices and the highest resolution 4-D imaging of the living cell cytoskeleton. This research activity aims to improve the practice of medicine by introducing new technological capabilities that provide increasing amounts of functional information regarding the molecular and cellular determinants of disease, as well as more cost-effective diagnosis of anatomical pathologies such as small breast tumors. In cellular imaging, new optical advancements allow discovery of the fundamental molecular systems controlling cell behaviors such as adhesion, migration and proliferation that play a central role in diseases ranging from cancer to atherosclerosis.

Nanoelectronics – SEAS researchers are leading the search for new materials and nanostructures for logic and memory applications beyond the current technology used in integrated circuits. The new materials and structures (spintronics and phase transition materials) will require much smaller switching energies, without compromising performance.

Next-Generation Aerospace Science – SEAS is developing the next generation of jet engines that may one day enable people to fly around the world in high-speed aircraft or to fly into space using technology that is more reliable, safer and cheaper than the space shuttle, for example. These engines are called scramjets and they could potentially transport people and goods at speeds of more than 10,000 mph. At this speed one could fly anywhere in the world in about 1.25 hours. These engines could also be used to fly into space at a cost per pound of payload that is one to two orders of magnitude cheaper than today's cost using conventional rocket technology.

Optimization and Control – Many applications require high-fidelity modeling tools that allow improvement of system performance by active control of important parameters. Examples include analysis of electricity markets, control algorithms for an artificial pancreas and cyber security related to wireless networks.

Pervasive Computing – Computing has seemingly permeated all aspects of modern life, but challenges remain in the areas of real-time computing, cyber physical systems, and ad hoc wireless sensor networks. Such networks are being applied to saving energy in both residential and commercial buildings as well as for ad hoc networks for first responders to disasters.

Risk Management of Engineering Systems – SEAS research builds on the risk assessment process by seeking answers to a set of three questions: What can be done and what options are available? What are the associated trade-offs in terms of all costs, benefits and risks? And what are the impacts of current management decisions on future options? To be effective and meaningful, risk management must be an integral part of the overall management of a system. This is particularly important in the management of technological systems, where the failure of the system can be caused by the failure of the hardware, the software, the organization or the human element. Some of SEAS' applications include critical infrastructure protection, infrastructure interdependencies, dependence of defense infrastructure on civilian infrastructure, continuity of operations planning, transportation systems, environmental impact, water resources, civil infrastructure, software acquisition, aircraft and space systems, information management, ground transportation and highway vehicle safety.

Scalable, Efficient and Reliable Circuits, Architectures and Systems – Society increasingly relies on information technology — especially the ability to analyze massive amounts of data and simulate complex systems — to improve quality of life and advance scientific understanding. This in turn requires continuing advances in raw computing performance, as well as advances in energy-efficiency and reliability as system sizes and complexities reach unprecedented scales. This work focuses on reliable, energy efficient circuit design for applications ranging from high-performance servers to portable electronics to wearable body sensors.

Software Engineering, Programming Languages and Compilers – The overall goal of this research effort is to develop innovative techniques that enable the deployment of secure, robust and resilient cyber-infrastructures, even in the presence of cyber attacks, bugs in software, and run-time variations and wear-out of hardware.

Sustainable Infrastructure Systems - The coming century will put unprecedented demands on our natural and engineering infrastructure that will require novel engineering approaches. To provide basic amenities to the developed and developing world equally, SEAS researchers are seeking to make significant advances in terms of resilient and adaptive infrastructure, understanding the nexus between water and energy systems, hydrogeochemical cycling, ecosystem restoration, water reuse, carbon cycling, contaminants of emerging concern, and related areas.

Systems Biology and Cell Signaling – Approaches from engineering and physics are used to examine how complex biological functions emerge from the network of interactions between proteins, metabolites and cells. SEAS researchers develop quantitative experimental approaches to take system-wide measurements of how biological systems respond to genetic perturbations or changes in their environment. They use computational approaches to integrate these data and develop predictive models that help us explain biological complexity and design therapeutic strategies for cancer, cardiovascular disease and infectious disease.

Terahertz Science and Engineering – The terahertz region of the spectrum is critical for radio astronomy because it encompasses spectral information concerning the makeup of the interstellar medium, distribution of cosmic background radiation and formation of new galaxies. It also includes information on the molecular transitions that are crucial to our understanding and monitoring of global ozone depletion over the polar regions. Recently, engineers have recognized the advantages of the terahertz region for applications ranging from high-resolution imaging for navigation and security to spectral identification of chemical and biological materials, and high-bandwidth communications. The terahertz science and technology research carried out at the University of Virginia focuses on the development of solid-state circuit components for state-of-the-art receivers, sources and instrumentation operating from 100 GHz to 3 THz.

Transportation Studies – This research activity focuses on developing and applying technology to make transportation safer, more efficient and more reliable. SEAS researchers are known as leaders in harnessing advances in information technology to improve the operation of traffic signal systems, creating better information for travelers, enabling enhanced public transportation services and allowing for improved maintenance of the extensive transportation system. They also focus on improving how we design, build, monitor and maintain the physical infrastructure underpinning the system — including pavements, structures and storm water management.

Wireless Health – Wireless health is an emerging field that seeks to infuse wireless technologies into health care and medical research with the goals of improving patient care and quality of life while reducing health care costs. Efforts in this field are necessarily interdisciplinary, bringing engineers together with doctors, nurses, psychologists, medical researchers, caretakers, family members and patients themselves. Ongoing SEAS projects include: in-home sensors for identifying signs of depression, body-worn sensors for fall risk assessment and an artificial pancreas that combines blood glucose sensing and insulin pumping for Type I diabetics.