Organizing cyber-physical research across the nation

Vanderbilt University researchers are leaders in cyber-physical systems (CPS) research, extending the use of the Internet to create a deeply connected world where humans, their machines, and the physical environment interact seamlessly, continuously, and without mistakes and breakdowns that could lead to safety issues. Designing CPS requires the ability to keep track of interactions between computers and machines (such as traffic lights, dryers, dishwashers, and HVAC systems) while ensuring the safety, security, and stability of those connections. The Vanderbilt Institute for Software Integrated Systems, led by director Janos Sztipanovits, is managing the Cyber-Physical Systems Virtual Organization for the NSF, linking together all of the organizations working on the topic, archiving and disseminating documents produced by research, and offering collaboration and experimental platforms for thousands of CPS researchers. In 2015, Vanderbilt, with collaborators from the University of Pennsylvania, the University of Arizona, and the University of California, Los Angeles, won a $2 million grant from NSF to support the project, with a commitment of an additional $3.6 million over the next three years.

Recent CAREER awards at Vanderbilt

The Faculty Early Career Development (CAREER) Program is a foundation-wide activity that offers the NSF’s most prestigious awards in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organizations. Following are examples of research being conducted by CAREER award recipients.

- Assistant Professor of Chemistry Janet Macdonald has been using her CAREER grant to synthesize new nanoparticles that aim to be the core of new solar-to-fuel technologies. Her design for nanoparticles combines one material that can absorb sunlight and another that can catalyze chemical reactions on its surface. The two work together to use sunlight to synthesize green, renewable fuels.

- Assistant Professor of Biomedical Engineering Craig Duvall’s CAREER award supports research on advanced drug delivery systems designed to enhance the performance of stem cell therapies for use in tissue engineering, drug delivery, and regenerative medicine. Duvall’s research aims to develop injectable hydrogels that contain cells to promote wound healing in diabetic patients who are more susceptible to non-healing skin wounds. The award also supports career-related mentoring for high school students who participate in a STEM program at Harpeth Hall, a Nashville school for girls.

- Assistant Professor of Mechanical Engineering Jason Valentine’s CAREER award funds continued research that will lead to a new class of ultra-compact optical elements that can improve the performance and integration of a wide range of devices such as visible and infrared cameras and light-wave imagers, as well as be an enabling technology for applications such as free-space telecommunications and optical manipulation. Valentine is developing metasurfaces for manipulating the phase and wavefront of light for ultra-compact optical elements such as lenses, waveplates, and beam formers.

Quantum dots made from fool’s gold boost battery performance

Vanderbilt researchers have made an important contribution to research on how nanoparticles can improve battery life. With support from NSF, Assistant Professor of Mechanical Engineering Cary Pint and graduate student Anna Douglas found that adding quantum dots (nanocrystals 10,000 times smaller than the width of a human hair) made of iron pyrite to a smart phone battery can produce batteries that charge quickly and work for dozens of cycles. Iron pyrite, also known as fool’s gold, is one of the most abundant materials in the Earth’s surface and is very inexpensive.

Anna Douglas holding one of the batteries that she has modified by adding millions of quantum dots made from iron pyrite. (John Russell/Vanderbilt)
**Feedback can hinder kids’ math outcomes**

A study by Peabody College of education and human development doctoral student Emily Fyfe found that sometimes providing verbal feedback (positive or negative) actually causes more harm than good in teaching elementary school students mathematics. She found that most children benefitted from feedback during problem solving, but children who already had some knowledge of a particular task learned more without feedback. The study results challenge the notion that feedback is always a good thing. It reinforces that small changes to teaching approaches may significantly improve a child's learning experience. Fyfe's research focuses on developing ways to improve problem solving and early mathematics understanding. Fyfe was supported by an NSF graduate research fellowship.

**New insight on how brain performs “mental time travel”**

A team of Vanderbilt psychologists has shed new light on how the brain retrieves memories of past experiences. This cognitive process is known as "mental time travel," because when a memory is retrieved it can be like revisiting that past moment, reactivating details of the experience and making other memories of nearby events more accessible. The Vanderbilt team analyzed the brain activity of individuals performing a simple memory recall task. Using activity patterns in a specific region of the brain substantially improved the researchers' ability to predict the order in which the participants recalled information that they had recently studied. Specifically, the team was able to predict when a person would recall a series of memories that all happened nearby in time to one another, suggesting that the person had mentally time traveled to that moment from the study experience. Studying how memories are made and retrieved may help develop treatments for memory disorders (for those with diseases such as Alzheimer’s) and identify adverse effects that psychotropic drugs may have on memory.

**Education programs funded by NSF**

Sixteen Vanderbilt graduate students won prestigious NSF graduate research fellowships in 2015. The program is aimed at aiding individuals who have demonstrated notable potential early in their research careers. An additional goal is increasing the diversity of the science and engineering workforce. The fellowship provides three years of support within a five-year fellowship period. With a $34,000 annual stipend and $12,000 cost-of-education allowance, the fellowship supports 2,000 graduate students in science and engineering nationwide. Eighty-one students at Vanderbilt are receiving NSF graduate fellowship support.

Tennessee State University (TSU) and Vanderbilt are partnering to lead a new “bridge to doctorate” program to increase the number of minority students who earn Ph.D’s in science, technology, engineering, and math. NSF awarded $987,000 to TSU to launch the program as an expansion of the Tennessee Louis Stokes Alliance for Minority Participation, or TLSAMP. TLSAMP is an NSF-funded collaborative effort by ten Tennessee colleges and universities to increase and improve the retention of underrepresented minority students in STEM fields statewide. Vanderbilt is the inaugural host of the new program, which will fund twelve students. TLSAMP is led by TSU and includes Vanderbilt, Fisk University, LeMoyne-Owen College, Middle Tennessee State University, Nashville State Community College, Southwest Tennessee Community College, Tennessee Technological University, University of Memphis, and University of Tennessee–Knoxville.

The TLSAMP program will build upon the success and lessons learned from the Fisk–Vanderbilt Masters-to-Ph.D. Program. Launched in 2004 with NSF support, the Fisk–Vanderbilt two-year program has built a detailed, research-based toolkit to support underrepresented minority students on their path to earning Ph.D’s, and has made Vanderbilt the leading producer of underrepresented minority Ph.D’s in astronomy, materials science, and physics in the United States.