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Subcommittee on Research and Science Education
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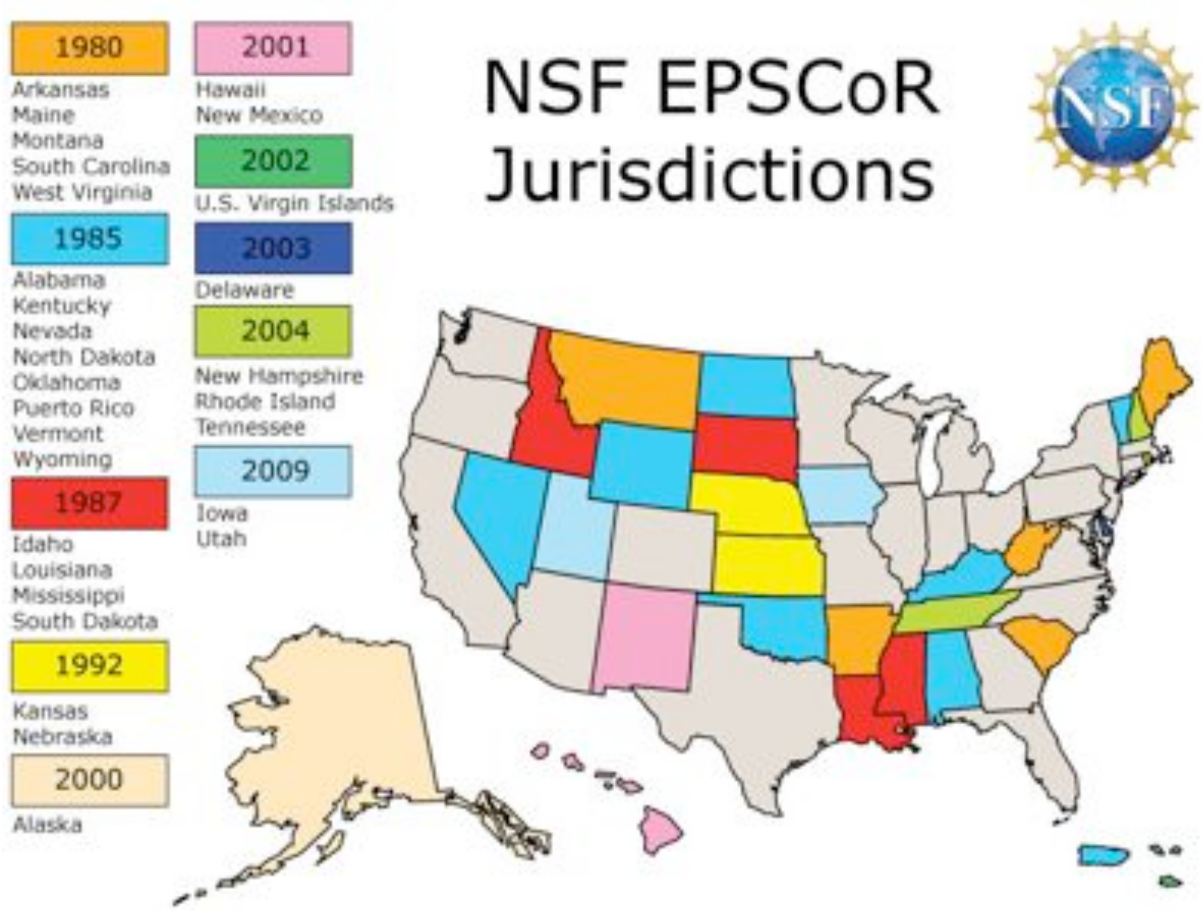
Mr. Chairman and Members of the Subcommittee, my name is Dr. John Raymond. I am Vice President for Academic Affairs and Provost at the Medical University of South Carolina. I have also served as Chair of the State of South Carolina Experimental Program to Stimulate Competitive Research (EPSCoR) Committee for the past 8 years. Thank you for the opportunity to testify today regarding the research infrastructure needs of our universities and colleges including research facilities and cyber-infrastructure capability, the capacity of the research infrastructure to meet the current and future needs of U.S. scientists and engineers, and the appropriate role of the Federal government in sustaining such infrastructure.

In this testimony, I have been asked to answer questions related to the current National Science Foundation EPSCoR grant awarded to South Carolina. Specifically, I will address EPSCoR's role in facilitating partnerships with state and local governments and the private sector to improve our research infrastructure, its leveraging effect on improving cyber-infrastructure capabilities, and its impact on the Medical University of South Carolina. Secondly, I will describe the state of research infrastructure and research facilities at the Medical University of South Carolina and our unmet research infrastructure needs. Thirdly, I will provide recommendations on how to improve the EPSCoR program based on the findings and recommendations of the EPSCoR Foundation.

Before answering the three specific questions posed to me, it might be useful to provide a brief summary of the EPSCoR program and my university to place my answers into the appropriate context. The National Science Foundation EPSCoR program has a statutory function "to strengthen research and education in science and engineering throughout the United States and to avoid undue concentration of such research and education." This is accomplished through two goals, which are (1) to provide strategic programs and opportunities for EPSCoR participants that stimulate sustainable improvements in their R&D capacity and competitiveness; and (2) to advance science and engineering capabilities in EPSCoR jurisdictions for discovery, innovation and overall knowledge-based prosperity. South Carolina is one of the original NSF EPSCoR-eligible states designated in 1980 (please see **Figure 1**). Twenty-nine jurisdictions including twenty-seven states, the Commonwealth of Puerto Rico, and the U.S. Virgin Islands are currently eligible to compete for support through various NSF EPSCoR mechanisms.[1] Those 29 jurisdictions comprise 20 percent of the U.S. population, 25 percent of the research and doctoral universities, and 18 percent of the nation's scientists and engineers. NSF EPSCoR funding is awarded through a rigorous process of merit-based peer-review to ensure quality, accountability and sustainability. Many other federal agencies support programs similar to the NSF EPSCoR program; for example, the National Institutes of Health has a program called the Institutional Development Award (IDeA) program.

[1] Eligible EPSCoR jurisdictions: Alabama, Alaska, Arkansas, Delaware, Hawaii, Idaho, Iowa, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Puerto Rico, Rhode Island, South Carolina, South Dakota, Tennessee, U.S. Virgin Islands, Utah, Vermont, West Virginia, and Wyoming.

Figure 1*. National Science Foundation EPSCoR Jurisdictions*



From http://www.nsf.gov/div/index.jsp?org=EPSC

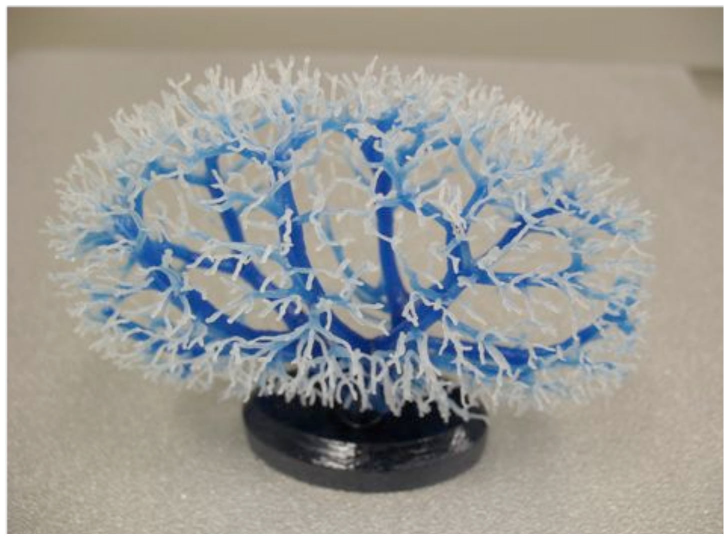
Founded in 1824, the Medical University of South Carolina is a freestanding academic health science center composed of six health-related colleges (Dental Medicine, Graduate Studies, Health Professions, Medicine, Nursing, Pharmacy). Until recently, our institution made relatively modest contributions to the creation of knowledge in science and engineering disciplines; with the assistance of programs like NSF EPSCoR, we now are poised to contribute in a substantial and sustainable way to the competitiveness of our nation. We were awarded extramural research funding of nearly $218 million in FY2009-2010, of which $140 million was from federal sources, and $103 million from the National Institutes of Health.

The current NSF EPSCoR Research Infrastructure Improvement (RII) grant was awarded to South Carolina in July 2009. This RII has presented an exciting opportunity for South Carolina to implement a **statewide vision** towards building a competitive edge in the emerging field of “organ printing” – operationally defined as computer-aided, layer-by-layer deposition of biologically relevant material with the purpose of engineering functional tissues and organs. The idea is that we can use cultured cells and supporting materials as “ink” that can be built up using modified ink-jet printers and powerful computers to create human organs such as hearts, kidneys, and blood vessels. The patient’s own cells (such as fat cells) can be used to make these organs to provide a ready source for transplantation to treat and cure diabetes, kidney failure, heart failure and atherosclerosis. What patient with diabetes wouldn’t donate some of their excess fat cells to make a new pancreas to cure their diabetes?

Organ printing poses a grand challenge in terms of engineering and biological principles, and a grand opportunity for South Carolina to contribute to the competitiveness of our country. Currently, the thickness of printed tissue constructs is limited to four cell layers or less due to lack of a blood supply. In order to manufacture more complex organs, one must successfully engineer a vascular supply, which will require a 3-D tree-like network of blood vessels.

The grand vision of this RII has ample depth and breadth to bring together faculty and students from nearly all of South Carolina's institutions of higher education to work toward a common purpose. The 2009 SC NSF EPSCoR RII focuses on a diverse subset of institutions including three research intensive institutions (Clemson University, Medical University of South Carolina, University of South Carolina), three historically black colleges (Claflin University, South Carolina State University, Voorhees College), two other predominately undergraduate institutions (Furman University, USC-Beaufort) and 3 technical colleges (Denmark Technical College, Greenville Technical College, York Technical College). Together we form the SC Alliance for Tissue Biofabrication.

***Figure 2**. Bioprinted Kidney Vascular Tree Prototype*



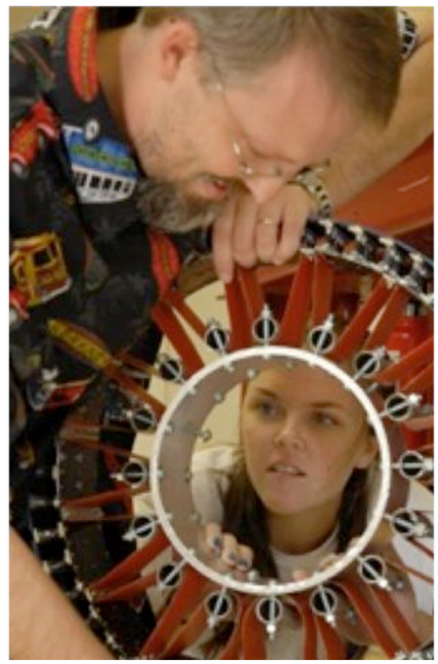
EPSCoR funds were essential for demonstrating the feasibility of using existing rapid prototyping equipment to print an intra-organ vascular tree. Drs. Vladimir Mironov and Roger Markwald at MUSC facilitated the fabrication of a 3-D "plastic" kidney (see **Figure 2**), which was recently printed based on a computer-aided design provided by Prof. Nicolas Smith from the University of Oxford (UK) using expertise and facilities at 3D Systems/York Technical College. This initial success and preliminary data strongly suggest that existing rapid prototyping technology using layer-by-layer addition of building blocks has sufficient resolution for bioprinting a complex branched vascular tree. Rapid prototyping is a rapidly growing, $100 billion/yr industry and 3D Systems, Inc, located in Rock Hill, SC, is a leading global provider of 3D printing, rapid prototyping and additive manufacturing products. This is an excellent example of EPSCoR funds being used to catalyze academic–industrial collaborations towards building an advanced biomanufacturing industry in South Carolina.

The NSF EPSCoR funds have been leveraged through the recruitment of new professors to the state of South Carolina through the Centers of Economic Excellence Act, and the Research Universities Infrastructure Act, two key economic development initiatives passed by the South Carolina Legislature in 2002 and 2004, respectively. Those acts provide state matching funds for recruitment of endowed professors, and for research construction. We have used state funds and private sector matching funds to create multi-institutional Centers of Economic Excellence in Regenerative Medicine, and in Tissue Biofabrication. Several of the professors recruited to these centers have faculty appointments at Clemson, USC and MUSC, thus serving as bridges between our institutions. These new centers will be based in a new 100,000 ft^2 Bioengineering Building, which will be completed in late 2011. This building will house engineers from Clemson and USC, and life scientists from MUSC, working in interdisciplinary teams to address grand challenges like the organ bioprinting project. We also have leveraged the NSF EPSCoR award by developing interdisciplinary educational programs that bring together students and faculty from the technical colleges, historically black serving institutions, four-year and research-intensive institutions.

Finally, the NSF RII award provided the impetus for South Carolina and Tennessee to partner on a new NSF EPSCoR cyberinfrastructure award that provides personnel and equipment to facilitate coordination with Clemson High Performance Computing support staff and TeraGrid specialists. This cyberinfrastructure grant also enables South Carolina institutions to have access to the TeraGrid Kracken system housed at Oak Ridge National Laboratory. This grant, along with a $21 million award from The Duke Endowment and an $8 million award from the Federal Communication Commission, has allowed us to develop a high-speed, high-bandwidth optical and wireless communication grid that spans the state and facilitates competitiveness.

NASA EPSCoR funds have catalyzed connections among Dr. Joshua Summers' team at Clemson, and Michelin, Milliken and the NASA Jet Propulsion Laboratory to design and test a useful and efficient lunar wheel for use on the Small Pressurized Rover that will enable astronauts to explore the moon. The futuristic rover with its "tweels" joined NASA astronauts in President Obama's inaugural parade on Pennsylvania Avenue. The accompanying **Figure 3** shows Dr. Summers and undergraduate student Ms. Samantha Thoe inspecting the metallic prototype.

Figure 3. *A "Tweel" Prototype*
(Image: Clemson University)



Other federal agency EPSCoR funds have been applied to the areas of energy and alternative fuels. For example, Dr. Terry Tritt's research group at Clemson University has extensive interactions with Oak Ridge National Lab and Savannah River National Lab through the DOE EPSCoR Partnership Program. Dr. Tritt has received international attention for his study of thermoelectric energy, and on materials that can recapture "lost" energy from "wasted" heat.

These are just a few examples of how EPSCoR funds have been used to advance research and science education in South Carolina.

With regard to MUSC's research infrastructure, we have a number of new, state-of-the-art research buildings focusing on childhood diseases, bioengineering and drug discovery and development. We also have a number of aging buildings that will require significant upgrades and renovations to accommodate our expanded scope of research; and new high-end instrumentation to enable our teams to perform the mass spectroscopy, magnetic resonance imaging, high capacity computing, emerging microscopic methods, and interactive teaching, materials sciences, and biofabrication, as well as other emerging methods. We share these needs with many educational institutions, even those in the research powerhouse states. The continued support of EPSCoR programs will be essential for our state, and for institutions like MUSC, to make sustainable contributions to scientific discovery, contemporary science and engineering, education, innovation and the overall competitiveness of our country.

We believe targeted options continue to be the most viable and effective pathways to develop the scientific infrastructure, talent and critical mass in the EPSCoR states. There should be a continued investment in competitive grant opportunities for states meeting EPSCoR criteria. We believe the current EPSCoR program could be improved by dividing it into several components – (1) research and (2) education and workforce. Alternatively, we could simply adopt the NIH dual model of COBREs which are research center development grants, and INBREs which are state network grants to educate and train the next generation of biomedical scientists. This would be a much more direct approach to meeting both research infrastructure and "pipeline" needs. Each component should, of course, be adequately funded at levels similar to those at NIH.

We would appreciate renewed efforts to involve EPSCoR states in the regular NSF programs. This means more representatives from EPSCoR states on the National Science Board, NSF Advisory committees and other relevant "planning" entities; more co-funding especially as the NSF budget is growing, and greater use of mechanisms that will ensure EPSCoR participation in major NSF initiatives. I believe that a few years ago, extra points were awarded for including EPSCoR states in certain applications for large programs. This should be reinstated. Other efforts should be made to assist EPSCoR states in participating in more large-scale NSF efforts such as Science and Technology Centers (STCs), Engineering Research Centers (ERCs), and Materials Research Science and Engineering Centers (MRSECs). Unless that is done, the dollar imbalance between the established states and the EPSCoR states will continue to grow. In this regard, I would suggest that NSF set a goal of doubling the percentage of its funds, annually, that are awarded to the 27 EPSCoR states and 2 jurisdictions – from slightly less than 10% to 20% within ten years. Then, coalesce some of the initiatives recommended above, as well as others gleaned from the broader EPSCoR community, into a "Strategic Implementation Plan" to meet that goal.

We also need assurance that as new states are added, the funding needed for them is requested and appropriated. It costs $5-10 million a year to bring a new state into the EPSCoR program during its first five years and these new EPSCoR states tend to be more competitive than some of the existing ones. Consequently, it is self-defeating to drain resources from one to help the other.

We should look at other mechanisms as well. EPSCoR states have trained a lot of scientists and engineers over the years who, regrettably, have then simply moved to other states. More are staying in our states as we build our infrastructure and attract innovative companies. We need incentives to keep and bring new talent to our states. Physical infrastructure initiatives outside of the EPSCoR program could also be useful. Renovations and equipment remains a major obstacle to competitiveness for the EPSCoR states. Cutting edge facilities, renovations and equipment remain a major obstacle to competitiveness for the EPSCoR states. A separate program or a set aside in existing programs would be helpful.

Physical infrastructure initiatives outside of EPSCoR or in addition to the existing EPSCoR program are essential. That is your focus today. The EPSCoR states unquestionably and unequivocally require such investments. Construction of scientific facilities, renovations and equipment remain a major obstacle to competitiveness in the EPSCoR states.

Finally, while South Carolina has made impressive progress in cyberinfrastructure, it has not been easy or inexpensive. Many of the EPSCoR states have not been as fortunate and many are still lacking the bandwidth and support systems that will enable modeling and simulations needed for climate change, biomedical and advanced research and for visualization.

We thank this subcommittee for its ongoing support of our states and for the wisdom to invest in programs that engage the populace of all of our states in building science and engineering capabilities that will broaden the base of talent and the capacity for innovation throughout the United States. We believe in the value, effectiveness and sustainability of EPSCoR programs – both as a catalyst for improving our respective states and to enhance America's competitiveness in the global economy.

In closing, I thank you for the opportunity to address the Subcommittee today.