THE UNIVERSITY OF TENNESSEE AT CHATTANOOGA

CENTER OF EXCELLENCE

IN APPLIED COMPUTATIONAL SCIENCE AND ENGINEERING

Annual Report to the Tennessee Higher Education Commission Fiscal Year 2012-2013

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Executive Summary

The Center of Excellence in Applied Computational Science and Engineering (CEACSE) has recently completed its eighth year of operation. The previous years have led to the establishment and development of an effective operation. This period has provided an opportunity for inculcating a culture of the securing external funding as an outcome of seed research funding provided by CEACSE. There have been and continue to be some challenges as the Center continues operation. One issue is the necessity to promote and stimulate grant competition from a broader spectrum of individuals and technological areas. This is affected by current teaching demands, which impact capabilities and time required for research and proposal development and paths. There are continuing issues as well, the national economic environment, level of external funding committed to research and development funding, and increased externally competitive environment. The reporting year has proceeded with the awarded research funds being expended.

As is noted in this report, CEACSE continues to accomplish its mission and objectives. Through the awards, the researchers and associated academic units have maintained external funding from various agencies, companies, and governmental entities. CEACSE monies from the 2013 fiscal year as well as from past years continue to provide returns, reaping benefits through additional awards/grants. (Figure 1).

Fiscal Year 2013 Seed Funding Awarded vs. External Funding Received

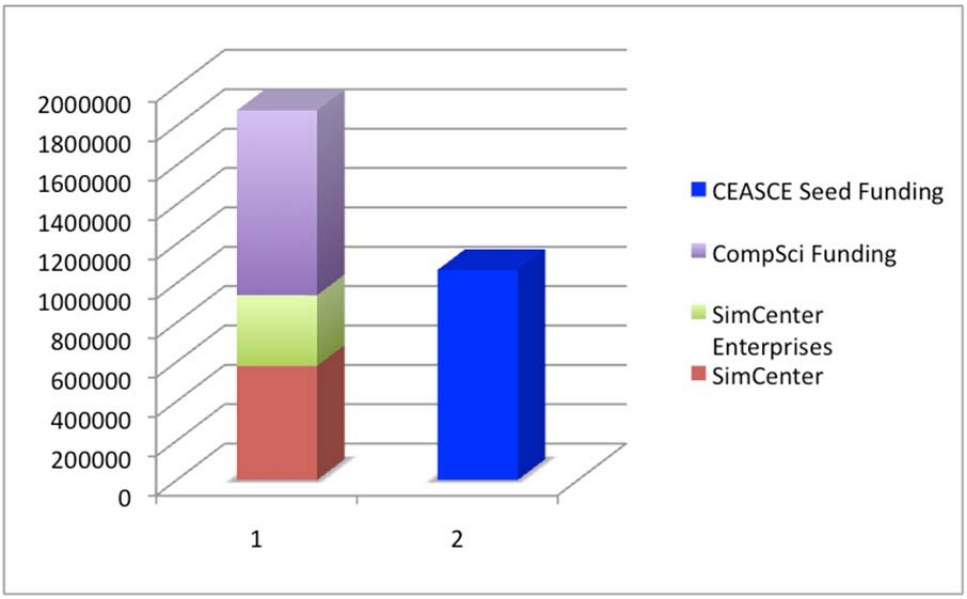


Figure 1

CEACSE continues to enhance the education aspect of students through the Ph.D. and M.S. graduate programs at the University of Tennessee at Chattanooga and its Graduate School of Computational Engineering within the College of Engineering and Computer Science. There is a continuing involvement of both graduate and undergraduate students and they have participated on various research activities undertaken as a result of CEACSE funding. Due to the research activities that some of the students have undertaken, local companies continue to have interest in the student's educational programs impacted by the CEACSE research.

The following is the Annual Report for fiscal year 2013 of CEACSE activities and efforts.

Introduction

The Tennessee Higher Education Commission formed Centers of Excellence within the Tennessee Higher Education System in 1984**.** These Centers of Excellence are designed to build upon the research strengths of the campuses of Tennessee Board of Regents and University of Tennessee. Their purpose is to focus on the capabilities of public higher education to serve the people of Tennessee by expanding the state's research base; thereby, increasing its national and international stature and its economic competitiveness. Funds to operate these centers are provided in the State of Tennessee's annual budget for higher education and subject to approval of the state legislature and the governor. The Center of Excellence for Applied Science and Engineering (CEASCE) at the University of Tennessee in Chattanooga is one of these Centers of Excellence. In accordance with the original enabling legislation the goal of CEACSE is to and build upon the established UTC strength in applied computational science and technology to evolve into and to be recognized as, a national 'Center of Excellence' and a premier multidisciplinary research and education center for computational science and engineering.

This is the eighth year of operation of the UTC CEASCE and this report summarizes the research programs supported by CEASCE funds in FY 2013 and the outcomes achieved by these programs in support of the Center of Excellence goals.

CEACSE is a UTC wide activity and builds upon the expertise resident within the SimCenter and the Graduate School of Computational Engineering within the College of Engineering and Computer Science, to expand the concept of computational simulation to consider a wider array of complex practical problem in science and engineering. Each

year a campus wide call for proposals is made, the principle requirements being that the proposed activity be a suitable research activity for a higher educational institution and supports the goals of CEASCE by using computational methods to address a relevant problem and demonstrate the potential of the approach to benefit the state and garner external support for its continuation. Thus, the research portfolio intends to broaden research contributions that enhance the educational and economic development mission of The University of Tennessee at Chattanooga**.**

Objectives, Activities and Uses of Center Funding

The CEACSE pursues goals and objectives that establish the necessary and on-going foundation from which to develop and earn recognition as a premier center of excellence for computational applications in the physical sciences with national and international stature.

Objectives

The primary objective of the Center is to expand the demonstrated capability of the University in the area of Computational Science and Technology and to seed research and educational activities that broaden and expand the Center's base of research expertise, thereby helping to attract new research funding.

The SimCenter has operational a significant cluster super computer. This machine is configured to perform and support computational simulations on large complex problems. Other organizations and universities around the world continue to upgrade their equipment, presenting continuing increased need for computing capability. This places increased pressure on existing resources for upgrading and/or defining access to other advanced computational capabilities that may be accessible. To achieve this access does require connection to advance communication and data networks to support such high level of data communication and security. Efforts are underway within the University to address this issue.

The utilization of available cluster-supercomputer resources for appropriate and promising research projects is of considerable importance. A ranking of a computing machine is a measure of raw computing power, but it does not ensure that the research undertaken is itself worthwhile or that the computed results produced are significant. The intellectual and practical value of each specific research project is the primary objective, and the computer itself serves as the enabling resource. Consequently CEASE provides some funds to support the SimCenter cluster in order that computational resources be available for grantees.

There has been an ongoing expansion of capabilities to broaden research and support activities. CEASCE requires that at least one external proposal be developed for each seed funded activity and submitted to a funding agency for continuation and expansion of the CEACSE funded research or related research. During this most recent year of operation it can be seen that the Center's funded activities and philosophies are continuing to achieve results (Figure 1 & Table 1).

At the start of its eighth year, CEACSE granted funding to nineteen proposed research projects. In addition, several exploratory research activities were approved and funded during Fiscal Year 2013 (Table 2). The exploratory research activities included research performed in support of requests for proposals (RFPs) received from external funding agencies, efforts to find external funding opportunities for a number of the CEACSE funded projects, white paper and proposal preparation assistance, and research activities undertaken by the Center's Staff. As a result,

several of these opportunities have been identified throughout the course of the fiscal year. The activities arise throughout the year and fall outside the standard award cycle. These exploratory activities are evolving as increasingly important components of research activities. These are needed to respond increasingly to frequent demands to the new complex evolving problems. Consequently, these research activities were initiated at the discretion of the Center's Director based on needs and potential for following-on funding.

Table 1

CEACSE Seed Funding Committed for FY 2012-2013 Research Activities

Project Title	Budget	One-Year Extension	Expenses	Proposal Submitted	Externally Funded	External Funding Source(s)
Numerical Simulation of Respiratory Flow Patterns Within Human Lung	$59,328	N	$53,555	N	N	
Sensitivity Analysis and Shape Design for Turbomachinery Using Sliding Interfaces	$71,127	N	$55,815	N	N	
Development of a Generalized Fluid-Structure Interaction Interface for SimCenter Software	$83,485	N	$78,132	N	N	
Multiwavelet Discontinuous Galerkin Method	$18,700	N	$18,288	N	N	
High-Fidelity Modeling of Wind Turbine Wakes	$38,400	N	$3,301	Y	Y	NSF, $283,210
Authentication in Mobile Platforms	$54,244	Y	$51,698	Y	Y	NSF. $585,020; NSF $119,869; NSF, $209,981
A Power Efficient Scheme Using Compressive Sensing	$51,660	Y	$38,397	Y	N	
Shape Optimization for Flows with Particles	$60,804	N	33,318	Y	Y	SCE, $35,000
Conjugate Heat Transfer Analysis of Turbine Vane Cascade	$31,027	N	$27,818	N	N	
Validation of Centrifugal Compressor Performance using Tenasi	$37,506	N	$34,477	N	N	
Development of a Multi-Regime Solution Capability for Tenasi Flow Solver	$57,566	N	$56,703	Y	Y	NSF, $296,318
Design of Stents for Bifurcated and Limb Arteries	$76,526	N	$64,582	Y	N	
Computational Modeling of Physiological Data Using Inexpensive and Unobtrusive Sensors: A New Paradigm for computational Physiology	$49,606	N	$43,718	Y	N	
Investigation of Possible Triangulation Procedules of GIS Data	$51,480	N	$49,732	Y	Y	SCE, $224,657
NSF GENI Project	$100,000	N	$100,000	N	N	
Discretization of Iconic Buildings, Roadways, and Railways for Realistic Urban Simulations	$40,104	N	$43,061	Y	Y	SCE, $99,388
TOTAL	**$881,560**		**$752,595**			**$1,853,443**

In summary the total external funding attributable to CEASCE seed funding obtained in FY 2013 of $1,853,443.00 comprises $579,528.00 awarded to the SimCenter from Government grants and contracts, $359,045.00 awarded to the SimCenter by SimCenter Enterprises in support of their commercialization activities and $914,982.00 awarded to Computer Science faculty by grants from Federal agencies. This is illustrated in Figure 1

Table 2

CEACSE Seed Funding Carried Forward from FY 2011-2012 to FY 2012-2013 Research Activities

Project Title	Budget	One-Year Extension	Expenses	Proposal Submitted	Externally Funded	External Funding Source(s)
Numerical Solution of Lithium Batteries	$42,410	N	$35,656	Y	N	
Extended Capabilities for Electromagnetic Simulations	$68,551	N	$59,244	N	N	
Navier-Stokes Utilizing Discontinuous Galerkin/Petrov Galerkin (DG/PG) Approaches	$104,258	N	$93,251	Y	N	
TOTAL	**$215,219**		**$188,151**			

Table 3

CEACSE Exploratory Research Activities for FY 2012-2013

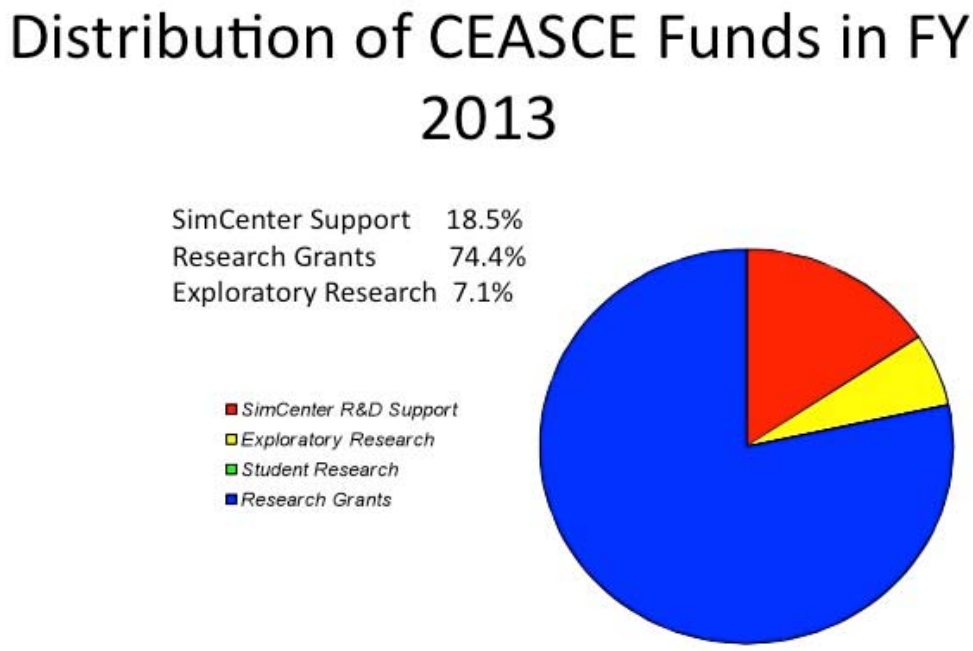
Project Title	Budget	One-Year Extension	Expenses	Proposal Submitted	Externally Funded	External Funding Source(s)
Exploratory Research for new initiatives	$62,178	N	$62,178	N	N	
Preliminary Research on Disaster Mitigation Technologies	$9,751	N	$9,751	N	N	
TOTAL	**$71,929**		**$71,929**			

Table 4

Summary of Funds Budgeted and Expended for FY 2012-2013

Expense	Budget	Expenses
SimCenter Staff Support for CEASCE	$187,358	$187,358
CEACSE Seed Funding for FY 2012-2013 Projects	$881,560	$752,595
CEACSE Seed Funding for FY 2011-2012 Projects Carried Forward	$215,219	$188,151
CEACSE Exploratory Research Activities	$71,929	$71,929
TOTAL	**$1,284,137**	**$1,200,033**

In order to ensure that the objectives of the Center's investment continue to be met, the financial progress of the projects is routinely tracked on a monthly basis via the UTC financial reporting system, and the technical progress of the projects is monitored via short monthly progress reports, mid-term and final reports submitted to the Center by the Principal Investigators. Subsequent external funding is also tracked and where appropriate is attributed to a specific Center project or groups of projects. Recipients of CEACSE seed funding are required to provide a copy of their submitted proposal and any subsequent information regarding award or non-award of follow on external funding. This information is given in Tables 1,2, 3 & 4. CEASCE expenses are show in Figure 2 with 'SimCenter Support' being mainly support supplied by SimCenter staff for the operations of CEASCE.



A secondary objective is to increase the participation of additional faculty, graduate and undergraduate students in the Center's research efforts and where possible assist in the recruitment of new faculty and students to the University.

CEACSE continued its efforts to broaden the scope of research through increased participation of additional faculty, graduate students and undergraduate students. CEACSE awarded seed funding to support the research activities of 18 faculty members from various disciplines, such as physics, computer science, and computational engineering,

Another objective is to engage in activities that are directly or indirectly supportive of economic development initiatives that benefit Tennessee, in particular activities that create collateral opportunities for new research.

CEASCE has had numerous visitors to discuss opportunities for research collaboration, and the Center has given numerous presentations at meetings hosted at the SimCenter on the UTC campus. During the past eight years, CEACSE faculty have made numerous presentations during meetings for discussions directly related to metropolitan engagement for the purpose of economic development, support of local businesses and government, and planning for SimCenter expansion. Some notable discussions, in collaboration with SimCenter Enterprises, Inc., pertaining to research opportunities occurred during this report period with Alstom Air Preheater Company, Airman Systems, and Cormetech. Research issues discussed included maximizing heat transfer, Class 8 vehicle aerodynamic drag reduction, and removing imperfections in an extrusion process. In addition, CEACSE sponsored research has created numerous opportunities for education of graduate students, thereby providing students the potential to secure high-paying quality positions and to be able to remain within Tennessee. Finally, CEACSE sponsored research contributes to and enables the following activities at the SimCenter that are supportive of economic development:

1. Alstom Air Preheater Company was interested in maximizing their regenerative heat exchange process that preheats air that flows into a boiler in a Fossil Fuel Power Generation Plant. They were particularly interested in minimizing losses due to air leakage in their process as well as maximizing heat transfer in the existing elements in their heat exchanger. Representatives of the SimCenter visited TVA's Widows Creek Fossil Fuel Plant to see an installed and working heat exchanger. The environment in which the heat exchanger functions is very harsh and the device itself is rather large. Discussions centered on performing airflow simulations through the heat exchanger passages in an effort to improve the existing designs from an aerodynamic perspective.

2. Airman Systems has designed a proprietary aftermarket aerodynamic drag reduction device for Class 8 vehicles (semi-trailers). The device has been outfitted on several tractor-trailers and has shown to be effective in reducing aerodynamic drag thereby increasing fuel efficiency. Unfortunately, in standardized tests performed for the EPA the device fails to increase fuel efficiency to the level that the EPA can certify the device. Hence, discussions revolved about the SimCenter performing an aerodynamic analysis of the device as installed on a trailer and suggesting design modifications to increase fuel efficiency so the device can be EPA certified.
3. Cormetech is a company that specializes in the manufacture of titania-based ceramic honeycomb catalysts for NOx emission control. These devices are

primarily used in Fossil Fuel Power Generation Plants to reduce NOx emissions. As part of the manufacturing process, these honeycomb ceramic catalysts are extruded through a geometry that transitions from a circular cross section to a square cross section. Periodically, the extruded pieces contain defects that require them to be discarded. The discussions included ways in which the SimCenter could simulate their process and try to ascertain the cause of the defect and then suggest mitigation strategies.

A final objective is to seek appropriate opportunities for educational outreach activities that a) help to create awareness and to stimulate interest in science and engineering among pre-college students, and b) help to stimulate interest in graduate study at UTC among undergraduate and graduate students.

Stimulating interest in science and engineering among pre-college students remained a primary goal of the CEASCE's outreach work as new STEM Outreach Coordinator Lindsey Frost Cleary took over the reins of the program in July 2012. During the 2012-2013 school year, 288 K-12 students and 61 K-12 teachers visited the SimCenter to learn about the work, to engage with the creative process of engineering design, and to explore career opportunities in STEM fields. These students and teachers represented a diverse cross-section of schools in the Chattanooga including the new STEM school, Orchard Knob Middle School, The Howard School, Girls Preparatory School, McCallie, CSLA, and Silverdale Baptist Academy. In addition, the Center conducted school site visits across the region talking to students about computational engineering and the engineering design process. Through these visits, more than 220 students were impacted in grades K through 12.

New and deepened partnerships allowed the CEASCE to expand the reach of its pre-college outreach programs this year. Most notably, a partnered with the Southeast Tennessee STEM Innovation Hub on a variety of projects was formed. Some of the region's best STEM teachers visited the SimCenter as part of the Hub's STEM Fellows program, and one of these teachers, Orchard Knob Middle School science teacher Ethan Evans, spent a day job shadowing at the SimCenter. Ethan said the

SimCenter's "mind blowing" work "reignited [his] passion for teaching and for science." The partnership with the STEM Hub also led to an exciting new opportunity with Chattanooga's STEM High School: this spring, sophomore students at the school will participate in a new problem-based learning unit based on the work of the Center. This learning unit will be shared across the region through the STEM Innovation Hub, potentially impacting hundreds of classrooms and thousands of students.

Outreach activities also continued to encourage graduate and undergraduate students to consider graduate study at UTC. UTC undergraduates have been recruited to work and are part of ongoing funded research projects, and this effort is continuing. Seven have been employed as research assistants through the most recent fiscal year. Planning efforts continue to identify and develop additional effective outreach activities for undergraduate and graduate students, although the inclusion of an engineering course in the UHON department (UHON 1200) and a teaching presence in the undergraduate design and solid modeling classes has already gone a long way in spurring interest.

Further, the Center participated in the engineering design senior capstone project this year in order to share the work of the SimCenter with undergraduates and to engage them with our research. Faculty member Dr. Kidambi Sreenivas and Outreach Coordinator Lindsey Frost Cleary guided undergraduates in the design of a tabletop wind farm model based on Dr. Sreenivas's research in optimal wind farm layout. This model will be used as part of the Center's ongoing K-12 outreach

programming. The senior undergraduates participating in this project presented their final design at the SimCenter, bringing them into our building and engaging them in our work in new ways.

CEASCE Plan for Achieving Objectives

The operation of the CEASCE is guided by strategic planning to identify promising research avenues within the broad area of applied computational science and engineering. Some promising areas have been identified that leverage existing research capabilities into new and related areas. The Center continues to seek ongoing participation from other UTC faculty and personnel to identify additional areas of strength based on their individual expertise and synergism with other Center activities. The Center continues to solicit these activities through a campus wide request for white papers and proposals. These white papers briefly describe the proposed effort, anticipated results, support required and a potential source of continued research funding, e.g. target agency, request for proposal etc. CEASC provides seed funding for initiatives in the most promising areas for project and program planning aimed at developing competitive proposals for new external funding. Such seed funding includes faculty and student support for exploratory feasibility studies, demonstration of new capability supporting proposals, contacts with sponsoring agencies, proposal development, and related travel. This solicitation procedure is a part of CEACSE annual operating cycle.

The criteria for evaluating promising research areas and initiatives includes relevance and potential for contributing to success in becoming an accomplished Center of Excellence

through the Center's goals of a) sustainable growth in research funding, b) excellence in integrated research and education, c) increase in national and international stature, and d) promoting regional economic development and economic competitiveness for the State of Tennessee.

Research Activities Funded by the Center

The following list of activities and uses of funding illustrate how the Center's plan is being implemented (Schedule 7 is attached)

Extended Research Activities Funded by the Center in Fiscal Year 2011-2012 and Completed in Fiscal Year 2012-2013

1. **Numerical Solution of Lithium Batteries**
    - Principal Investigator(s): Drs. Kyle Anderson and Sagar Kapadia, Graduate School of Computational Engineering
    - Objective(s): To develop computational methods for simulating lithium-ion batteries. Sensitivity derivatives will also be obtained for examining effects of physical parameters.
    - Seed Funding: $42,410
    - Results: Development complete and validated for one-dimensional simulations. Development continuing for three-dimensional simulations for inclusion in proposals. Proposal submitted to the University of Tennessee System for $50,000 was not selected or funding.

2. **Extended Capabilities for Electromagnetic Simulation**
    - Principal Investigator(s): Drs. Kyle Anderson & Li Wang, Graduate School of Computational Engineering
    - Objective(s): To continue the development of high-order accurate (p>1) finite-element methods for electromagnetic simulations.
    - Seed Funding: $68,551
    - Results: Development continuing to incorporate new capabilities, for inclusion in proposals including frequency-dependent materials.

3. **Navier-Stokes Utilizing Discontinuous Galerkin/Petrov Galerkin Approaches**
    - **P**rincipal Investigator(s): Drs. Kyle Anderson & Li Wang, Graduate School of Computational Engineering
    - Objective(s): To continue the development of higher-order accurate (p>1) discontinuous Galerkin (DG) and Petrov-Galerkin (PG) methods for delivering high-accuracy solutions of the Navier-Stokes equations. The emphasis for this project is to extend these capabilities for turbulent flow and to investigate the use of higher-order methods for large eddy simulations (LES).
    - Seed Funding: $104,258
    - Results: Technology developed and demonstrated. Proposal submitted to AFOSR for $359,523 which was not selected for funding; Proposal submitted to TN-SCORE for $50,000 which was not selected for funding; Proposal submitted to NSF for $408,186 which was not selected for funding; Proposal submitted to NASA Langley for $594,858 which was not selected for funding. Proposal submitted to AFRL for $2,499,999 which was not selected for funding. Proposal submitted to ONR was not selected for funding.

New Research Activities Funded by the Center in Fiscal Year 2012-2013

1. **Numerical Simulation of Respiratory Flow Patterns Within Human Lung**
    - Principal Investigator(s): Dr. Abdollah Arabshahi, Graduate School of Computational Engineering
    - Objective(s): To use computational fluid dynamics (CFD) to model the unsteady, cyclic flow through differenct models of the bronchial tree, or, henceforth, the conducting airways
    - Seed Funding: $59,328
    - Results: Validation studies underway and development continuing for modeling continuous breathing cycles.

2. **Sensitivity Analysis and Shape Design for Turbomachinery Using Sliding Interfaces**
    - Principal Investigator(s): Dr. Chad Burdyshaw, Graduate School of Computational Engineering
    - Objective(s): To expand Tenasi sensitivity capabilities to include sliding interface technology. This includes both forward mode and adjoint analysis for steady and time dependent computations
    - Seed Funding: $71,127
    - Results: Sensitivity Analysis using the forward mode method implemented and validated for steady state and time dependent cases. The adjoint approach implemented, but not performing as expected.

3. **Development of a Generalized Fluid-Structure Interaction Interface for SimCenter Software**
    - Principal Investigator(s): Dr. James Newman, Graduate School of Computational Engineering
    - Objective(s): To extend the Computational Fluid Dynamics (CFD) capabilities within the SimCenter to address multidisciplinary applications.
    - Seed Funding: $83,485
    - Results: Initial implementation complete and capability demonstrated in Tenasi and FUNSAFE

4. **Multiwavelet Discontinuous Galerkin Method**
    - Principal Investigator(s): Dr Lafayette Taylor, Graduate School of Computational Engineering
    - Objective(s): To reduce the computational burden of memory and runtime for Discontinuous Galerkin (DG) algorithms with large degrees of freedom
    - Seed Funding: $18,700
    - Results: Use of wavelets for multi-resolution analysis has been demonstrated. Potential future research areas identified; wavelet-based

multi-grid, wavelet-based data mining techniques, and wavelet-based reduced order methods

5. High-Fidelity Modeling of Wind Turbine Wakes

- **P**rincipal Investigator(s): Drs. Lafayette Tayor & Roger Briley, Graduate School of Computational Engineering
- Objective(s): Improved Wake Models for Wind Turbine Placement optimization algorithms.
- Seed Funding: $38,400
- Results: NSF proposal in the amount of $283,210 was funded.

6. Authentication in Mobile Platforms

- Principal Investigator(s): Dr. Li Yang, Computer Science and Engineering
- Objective(s): Investigate current status and challenges of securing mobile devices; Innovate cryptographic algorithms and protocols to authenticate both mobile devices and mobile users; Secure communication between mobile devices and users, which are robust to a variety of threats
- **S**eed Funding: $54,244
- Results: NSF S-STEM, Making Opportunities for Computer Science and Computer Engineering Students $585,020 awarded. NSF SaTC: A collaborative proposal on Bolstering Security Education through Transiting Research on Browser Security awarded $119,869. NSF SFS, Capacity Building in Mobile Security Through Curriculum and Faculty Development, $209,981 awarded.
- Proposal submitted to NSF CE21 program under review. Proposal submitted to NIH declined, Proposal submitted to NSF CyberSEES declined.

7. A Power Efficient Multicasting Scheme Using Compressive Sensing

- Principal Investigator(s): Dr. Mina Sartipi, Computer Science & Engineering
- Objective(s): To develop a distributed multihop multicast scheme that is simple, energy efficient, and reliable.
- Seed Funding: $51,660
- Results: NIH, mStroke: Mobile Technology for Post-stroke Recurrence Prevention under review.

8. Shape Optimization for Flows with Particles

- Principal Investigator(s): Dr. Ramesh Pankajakshan, Graduate School of Computational Engineering
- Objective(s): To add sensitivity derivative capabilities to the Tenasi particle module and apply it to shape optimization problems
- Seed Funding: $60,804
- Results: $35,000 proposal submitted to SimCenter Enterprises and funded

9. Conjugate Heat Transfer Analysis of Turbine Vane Cascade

- Principal Investigator(s): Dr. Robert Webster, Graduate School of Computational Engineering
- Objective(s): Construct grids and conduct simulations based on experiments of model turbine blade with internal colling passages and rib turbulator for heat transfer enhancement. Compare with experiment for various values of Reynolds number; rotation included.
- Seed Funding: $31,027
- Results: Initial validation of computations of heat transfer in turbine rotor blade cooling channels with rib turbulators completed.

10. Validation of Centrifugal Compressor Performance using Tenasi

a. Principal Investigator(s): Dr. Robert Webster, Graduate School of Computational Engineering
b. Objective(s): Construct a completely new computational grid based on the existing geometric description of the experimental centrifugal compressor; Conduct simulations at various operating points for multiple rotational speeds; Investigate details of the simulated flow field and compare.
c. Seed Funding: $37,506
d. Results: Progress limited due to unforeseen complications in the application of the sliding interface.

11. Development of a Multi-Regime Solution Capability for Tenasi Flow Solver

- Principal Investigator(s): Drs. Robert Wilson & Kidambi Sreenivas, Graduate School of Computational Engineering
- Objective(s): To build on first-year progress made in the development of a multi-regime capability for solution of flows containing multiple regimes separated by material interfaces.
- Seed Funding: $57,566
- Results: 8 proposals submitted to NSF which were not funded; Proposal in the amount of $296,318 submitted to NSF which was funded.

12. Design of Stents for Bifurcated and Limb Arteries

- Principal Investigator(s): Dr. Steve Karman, Graduate School of Computational Engineering
- Objective(s): Eliminate the small courant number restriction in the application of the Tenasi code to stent implants; Reduce failure rates in stent implants to bifurcated arteries; Reduce failure rates in stent implants in leg arteries
- Seed Funding: $76,526
- Results: Proposal in the amount of $300,000 submitted to NIH which was not funded.

13. Computational Modeling of Physiological Data Using Inexpensive and Unobtrusive Sensors: A New Paradigm for computational Physiology

- Principal Investigator(s): Dr. Yu Cao, Computer Science & Engineering
- Objective(s): To investigate, develop and validate new computer and mathematical models and algorithms to discover insights from physiological information using inexpensive and unobtrusive sensors.
- Seed Funding: $49,606
- Results: Two proposals in the amount of $2,593,268 were submitted to NSF, decision is pending;

14. Investigation of Possible Triangulation Procedures of GIS Data

- Principal Investigator(s): Dr. Ramesh Pankajakshan, Graduate School of Computational Engineering
- Objective(s): Create a viable work flow to process large amount of GIS point cloud data into an acceptable computational mesh
- Seed Funding: $51,480
- Results: Proposal submitted to SimCenter Enterprises and funded in the amount of $224,657

15. NSF GENI Project

- Principal Investigator(s): Dr. Farah Kandah, Computer Science & Engineering
- Objective(s): Explore the use of very high speed programmable software defined networks
- Seed Funding: $100,000
- Results: Delays have been encountered in getting the new GENI node operational.

16. Discretization of Iconic Building, Roadways, and Railways for Realistic Urban Simulations

- Principal Investigator(s): Dr. Kidambi Sreenivas, Graduate School of Computational Engineering
- Objective(s): A procedure for generating the surface mesh on iconic buildings as well as a procedure for incorporating the road/rail networks and building footprints into the urban terrain mesh
- Seed Funding: $40,104
- Results: Proposal submitted to SimCenter Enterprises and funded in the amount of $99,388

Summary of CEACSE funding allocation (Figure 2) illustrates the major categories into which the CEACSE budget was allocated for Center activities during the past fiscal year

of operation. It should be noted that grant awards from proposals and funding requests sought from this fiscal year funded projects normally will lag 6 to 12 months.

External Funding Awarded as the Result of the Center's `Research Investment*by year

External Funding Awarded in Fiscal Year 2005-2006:	$ 2,195,529
External Funding Awarded in Fiscal Year 2006-2007:	$ 3,291,102
External Funding Awarded in Fiscal Year 2007-2008:	$ 1,855,276
External Funding Awarded in Fiscal Year 2008-2009:	$ 4,765,948
External Funding Awarded in Fiscal Year 2009-2010:	$ 6,427,956
External Funding Awarded in Fiscal Year 2010-2011:	$ 1,111,097
External Funding Awarded in Fiscal Year 2011-2012:	$ 1,125,837
External Funding Awarded in Fiscal Year 2012-2013	$ 1,853,443
Total External Funding Awarded:	**$22,626,188**

These funds represent funds committed by external funding agencies. Some of the awards included are multi-year awards with each year's funding dependent upon availability of funds.

A multi-year view of the outcomes achieved by CEACSE is portrayed in Figure 3. The outcome from funding provided to CEACSE by The State of Tennessee and The University of Tennessee at Chattanooga illustrates the achievement of a two and one half-to-one ratio when compared to the amount of external funding generated by the State's investment in research. As illustrated, this rate of return continues through FY12. This performance has been consistent and CEACSE works toward continuous improvement.

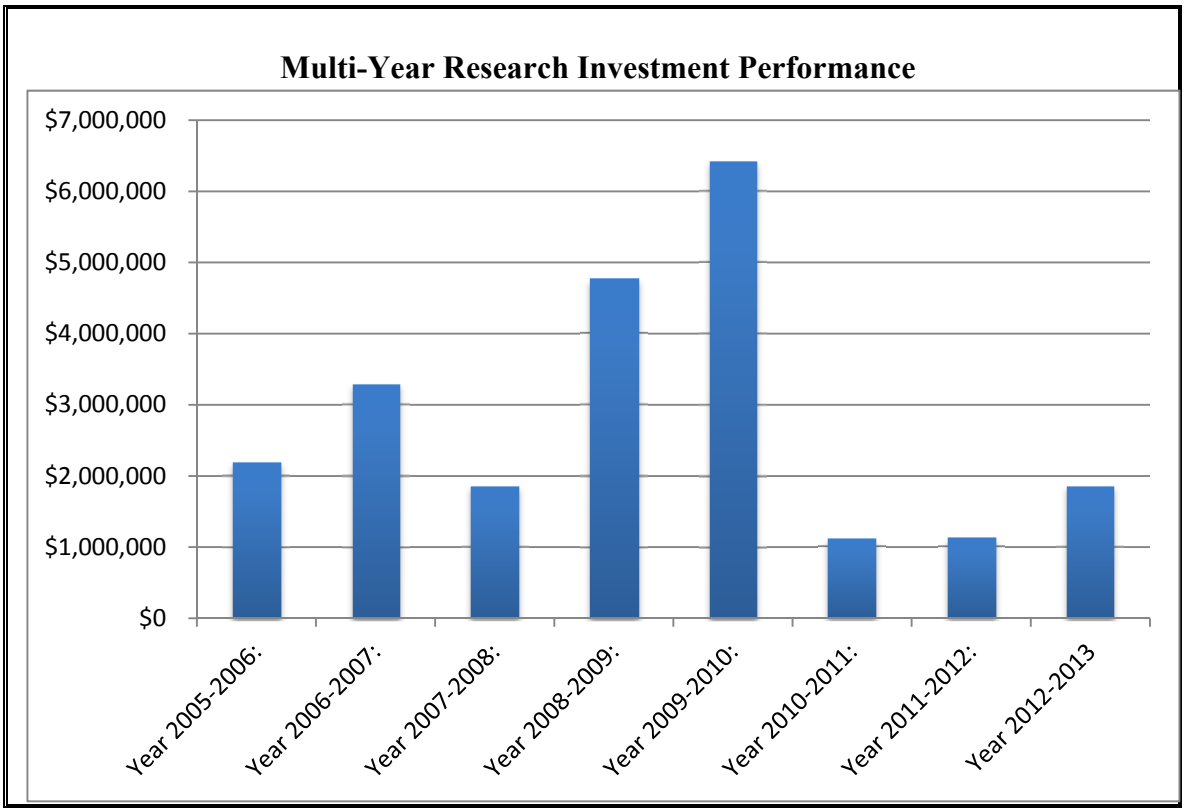

Multi-Year Research Investment Performance
$7,000,000
$6,000,000
$5,000,000
$4,000,000
$3,000,000
$2,000,000
$1,000,000
$0
Year 2005-2006:
Year 2006-2007:
Year 2007-2008:
Year 2008-2009:
Year 2009-2010:
Year 2010-2011:
Year 2011-2012:
Year 2012-2013

Figure 3

FY 2013 Publications and Presentations of the Center's Research Activities

1. Ahrabi, B.R., Sreenivas. K., and Webster, R.S., "Computational Investigation of Compressible Flow in a Diffusing S-duct," 49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference. San Jose, CA, July 2013, AIAA Paper 2013-3601

2. Flynt, G.A., Webster, R.S., and Sreenivas. K., "Computation of Heat Transfer In Turbine Rotor Blade Cooling Channels with Angled Rib Turbulators," 49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference. San Jose, CA, July 2013, AIAA Paper 2013-3621.
3. Lin, W., Sreenivas, K., Webster, R.S., and Hyams, D.G., "Effect of Casing Groove Locations on the Performance of an Axial Flow Stage," 49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference. San Jose, CA, July 2013, AIAA Paper 2013-3632.

4. Sreenivas, K, Hilbert, C.B., Mittal, A., Hereth, L., and Taylor, L.K., "High-Fidelity Computational Simulation of the Wake Characteristics of a Model Wind Turbine," 31st AIAA Applied Aerodynamics Conference, San Diego, CA, June 2013, AIAA Paper 2013-2416.

5. Taylor, L.K., Sreenivas, K., Webster, R.S., and Kress, J., "An Artificial Compressibility Algorithm for Convective Heat Transfer," 44th AIAA Thermophysics Conference. June 2013, San Diego, CA, AIAA Paper 2013-2894.

6. Glasby, R., Burgess, N., Anderson, W.K., Wang, L., Allmaras, S. and Mavriplis, D., "Comparison of SU/PG and DG Finite-Element Techniques for the Compressible Naiver-Stokes Equations on Anisotropic Unstructured Meshes," AIAA paper 2013-0691, 51st AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition, Dallas, TX, 07-10 January, 2013.

7. O'Connell, M. and Karman Jr., S. L., "Mesh Rupturing: A Technique for Geometry Insertion and Significant Mesh Movement," AIAA Paper 2013-1048, 51st AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition, Dallas, TX, 07-10 January, 2013.

8. Wang, L., Anderson, W.K, Erwin, T., and Kapadia, S., "High-order Methods for Solutions of Three-dimensional Turbulent Flows," AIAA Paper 2013-0856, 51st AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition, Dallas, TX, 07-10 January, 2013.

9. Mittal, A., and Taylor, L.K., "Optimization of Large Wind Farms Using a Genetic Algorithm," Proceedings of the ASME 2012 International Mechanical Engineering Congress & Exposition, Houston, TX, November 9-15, 2012.

10. Webster, R., Whitfield, D., Hilbert, B., Sreenivas, K., Hyams, D. and Briley, W., "Demonstration of Sub-system Level Simulations: A Coupled Inlet and Turbofan Stage," AIAA Paper 2012-4282, 48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Atlanta, GA, 2012.

11. Masters, J. S, Karman, S. L. Jr., “Manipulating Boundaries and Viscous Regions of Unstructured Meshes Using Winslow’s Equations”, AIAA Journal, Volume 50, Number 10, pp. 2080-2090, October 2012.

12. Wang, Li and Anderson, W. Kyle, “Shape Sensitivity Analysis for the Compressible Navier-Stokes Equations Via Discontinuous Galerkin Methods”, Computers & Fluids, Vol. 69, pp. 93-107, 2012.

13. Ghasemi, A., Sreenivas, K., and Taylor, L.K., "Unconditionally stable high-order picard iteration algorithm for computational electromagnetics," IEEE Antennas and Propagation Society International Symposium (APSURSI), 8 - 14 July 2012 , Chicago, IL.

14. Wang, Li, Anderson, W. Kyle, Erwin, Taylor, and Kapadia, Sagar, “Solutions of High-order Methods for Three-dimensional Compressible Viscous Flows”, AIAA Paper 2012-2836, the 42nd AIAA Fluid Dynamics Conference, New Orleans, LA, June 2012.

Conclusion

CEACSE has established operations and is positioned to continue to enhance and expand research and assist in the obtaining of external funding opportunities. Research funding for a number of diverse projects has engaged more faculty and students across the campus. The committed seed funding enabled various faculty to pursue their research and develop opportunities to obtain follow-on support externally. The Center has a requirement for recipients of funding to submit proposals to a credible agency and/or company which have an interest in the research being conducted. As evidenced, there is already a growing level of proposals being submitted and external funding being sought from the work supported by the Center. This should continue. With current external economic conditions and funding levels for research, there is increased competitiveness for the available funding.

There have been increased activities in both direct and indirect support of economic development for Tennessee. There have been a number of meetings with local and regional companies as well as indirect impacts. It is anticipated that these activities will continue.

Through the seed funding for research activities, undergraduate and graduate students are being engaged in a diverse range of topics. Additional efforts in this area assist in increasing the interaction and involvement of students with research faculty. Additional efforts will need to be defined, focused, and initiated to enhance/increase outreach to pre-college students. This area will receive additional and continued attention.

Finally, the role engineering and science must take in the US and Tennessee to maintain and improve the national economy is increasingly apparent. CEACSE is emphasizing and supporting the leveraging of its funding to enhance Tennessee's stature in engineering, science, and education in the arena of computational science and engineering. This in turn contributes to the ongoing economic development of Tennessee and the Chattanooga area. CEACSE believes if additional funding is identified for CEACSE, it would be possible for the Center to leverage, enhance and accelerate this growth and advancement of Tennessee's scientific and engineering capabilities and resources.

Schedule 7

CENTERS OF EXCELLENCE/CENTERS OF EMPHASIS
ACTUAL, PROPOSED, AND REQUESTED BUDGET

Institution UTC **Center** Center of Excellence in Applied Computational Science & Engineering

	FY 2012-13 Actual			FY 2013-14 Proposed			FY 2014-15 Requested		
	Matching	**Appropr.**	**Total**	**Matching**	**Appropr.**	**Total**	**Matching**	**Appropr.**	**Total**
Expenditures	405,600	764,498	**1,170,098**	405,600	792,061	**1,197,661**	405,600	831,664	**1,237,264**
Salaries									
Faculty	281,439	522,673	**804,113**	285,250	529,750	**815,000**	266,311	548,690	**815,000**
Other Professional	24,951	46,337	**71,288**	28,000	52,000	**80,000**	26,400	53,600	**80,000**
Clerical/ Supporting			**0**			**0**	0	0	**0**
Assistantships	15,070	27,987	**43,057**	19,250	35,750	**55,000**	18,150	36,850	**55,000**
Total Salaries	**321,460**	**596,998**	**918,458**	**332,500**	**617,500**	**950,000**	**310,861**	**639,140**	**950,000**
Longevity	53	98	**150**	**53**	**98**	**150**	**50**	**101**	**150**
Fringe Benefits	86,527	160,692	**247,219**	89,950	167,050	**257,000**	84,724	172,190	**256,914**
Total Personnel	**408,039**	**757,787**	**1,165,827**	**422,503**	**784,648**	**1,207,150**	**395,634**	**811,430**	**1,207,064**
Non-Personnel									
Travel	2,665	4,950	**7,615**	2,800	5,200	**8,000**	2,310	4,690	**7,000**
Software	820	1,523	**2,344**	840	1,560	**2,400**	660	1,340	**2,000**
Books & Journals			**0**			**0**	0	0	**0**
Other Supplies	829	1,540	**2,370**	875	1,625	**2,500**	660	1,340	**2,000**
Equipment	1,235	2,293	**3,528**	1,225	2,275	**3,500**	660	1,340	**2,000**
Maintenance	13	23	**36**			**0**	0	0	**0**
Scholarships	4,801	8,917	**13,718**	4,900	9,100	**14,000**	4,620	9,380	**14,000**
Consultants			**0**			**0**	0	0	**0**
Renovation			**0**			**0**	0	0	**0**
Other (Specify)			**0**			**0**	0	0	**0**
Communications	564	1,047	**1,611**	703	1,203	**1,906**	330	670	**1,000**
Printing	1,004	1,864	**2,868**	1,050	1,950	**3,000**	660	1,340	**2,000**
Postage	41	76	**117**	70	130	**200**	66	134	**200**
Total Non-Personnel	**11,972**	**22,234**	**34,207**	**12,463**	**23,043**	**35,506**	**9,966**	**20,234**	**30,200**
GRAND TOTAL	**420,012**	**780,022**	**1,200,033**	**434,965**	**807,690**	**1,242,656**	**405,600**	**831,664**	**1,237,264**
Revenue									
New State Appropriation		764,498	**764,498**		792,061	**792,061**		831,664	**831,664**
Carryover State Appropriation		31,153	**31,153**		15,629	**15,629**			**0**
New Matching Funds	405,600		**405,600**	405,600		**405,600**	405,600		**405,600**
Carryover from Previous Matching	43,777		**43,777**	29,365		**29,365**			**0**
Total Revenue	**449,377**	**795,651**	**1,245,028**	**434,965**	**807,690**	**1,242,656**	**405,600**	**831,664**	**1,237,264**