Faculty Plan

Center for Computation & Technology
Louisiana State University

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CCT Faculty Plan

Among the obstacles to progress are rigid disciplinary silos in academia ... These silos stifle the development of multidisciplinary research and educational approaches essential to computational science. Our report recommends that both universities and Federal R&D agencies must fundamentally change these organizational structures to promote and reward collaborative research.

PITAC Report [1]

1 Summary

The Center for Computation & Technology (CCT) at Louisiana State University has undergone rapid growth since its inception in 2003. The CCT has developed in line with the original plan produced by Director Seidel, Gabrielle Allen, John Towns[1], and Harold Silverman over the spring of 2003. An emerging revision of the original themes is a focus on *Complex Applications for Future Systems*. This theme encompasses advanced high performance computing (HPC) architectures, software, data, networks, sensors, and complex discipline-specific applications that exploit them all to solve problems in critical areas to the state, such as coastal and environmental studies, geosciences, astrophysics and business.

We believe that we are well on track to develop a unique and world leading research center across a comprehensive set of disciplines. The CCT is a central component of LSUs academic development in the coming decades. This document represents a further step towards aligning CCT and departmental priorities across LSU. We expect that as the CCT develops, departments across the university will be able to hire faculty, without CCT-specific funds, that will leverage the center's strengths and programs. The success of the CCT as a force on campus depends critically on alignment across the university. *As current CCT funding becomes fully allocated, it will be very important for departments to continue to hire faculty in areas that resonate with the CCT's strengths. We see the CCT as seeding and catalyzing computationally oriented interdiscplinary research activities across campus.*

In this document, we review the original plans, describe progress to date, and discuss faculty hiring priorities that will bring CCT to an internationally prominent position in computational sciences and applications of importance to the state. It is important to note that the CCT has aligned itself very strongly with the Presidential Information Technology Advisory Committee (PITAC) report [1], whose principal recommendations are summarized in an appendix, and the NSFs newly created Office of Cyberinfrastructure, which is developing a strategic plan for 21st Century Discovery [2]. We strongly recommend reading these documents to obtain a better understanding how we intend to build the CCT, and the qualities we will look for in future faculty and staff hires.

We have also developed the CCT Strategic Plan, which articulates concrete and measurable deliverables and milestones that are fully aligned with LSU's Flagship Agenda across 5 areas: Research, Education, Service, Infrastructure and Economic Development, but which does not discuss specific reseach areas to be developed. This Strategic Plan has been developed over more than six months, in close connection with Vice Chancellor Silverman, consultant Jim Firnberg, and has been discussed with all campus Deans. The CCT Strategic Plan can be found at http://www.cct.lsu.edu/about/strategic_plan. Together, this Faculty Plan and the CCT Strategic Plan form the basis for CCT's future development.

2 Original CCT Plans

The CCT developed the following original plan in Spring 2003, with some small modifications:

[1] Director of Persistent Infrastructure at the National Center for Supercomputing Applications

- The CCT is an interdisciplinary research center consisting of overlapping research groups led by faculty in many areas on campus. Faculty appointments are generally split with departments on a 50-50 basis, with both service and research components in both units. Joint faculty are expected to spend time, develop programs, and have a significant presence in both units. Tenure resides in the department, but promotion and tenure processes are jointly carried out with both units.
- Although Focus Areas are developed across many disciplines, a strong thematic focus for all groups is computational sciences. The first groups are in critical areas of Core Computational Sciences: Scientific Computing, Grids, Networks, Software Toolkits, and Computational Mathematics. These groups are being reorganized slightly as discussed below to provide stronger leadership and synergies between research activities. The primary departments to partner with in these areas are Computer Science, Electrical and Computer Engineering, and Mathematics.
- Application disciplines are developed with departments across campus. Initially, numerical relativity, CFD, business, materials, and digital arts were targeted, while potential areas of future investment include, but are not limited to, coastal modeling, geosciences, biomedical computing, and computational materials/chemistry. Research groups have been organized in thematic Focus Areas: initially Core Computational Sciences, Coast to Cosmos (C2C), Material World, Visualization, Interaction, Digital Arts (VIDA), and Business, Medical and Social Informatics (BMSI). These areas are currently being reorganized as discussed below.
- All areas are expected to have strong multidisciplinary overlap, and much effort is spent to develop cross-cutting projects that involve multiple research groups. For example, a comprehensive coastal modeling initiative should include prominent discipline specialists who are also leaders in applying modern cyberinfrastructure to coastal modeling, as well as faculty in computational mathematics, scientific computing, visualization, grids, etc. (See Centers of Excellence below.)
- Each research area needs to be sufficiently focused and sized to ensure critical mass, e.g., a single faculty member in an area would not be enough to form a world leading effort in interdisciplinary research. The faculty need to be clustered in research groups of sufficient numbers.
- Although most CCT funding is on faculty development, the CCT supports a smaller number of high level research staff in appropriate areas of computational science, ranging from research programmers and staff scientists (http://www.cct.lsu.edu/about/people/researchstaff.php) to HPC support personnel.
- The CCT is developing an advanced HPC environment that must ultimately be greatly augmented by external funds, ideally leading to the establishment of CCT as a national center.
- Several important programs within the CCT include: (1) a visitor program, bringing many visitors from across the world to give seminars and establish collaborations with LSU researchers; (2) a graduate student fellowship program; (3) a postdoc program; and (4) a General Development Program designed to seed collaborative projects that could attract external funding.
- An executive committee to advise and coordinate developments within CCT and with units across campus is critical. The original executive committee of five members has been redeveloped into an advisory committee consisting of all campus deans and the Vice Chancellor for Research, and will meet each semester.

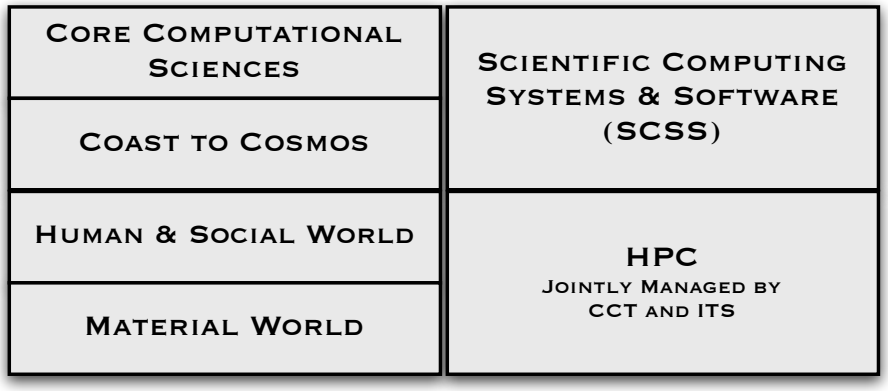

Figure 1: The overview of the CCT. The (now) four Focus Areas, where faculty-led research groups are developed, are shown on the left. The SCSS division, led by Professor Dan Katz, will have high level staff who work with CCT research groups and HPC (as well as the Laboratory for Creative Arts and Technology or LCAT) to develop an advanced environment, using tools from CCT and elsewhere, to advance the Focus Areas research. HPC, now jointly operated by CCT and Information Technology Services (ITS) at LSU, operates and maintains the HPC computing environment.

3 Recent Progress

3.1 Faculty Hires and Research Groups

In the past two years, good progress has been made in setting up a thriving center. Visitors have been uniformly impressed, and our ability to attract top faculty has steadily increased. A new category of CCT Associate Faculty has been created, providing summer salary, an office, and access to CCT programs, to create stronger and more numerous ties with units across the campus. Further policies to create "CCT Fellows" are underway. Since the initial recruitments beginning July 2003 (Seidel, Allen, Diener), new joint 50-50 faculty have been recruited in physics (Tiglio), computer science (Kosar, Park, Sterling, Ullmer), mass communication (Porter) and mathematics (Aksoylu, Brenner), and J. Ramanujam in ECE was made a CCT faculty member. Additional recruitments have been in process this spring. Five CCT Associated Faculty members have been appointed to accelerate CCT application areas of strategic importance: Acharya (Mechanical Engineering), White (Petroleum Engineering), Pullin (Physics), Twilley (SCE), and Tohline (Physics). The emerging strengths and research groups are discussed below. Collectively, CCT faculty have been involved in roughly $20M in external funding, and have also been instrumental in initiating large state funded projects.

These new hires join existing faculty recruited or paid (partially or fully) by LSU CAPITAL, prior to CCT initial recruits above, without the concept of a thematic, co-located Center in mind: Beck (Music), Iyengar (CS), Karki (CS), Daniels-Race (ECE), Wei (ECE), Hirschheim (ISDS), Clark (ISDS, retiring in August), Daigle (Accounting), Hayes (Accounting), Sanger (Finance), Watson (ISDS), Wiley-Patton (ISDS).

Table 2 shows current faculty at CCT Normally, CCT tenured or tenure-track faculty should have appointments which are funded 50 percent at CCT and 50 percent in their home departments, and should participate in both units. More information about CCT faculty can be found at
http://www.cct.lsu.edu/about/people/faculty/all.php.

Computer Science
Sitharama Iyengar
Thomas Sterling
Gabrielle Allen (Adjunct Physics)
Bijaya Karki
Tevfik Kosar
Seung-Jong Park
Ian Taylor (Visiting Professor)
Brygg Ullmer

Mathematics
Susanne Brenner
Burak Aksoylu
Paul Saylor (Visiting Professor)

Petroleum Engineering
Chris White (Associate Faculty)

Mechanical Engineering
Sumanta Acharya (Associate Faculty)

Music
Stephen D. Beck

Mass Communications
Lance Porter

Electrical Engineering
Dan Katz (Research Faculty)
J. Ramanujam
Bingqing Wei
Theda Daniels-Race

Oceanography & Coastal Science
Robert Twilley (Associate Faculty)

Physics
Jorge Pullin (Two year appointment)
Edward Seidel (Also CS)
Joel Tohline (Associate Faculty)
Manuel Tiglio
Peter Diener (Research Faculty)

Finance
Gary Sanger

ISDS
Rudy Hirschheim
Edward Watson
Sonja Wiley-Patton

Accounting
Ron Daigle
David Hayes

Figure 2: Current faculty at CCT, listed by academic department, including reseach, associate and visiting faculty

3.2 Facilities

ITS and CCT have entered into an agreement to jointly manage and fund HPC resources on campus. In addition to CCT's Supermike, Helix, Santaka, and Nemeaux machines, and the ITS Pelican machine, we have developed a plan to further strengthen our joint HPC offering and to better support users across campus. We are also developing incentives for campus groups to jointly invest with us to manage collective HPC resources in exchange for guaranteed time on centrally managed resources.

LCAT is a CCT—wide facility that serves as the physical laboratory for much of the activity surrounding not only digital arts and visualization, but also other CCT research groups and interested groups across campus. LCAT is directed by Prof. Stephen David Beck, who is responsible for working with its many groups that both develop the technologies and use them to advance their application areas.

CCT has created a division entitled Scientific Computing Systems and Software, or SCSS, and recruited several staff and a well-known director, Prof. Dan Katz, formerly at Caltech-JPL who has great experience in HPC and visualization systems, software, and their use. SCSS is responsible for providing leadership to advance the environment of both HPC and LCAT, in accordance with the needs of the users. We expect to develop a unique and highly competitive and compelling computing, networking, visualization, collaboration, and audio environments that will give our application groups the ability to carry out research that is difficult or impossible elsewhere. SCSS will also work closely with the Core Computational Science groups and other such groups around the world to help advance, test and deploy the research

tools under development.

As CCT hires more faculty and staff, it will have less funding available for HPC systems. For this reason, it is critical both that local (ITS, LSU, State) and Federal funding sources be sought to keep our facilities at the forefront. To this end, a $67M proposal has been submitted to NSF to establish a national supercomputing facility of more than 12,000 processors; other large proposals will follow.

CCT has also been very active in developing and promoting regional infrastructure and collaborations that will make us much more competitive for our research and for external funding. We spearheaded the Louisiana Optical Network Initiative (LONI), which was funded at a level of $40M by Governor Kathleen Blanco and led a SURA initiative to build an HPC computing grid across the southeast region.

We will build on current faculty and staff strengths, our leading infrastructure, and recruitment of additional faculty in targeted areas to create several "Centers of Excellence" (e.g., "Gravitational Wave Physics," and "Modeling the Mississippi Delta," see Sec. 5 and Fig. 7 below.). These comprehensive and uniquely powerful research teams may draw from all Focus Areas and from faculty across campus, whether or not they have formal CCT appointments. In time, we advocate that many faculty who are not paid through CCT join such efforts.

4 Focus Areas

4.1 Overview

In a new reorganization, research activities of CCT are presently organized around four *Focus Areas*, shown in the left column of Fig. 1. Each Focus Area (FA) is led by a senior faculty member and could be thought of as similar to an LSU Department, with the Focus Area leader functioning as a Department Head. The Focus Areas contain broad *research clusters* that generally contain multiple CCT faculty members and are led by faculty who provide intellectual leadership for the cluster area, initiating and supporting appropriate projects, ensuring that the cluster is performing interdisciplinary research, and providing some amount of support funding and administration for the cluster. Research clusters may be fairly broad, with multiple *research groups* led by individual faculty members, but they should be multiply connected to other research efforts.

Each Focus Area needs to have a critical mass of experienced interdisciplinary researchers if it is to develop world leading programs. At present, two of the areas (Core Computational Sciences (CCS) and Coast to Cosmos (C2C)) have nearly reached this stage, although there remains much work to be done.

4.2 Criteria for CCT Faculty

Faculty are the crucial component of the Focus Areas and hence the CCT. They provide the vision and direction of CCT research, produce bridges and connections between CCT and departments, mentor students and postdocs in interdisciplinary research, and produce research papers and lead funding opportunities. CCT Faculty need to:

- Be world class experts in their discipline, with a proven record of innovation and advancement.
- Be leaders in the use and development of computational/technological approaches to the discipline.
- Understand and believe in the ideas contained in recent reports of the PITAC committee [1], and the NSF Cyberinfrastructure Strategic Plan [2].
- Be able to engage in interdisciplinary research, which integrate with exisiting and future CCT research groups in a meaningful way.
- Possess interactive personal qualities and leadership abilities.

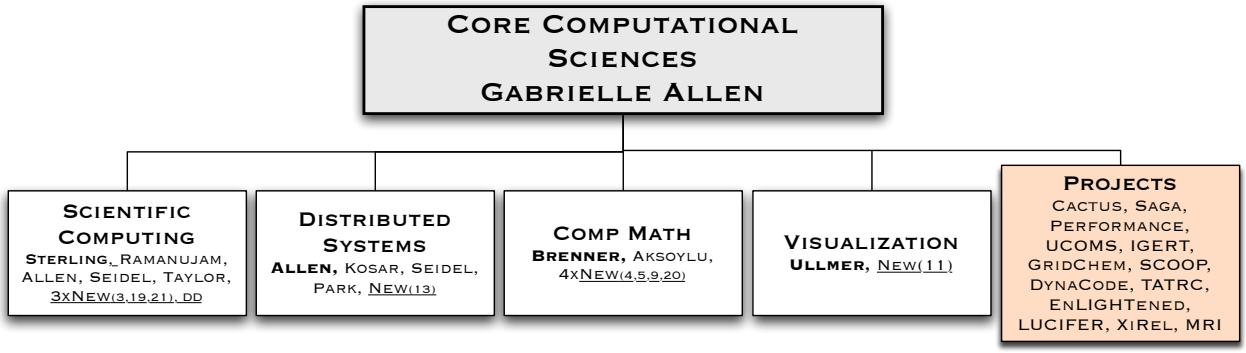

Figure 3: Core Computational Sciences Focus Area. Proposed research cluster leaders are shown in boldface and planned recruits are indicated (see table in Section 6). DD here is the Deputy Director, targeted as a position in large scale systems. Representive cross-cutting projects of the groups are also shown.

Since the CCT was created, numerous faculty have been recruited who possess these qualities, forming strong, interactive research clusters. However, two problems should be mentioned: First, the CCT needs more senior faculty with an established track record to help lead their areas forward. Second, a number of faculty who were hired with CCT funds prior to its founding are not well aligned with its mission, and do not participate in its programs. Future hires must address these issues.

4.3 Core Computational Sciences (CCS)

The Core Computational Sciences area (see Fig. 3) is currently led by CS Prof. Gabrielle Allen, and provides the computational foundation on which other CCT research groups will build. The Core CS area is broken down into four research clusters: Scientific Computing (e.g., future systems, computational frameworks, data, and application tools), Distributed Systems (e.g., Grid computing, collaborative environments, advanced networking and sensors), and Computational Mathematics (e.g., linear systems, partial differential equations, multigrid, and multiscale algorithms), and Visualization (e.g., remote visualization, algorithms for large data, tangible devices).

Core CS is already very strong in computational sciences and applications, and is leading the CCTs involvement in several large funded projects. The broad research interests of current faculty cover:

- Application tools and frameworks (Gabrielle Allen (CS), Ian Taylor (CS), Ed Seidel (Physics))
- Data and grids (Tevfik Kosar (CS))
- Architectures (Thomas Sterling (CS))
- Networks (Seung-Jong Park (CS))
- Performance (J. Ramanujam (ECE))
- Finite elements and multigrid (Brenner (Math))
- Multiscale algorithms (Aksoylu (Math))
- Scientific computing (Dan Katz (ECE))
- Visualization (Brygg Ullmer (CS))

With some additional strong recruits, our faculty can create one of the most powerful, most comprehensive efforts worldwide. Areas of top priority to facilitate this are: compilers and operating systems, visualization, programming languages, scientific computing, linear and hyperbolic systems, and large scale systems. The CCT is sufficiently advanced in Core CS that it should be very competitive for recruiting some of the top people in these fields forming an incredible foundation on which to build the

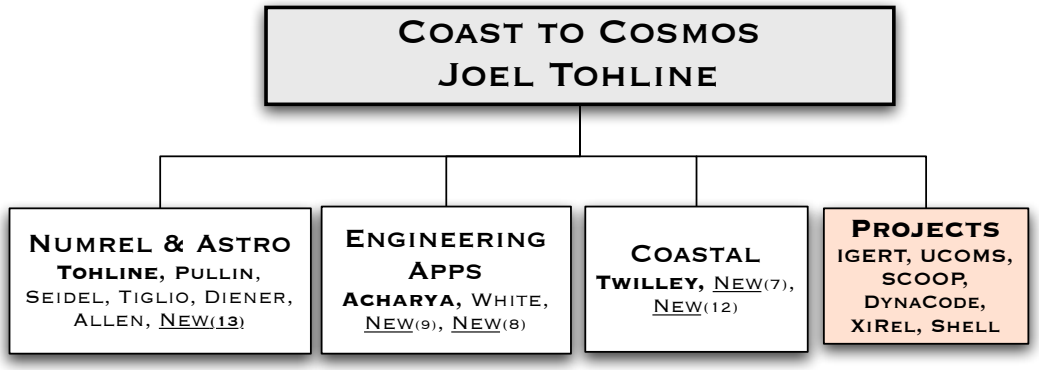

Figure 4: Coast to Cosmos (C2C) area, led by Prof. Joel Tohline is concerned with modeling the physical world in which we live.

application clusters described below.

4.4 Coast to Cosmos (C2C)

The Coast to Cosmos area, now led by Prof. Joel Tohline (Physics), contains research clusters concerned with modeling the physical world in which we live, from ecosystems in the Mississippi Delta to the large scale structure of the Universe. These topics are broken down into three research clusters: Numerical Relativity and Astrophysics (including relativistic and newtonian models of neutron star and black hole binaries), Engineering Applications (including turbomachinery, biomedical flows and porous transport), and Coastal Processes (including hurricane and ecological modeling in the Delta). A future research cluster in Geosciences is under consideration. Cross cutting themes for all these groups include the use of computational frameworks, and need for scientific visualization and large scale compute resources, as well as algorithms and linear systems.

The broad research interests of current faculty cover:

- Numerical relativity (Edward Seidel (Physics), Manuel Tiglio (Physics), Gabrielle Allen (CS), Jorge Pullin (Physics), Peter Diener (Physics))
- Astrophysics (Joel Tohline (Physics), Jorge Pullin (Physics), Edward Seidel (Physics))
- CFD engineering applications (Sumanta Acharya (MechEng), Chris White (PetEng))
- Reservoir simulations and porous flow (Chris White (PetEng))
- Ecological modeling (Robert Twilley (SCE))

Current planned hires in this area will provide core expertise in engineering and coastal modeling. The coastal modeling area has been the focus of much activity for two years, as core computational sciences projects have been developed with both internal (CCT) and external funding (e.g., the SURA Coastal Ocean Observing and Prediction (SCOOP) project and the associated NSF DynaCode project). Important collaborations with modelers from other states have been established. However, a serious difficulty has been that there are no in-house discipline experts in large scale coastal modeling at CCT or on campus. *It is critical that a senior, experienced leader, possing the qualities described in Sec. 4 above, be recruited to anchor this effort as it it moves forward. This is an area where LSU can and should be a world leader. In order to achieve this, it will be necessary for departments across campus to consider hiring relevant faculty to add to the "Center of Excellence" model described below.*

An additional hire is targeted to an area with large scale data needs, for example a faculty member with expertise in LIGO data would be of great relevance to the Astrophysics cluster.

4.5 The Human & Social World

The "Human & Social World" deserves special comment. Formerly, we had two separate Focus Areas, Visualization Interaction and Digital Arts (VIDA) and Business, which had various difficulties of critical mass, alignment, and appropriate connection to other parts of the CCT. To address this, in 2005, Prof. Rudy Hirschheim (ISDS) was appointed the Business Focus Area lead, and charged with constructing and executing a plan for alignment with the CCT and Vision 20/20 mission. BMSI, or Business, Medical and Social Informatics, was an initial attempt to rework the original Business Focus Area. At the same time, VIDA had an artistic mission, but also contained scientific visualization and collaborative environments groups. Although an excellent and novel concept, the result was that these groups did not have strong enough interaction with the CCS groups. Further, it mixed the mission of VIDA to have both application and tool-building groups, unlike the other areas which concentrate on one or the other.

After much discussion, we moved Scientific Visualization into CCS, where it will be better connected to other computational sciences. This will also allow the digital arts and humanities groups to become more focused on the *applications* of the visualization and other computational sciences, rather than their *development*. Recognizing similarities between the nontraditional application areas in VIDA and BMSI, and current lack of critical mass in either, we have combined the active parts into one FA, called the *Human & Social World* (HSW). This area will represent the emerging and nontraditional applications that encompass arts, humanities, and social sciences. A major thrust of this area will continue to be digital arts, but will now also include areas formerly in the business application area.

The HSW focus area is led by Prof. Beck (Music). HSW will develop application-oriented research programs that exploit computation and technology to advance nontraditional and emerging disciplines in art, humanities, social sciences, business, and medicine. It will retain the unique artistic mission of VIDA, to imagine and realize intersections of technology, creativity, communication, and other forms of human expression. HSW will investigate how new technologies can be used to complement the work of researchers in science and the humanities, as well as to investigate the use of new tools, platforms and environments for artistic expression. It will also explore applications in areas such as computational humanities and business. At the same time, HSW will retain the technology adoption prevalent in the areas of BMSI, led previously by Prof. Hirschheim, with a plan to research the broad spectrum of information technology application adoption in organizations embodying planning, requirements, deployment, implementation, use, and evaluation.

Initially, HSW will have two research clusters that reflect its primary missions: (i) emerging applications; and (ii) technology adoption. Prof. Beck will lead the emerging applications area, while Prof. Hirschheim will lead the technology adoption cluster. It will be critical to carry out searches for a few highly experienced faculty with a track record of using cyberinfrastructure to advance their disciplines in the coming year or two, to turn this into a world leading unit. As faculty are recruited, with targets already set for computational art, music and humanities, more research clusters and reorganization will be likely. In particular, the emerging applications cluster may split into computational humanities and digital media and art, depending on faculty recruitment.

The initial plans in the technology adoption cluster involve faculty outside the CCT, which is highly encouraged, including Drs. Kaganer, Rinks, Pawlowski, Schwarz, Hillebrandt, to investigate areas such as business use of grids, medical technology, emergency response and decision making. In the emerging applications cluster, we have identified projects in areas as diverse as financial modeling, traffic simulations, computer music, and digital art.

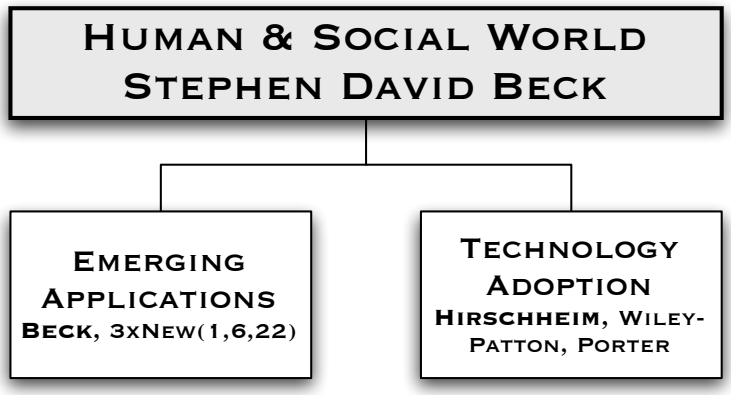

Figure 5: The Human and Social World (HSW) Focus Area seeks to imagine and realize intersections of technology, creativity and communication. It will initially have two research clusters: emerging application areas (arts, humanities, social sciences, & business), and technology adoption in the social world.

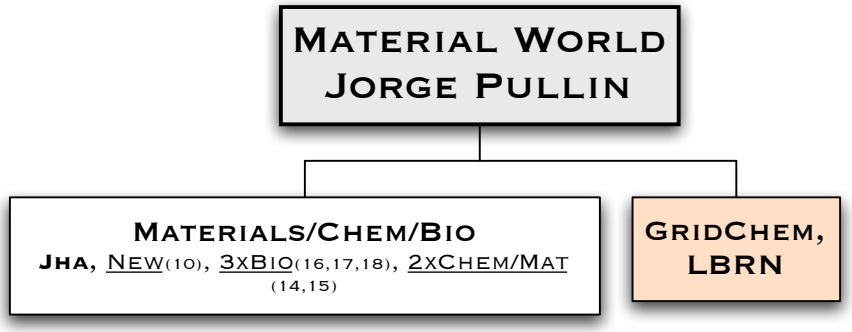

Figure 6: Material World Focus Area. Planning and faculty recruitment activities for this focus area are currently underway.

4.6 Material World (MW)

The Material World Focus Area (see Fig. 6) is envisioned to have groups who use computational approaches to complex problems in biology, medicine, chemistry, and/or materials science. Although CCT currently pays two outstanding faculty in the materials area (Daniels-Race, Wei) hired before the creation of CCT, it does not currently have faculty who align with the CCT mission as described above. We are presently developing an advisory board consisting of local and external faculty who are prominent in computational approaches to these disciplines to help us develop a plan to achieve our goals. We have recently hired an experienced staff member, Dr. Shantenu Jha, to work with Focus Area lead Prof. Jorge Pullin (Physics) to help us launch this Focus Area.

Much of the future direction of this FA will depend on the advice of the advisory board and initial faculty recruits. The recent visit of Professor John Wooley (UCSD) initiated a discussion of how coastal ecology could provide a rich and unifying theme for computational biology that would resonate with the coastal modeling efforts described above. Currently operating projects in MW include GridChem and the $16.9M Louisiana Biomedical Research Network (LBRN) project funded by NIH. Building on this, we have hired a postdoc to help develop a Bio-informatics Toolkit in Cactus.

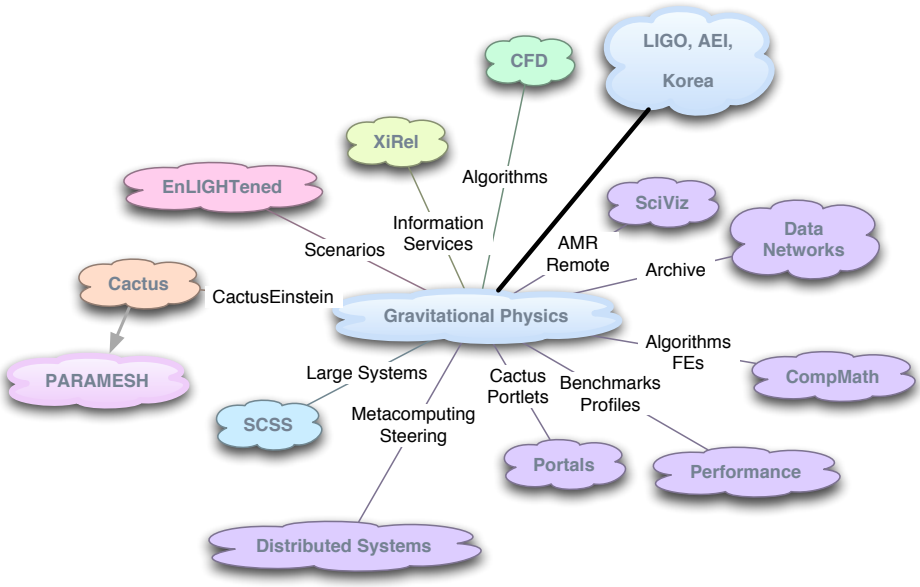

Figure 7: The Center of Excellence for Gravitational Wave Astronomy will involve faculty and researchers from across the CCT, as illustrated in this diagram of existing connections between the numerical relativity group and other research groups and projects at CCT.

5 Centers of Excellence

The previous section has outlined the structure and research clusters of the still evolving CCT Focus Areas. Although the Focus Areas provide the fundamental research homes for CCT faculty, we have recently developed the idea of promoting interdisciplinary clusters of faculty via *Centers of Excellence*. Each center of excellence at CCT will join faculty and researchers in pursuit of a *Grand Challenge* problem of science, engineering or art. Although driven by application areas, these teams will necessarily involve groups from CCS clusters and SCSS. Centers of Excellence will also engage faculty from across the LSU campus and other Louisiana universities.

Initial ideas for centers of excellence at CCT include Gravitational Wave Astronomy, Modeling the Mississippi Delta, Turbomachinery, Computational Humanities. Fig. 7 shows the existing connections across active groups and projects at the CCT which would together form the Center of Excellence for Gravitational Wave Astronomy. With a meaningful connection to the LIGO group in Physics, this could be the leading team in the world, surpassing similar efforts at top sites such as Caltech.

We intend to develop a similarly comprehensive Center of Excellence in Modeling the Mississippi River Delta, that builds on many exisiting efforts at CCT and across the campus. Many faculty and staff in computational sciences would also participate in this area, as would experts in CFD and other areas. But in contrast to Gravitational Wave Astronomy, where we already have a critical mass of discipline experts who have established track records of leadership aligned with the PITAC report and NSF's Cyberinfrastructure Strategic Plan, we must identify and recruit top discipline-specific LSU faculty to establish a Center of Excellence in this area. We believe the first hire in this area will be critical to its future success. A candidate must be identified who fits all qualities described in Sec. 4.2 above.

6 Next Steps for Faculty Hires

Building on the current strengths and increased visibility internationally, CCT is now in a position to partner with campus units to recruit targeted faculty at both junior and senior levels to build world leading groups in virtually every area of investment. Each recruitment must be developed very carefully to make sure it addresses both the strategic and functional needs of the CCT, the departments, and the joint research clusters. Ad hoc hires in any discipline could easily impede the ability of CCT to carry out its mission, and hinder the development of synergistic relationships between departments and CCT. Each faculty appointment within CCT is critical, because each research cluster is relatively small and yet must overlap with and support others.

To address these issues, CCT has been developing policies and procedures which must urgently be completed and activated, with close departmental involvement. Existing documents address procedures for joint faculty hires and involvement of CCT in the mentoring of joint faculty. To be ultimately successful, the CCT should be a catalyst for a change across LSU departments to embrace high end computational and technology, with future departmental hires made that resonate with CCT programs.

The next table lists *potential* faculty hires at CCT, along with tentative departments. The number in the first column is used in the focus area organizational charts in Fig. 3, 4, 6 and 5. The second column indicates the possible level of the position, while OH indicates a purely opportunistic hire targeted at the recruitment of a particular person.

	Field	**Level**	**Poss. Dept**
1	Art/Visualization	OH	Art
2	Scientific computing	Any	ECE
3	Operating systems & compilers	Senior	ECE (CS)
4	Linear systems	Senior	Math
6	Music	Junior	Music
7	Coastal modeling	Senior	SCE/Civil Eng
8	Petroleum Eng/Porous Flow	Junior	Pet Eng
9	Computational fluid dynamics	Junior	Mech Eng
10	Photonics	Junior	ECE
11	Scientific visualization/graphics	Any	CS
12	Coastal process modeling	Junior	SCE
13	Data applications	Senior	Phys/Chem/Bio
14	Computational materials	Senior	Phys/Chem/ECE/ME/CE
15	Computational materials	Junior	Phys/Chem/ECE
16	Computational biology	Junior	Biology
17	Computational biology	Senior	Biology
18	Computational biology	Junior	Biology
19	Scientific computing	OH	CS/ECE/Math
20	Hyperbolic PDEs & AMR	Senior	Math
21	Programming languages	Senior	ECE (CS)
22	Computational humanities	Senior	

References

[1] Report to the President of the US, June 2005. Computational Science: Ensuring America's competitiveness. President's Information Technology Advisory Committee, http://www.nitrd.gov/pitac/reports/20050609_computational/computational.pdf

[2] NSF Cyberinfrastructure Council. NSF's cyberinfrastructure vision for 21st century discovery. Technical Report 5.0, January 2006. http://www.nsf.gov/od/oci/ci_v5.pdf

Appendix A: PITAC Recommendations

The CCT has aligned itself strongly with the Presidential Information Technology Advisory Committee (PITAC) report [1], the main recommendations of which are:

- Universities must significantly change organizational structures: multidisciplinary and collaborative research to remain competitive in global science.
- Federal investments must rebalance to: **Software:** create reliable, easy to use, scalable software that will enable scientists to focus on discovery. **Hardware:** develop, prototype, evaluate new hardware architectures to deliver larger peak and sustained performance at the petaflop level for scientific applications. **Data:** focus on data-intensive solutions to address the coming data explosion with advances in sensors and sensor networks.