

1 Status and Overview

Support from the National Science Foundation has played a key role in the state of Mississippi. With NSF resources we have been able to expand our research infrastructure and to increase our competitiveness. The entire jurisdiction has united to build a holistic research capacity at each of its research institutions. This has resulted in an increase in total external funding for the Mississippi Institutions of Higher Learning (IHL) from \$373,279,597 in FY 2002 to \$528,055,536 in FY 2007. The number of projects supported during the same period has grown from 2,757 to 3,056. This 27% increase in the average award reflects a major shift from small, single-investigator grants to large, interdisciplinary, collaborative projects. EPSCoR funding has significantly impacted our ability to build human and technological infrastructure, to broaden participation among underrepresented groups, and to promote multidisciplinary teams of investigators who are increasingly competitive for external funding.

Strengths and Barriers: As part of its strategic plan, the State has invested significantly in high-performance computing (HPC) resources in each of its major research institutions with the result that Mississippi now ranks seventh in the June 2008 TOP500 Supercomputing Sites list [1]. The Mississippi State University (MSU) High Performance Computing Collaboratory, initially an NSF Engineering Research Center (ERC), originated in 1990 and has been self-sustaining since 2001. It has a long history of providing high-end computing resources in support of research activities and has appeared in 17 of the past 23 Top 500 Supercomputing lists [1]. Currently, its largest system is a 2048-processor system that at installation ranked as the 115th most powerful computer in the world and the 18th most powerful in U.S. academia [1]. The Mississippi Center for Supercomputing Research (MCSR) is housed at the University of Mississippi (UM) and provides free access to a range of HPC resources for all eight IHL institutions. Platforms include a distributed memory Linux Beowulf Cluster, a Silicon Graphics Origin 2800, a Silicon Graphics Altix 3700, and a Silicon Graphics Altix XE 250/310. Jackson State University (JSU)—the State's largest HBCU—utilizes HPC in support of the computational sciences through the Center for Applied Computational Sciences, Computational Center for Molecular Structure and Interactions and the High Performance Computing Visualization Center Initiative. The University of Southern Mississippi (USM) utilizes the MCSR and collaborates in HPC with the other institutions. These impressive resources provide the tools and opportunities for institutions to build a highly competitive research infrastructure.

In conjunction with prior and current EPSCoR investments, the State has worked to develop a critical mass of faculty at research universities with expertise at the intersection of biosciences and HPC, one of Mississippi's embryonic and niche areas. Yet barriers to establishing a nationally competitive multidisciplinary research teams remain including the recruitment of new faculty, development of younger faculty, and retention of experienced faculty. Furthermore, our existing expertise in key research areas is comprised primarily of small and geographically dispersed groups, making inter-institutional and interdisciplinary collaborations more difficult. Additional barriers include the need for added statewide connectivity, financial resources to upgrade and purchase research equipment and limited financial resources at the state level. These barriers are limiting as we strive to build teams capable of competing for large, multi-disciplinary research efforts and to develop a larger virtual research community.

Opportunities: The EPSCoR funding sought in this proposal will provide Mississippi with a unique opportunity to nurture a new research focus area that is closely aligned with the State's economic development plan. Mississippi has previously leveraged investments in computational infrastructure to attract new industry in need of expertise and research capacity in the computational sciences. Our research universities continue to be vital drivers of economic growth in the State and its goal of identifying and pursuing high-value, high-growth industries in both manufacturing and services and incentives that are aligned around these targets. This effort has attracted growth in the automotive, aerospace and materials sectors and has seen Nissan, Toyota, Eurocopter, Aurora, Stark Aviation, GE, and Hybrid Plastics locate in the State within the past five years. We will use this prior success by expanding the focus of our research universities into the area of biosciences with the goal of establishing a nationally competitive research presence that can assist the State in attracting industry in such key areas as biotechnology, health care and pharmaceuticals.

Background and rationale for our scientific vision: The Mississippi Research Consortium (MRC), comprised of the chief research officers at our four research institutions—JSU, MSU, UM, and USM—has played an integral role in driving the Science and Technology (S&T) plan for the State since the MRC was designated in Mississippi Executive Order 713 as the scientific and technical research advisor to the governor. The Mississippi S&T Action Plan, approved in 1998, presented a vision that “Science and technology will enable current and future Mississippi businesses to compete globally in the 21st century, by producing knowledge, significant and sustainable improvements in the State’s economy, workforce, and quality of life.” Strategic goals include achieving “national and regional recognition of the State’s technology application and commercialization success and promoting and sustaining” accessible research and development.

Subsequent initiatives include Blueprint Mississippi [2], a plan developed by business and education leaders to propel Mississippi’s economy while increasing diversity and enhancing its economic base. Recommendations include identification and pursuit of high-value, high-growth industries in both manufacturing and services; alignment of incentives and resources around these targets; and increasing public and private research and development funding and improving the effectiveness of technology transfer and capital accessibility programs to help commercialize innovations. The highest priority recommendations of BluePrint Mississippi were accepted by Momentum Mississippi [3], formed in 2004 by Governor Haley Barbour to address the State’s long term economic plans. Modeling and simulation of complex systems plays a critical role in industries identified in the 15 target areas: aerospace/aviation; automotive, assembly and suppliers; communication/information technology; defense/homeland security; and plastics/polymers/chemicals. Other recommendations consistent with the focus of this RII proposal call for an increase in public and private R&D funding and improvement in the effectiveness of technology transfer and capital accessibility programs for commercializing innovation. It was recognized that existing programs should be explored to further encourage R&D through research universities as well as a program for growing the defense industry in Mississippi.

With a focus on the state plan for economic growth and building on the strengths at our four institutions, this RII aims to build infrastructure in modeling and simulation of complex biological and biologically relevant systems. Our overall strategy is to establish infrastructure and human capital across a broad spectrum of application areas that will yield next-generation science and technology advances in computational simulation and modeling. We will continue to build a critical mass of expertise in biological systems simulation, computational biology, and computational chemistry through recruiting and training of students from diverse populations, using start-up funds for new faculty hires or career changes by faculty, and providing seed grants for faculty to enter our EPSCoR program. We will further develop human capital by mentoring and supporting young faculty including those hired in our current RII grant. These students will increase the highly skilled technical workforce and will contribute to the State’s economic growth and participation in the global economy.

2 Results from Relevant Prior NSF Support

Prior support resulted in new faculty hires in key areas, as well as in publications, external funding, national and international presentations, and significant K-12 outreach. Accomplishments as of November, 2007 are summarized in Table 1. This RII proposal, *Modeling and Simulation of Complex Systems*, builds on the base established by the current RII award (Innovations Through Computational Sciences, NSF #EPS0556308), and

Table 1 MS EPSCoR Accomplishments May, 2006-Nov., 2007

Peer Reviewed Articles	152
Books	20
Presentations	127
Theses/Dissertations	20
Copyrights/Patent Applications	5 Copyrights/5 Patent apps
Faculty CAREER Awards	1 awarded/1 pending
Faculty Recruited	7
Faculty Promoted	8
K-12 Teachers Trained	70
K-12 Students Impacted	3,000
Professional Development Workshops (K-16)	8
Graduate Students Supported	93
Undergraduate Students Supported	58
Proposals	129
Awarded	\$25,446,488
Pending	\$17,419,955

seeks to develop strength in the research focus areas of Biological Systems Simulation (BioSim), Computational Biology (CompBio), and Computational Chemistry (CompChem).

BioSim. The primary infrastructure accomplishment was a shift from a group of isolated, independent researchers at multiple universities to an interdependent, highly connected, productive research team. We have established the Mississippi BioSim Cluster, currently comprised of seven faculty members at three institutions with research interests in the application of computational technology to simulating biological and biologically relevant systems such as human physiology and biomedical devices. Scientific accomplishments include development of an open source, multi-scale model of human physiology, Quantitative Human Physiology (QHP), and high-fidelity airway models of the human lung based on computational fluid dynamics (CFD) simulation of airflow and particle deposition in the bronchial tree.

CompBio: The Mississippi Computational Biology Consortium (MCBC) was established to enhance networking and interdependent collaborations among computational biology and bioinformatics researchers statewide. EPSCoR funding was used by JSU, MSU, and USM to hire five new computational biology faculty into tenure track positions and thus ensure sustainability. These hires, existing senior faculty, and additional tenure-track computational biology faculty (six) added by the four research institutions have yielded a cadre of talented young faculty with the potential to move Mississippi to the next level in computational biology. Areas of expertise of these faculty are biological databases, data mining of genomics data, ecoinformatics, systems biology, hardware accelerated algorithms, and machine learning. Six seed grants were awarded to MCBC faculty teams at JSU, MSU, and USM.

CompChem: The primary accomplishments were the investment in faculty and graduate students. A new tenure track faculty position was created and filled in the Department of Chemistry and Biochemistry at USM. In addition, two other tenure track hires were facilitated at other Mississippi universities by the start-up funds from the current RII. Funding also supported 11 assistant professors, five of whom have received tenure and been promoted to associate professor and three who are currently being reviewed for tenure and promotion. Two associate professors have also been promoted to full professor. This research area invested significantly in training and educating a large and diverse body of students, including support of 53 graduate students and 16 undergraduates from underrepresented groups.

3 Research Program

This RII builds on Mississippi's S&T plan and the human capital investments made by the participating institutions through the current EPSCoR RII grant. The overall goal of the proposed research is to establish Mississippi as a national leader in modeling and simulation of complex systems. To achieve this goal, we will build infrastructure in three critical focus areas—biological systems simulation (BioSim), computational biology (CompBio), and computational chemistry (CompChem)—and then integrate

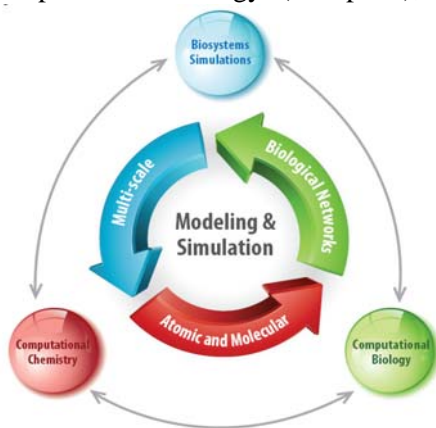


Figure 1 Overall collaborative framework.

advances from these three multidisciplinary areas to address emerging scientific and workforce development challenges. Researchers from diverse fields will collaborate on complex multidisciplinary problems, train students who will become the next generation of research leaders, and build a computationally skilled workforce. Figure 1 illustrates our collaborative framework to understand, investigate, and predict the behavior of complex systems through realistic multi-scale modeling and simulation. We will focus on three specific areas of complex systems:

- A. **Multiscale Simulation of Biological Systems (BioSim)** will develop accurate models of physiologic behavior and apply these models to realistic problems with biological significance.

B. **Modeling Biological Networks (CompBio)** will develop novel cyber-enabled data mining, data integration, data tracking, and model learning algorithms for building accurate, understandable models of biological networks.

C. **Modeling and Simulation of Nanoscale Chemistry (CompChem)** will develop an understanding of fundamental chemical phenomena at the nanoscale level through modeling and simulation to improve synthetic control, assess the environmental impact, and facilitate biomimetic design of nanosystems.

Our focus over this five-year effort will be to build scientific infrastructure in these three research areas. In years 3-5, we will also identify and target seed grant funding for projects that bridge these focus areas to investigate specific complex biological systems and processes with significant societal impact. Examples of cross-cutting integrative application areas include:

- Develop models of the biological effects of particle deposition on lung tissue at the molecular level and employ them as a basis for enhancing our current model of integrative human physiology.
- Extend and apply new algorithms for data provenance to computational chemistry and biosystems simulation tasks to bridge the gap between experiments, data, and models.
- Use computational chemistry techniques to characterize nanoparticle/biomolecule interactions and to inform the development of improved boundary condition models for computational fluid dynamics (CFD) simulation of inhaled particle deposition and absorption.

3.1 Integrated Research Plan

In the 2006-09 EPSCoR funding period, the research universities in Mississippi and NSF invested substantial resources to establish a critical mass of human expertise in the three focus areas of biosystems simulation, computational biology, and computational chemistry, each of which have collaborative, multi-disciplinary research efforts. The proposed RII is essential to strengthen, grow, and propel the research groups to national competitiveness. Our major goal is to capitalize on our previous investments by: 1) strengthening the quality of research in each area; 2) increasing statewide collaborations in each area; and 3) establishing meaningful research collaborations between the three groups in emerging research areas. Our research infrastructure goal is conceptualized in Figure 2.

3.1.1 BioSim

The long-term BioSim intellectual focus is a *Multi-Scale Simulation Framework for Biological Systems*. The specific goal is to develop a multi-scale simulation framework for investigating human biological processes and to make this framework freely available via cyber-infrastructure for research, education, and training. This framework will enable prediction of biological function ranging from fluid and structural mechanics to cellular level physiology to molecular chemistry. Our approach is multi-scale in that it will tightly integrate: 1) a macro-scale Quantitative Human Physiology (QHP) model of integrative human physiology to determine the mechanisms responsible for alterations in human pulmonary and cardiovascular physiology; 2) meso-scale computational fluid dynamics (CFD) simulations of individual organs and organ systems; 3) meso-scale probabilistic simulations of organ and

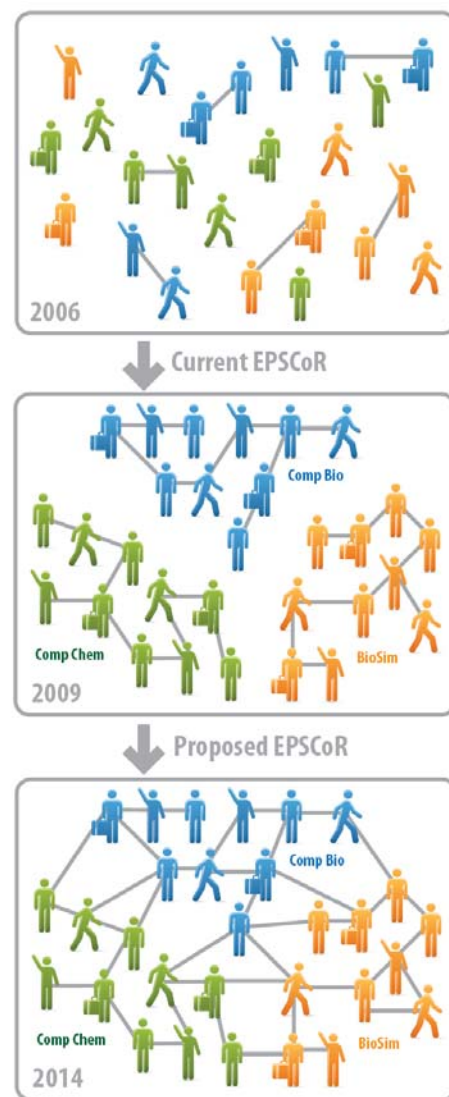


Figure 2 Vision of infrastructure expansion and integration.

organ system subcomponents where deterministic simulations are not practical with current computing capabilities; and 4) micro-scale modeling and physiochemical characterization of inter-component interactions. The broader scientific impacts of the research will be highlighted with a compelling demonstration of practical value, specifically the simulation of inhalation exposure to nanoparticles (NP) and the resulting deleterious effects on respiratory and cardiovascular function. Understanding the mechanisms responsible for the biological effects following NP exposure is challenging and requires a multi-scale integrative quantitative analysis of physiology. Broader education and training impacts will be accomplished through support of two post-doctoral researchers, five graduate students, and four undergraduate students per year.

The **BioSim Research** agenda forms a roadmap for developing, integrating, and demonstrating key enabling technologies to allow simulation of complex models of human physiology. The projects are coordinated as illustrated in Figure 3.

Multi-Scale Modeling Framework. The bulk of our research effort will focus on integrating separate simulation tools applicable at different levels of scale into a single analysis methodology for analyzing and predicting human physiological behavior. Our approach will couple simulation at the macro-scale (whole body physiology), meso-scale (deterministic and probabilistic simulations of individual organs and systems), and micro-scale (biochemical interaction modeling).

Task 1: Enhancements to Whole Body Physiological Modeling via QHP. With the Guyton cardiovascular model, Drs. Arthur C. Guyton and Thomas G. Coleman of the University of Mississippi Medical Center demonstrated in the late 1960's the first use of computer simulations to develop and test hypotheses concerning physiological systems [4-7]. Many publications describe mathematical simulations of individual organ systems, but few demonstrate integration across systems. Because of the multitude of complex interactions within organs and among organ systems, a verbal description of the physiological processes within the human body has major shortcomings, and a mathematical description of the human body is required. We have developed a state of the art physiological model of the human body, Quantitative Human Physiology (QHP) that is unique in its detail of physiological processes and predictive ability. Versions of the current QHP mathematical model have been used for studies funded by NIH (NHLBI) [8, 9], NASA [10, 11], and the EPA [12]. We have also identified the requirements to couple computational fluid dynamics (CFD) simulations with QHP to provide truly multi-scale modeling of human biology. The proposed project will extend this effort to a web-disseminated Unix based model that will combine high-fidelity meso-scale CFD simulations of particle deposition and absorption with our macro-scale model of human integrative biology.

Task 2: Deterministic CFD Simulation of Airflow and Particle Deposition in the Upper Lung Airway. Although numerous simulations of airflow and inhaled particle deposition are reported in the literature, due to the prohibitive computational expense associated with simulating the complete problem, most have focused on subsets of the bronchial tree or components of the upper airways. Particle deposition simulations are reported in the literature for numerous idealized symmetric and asymmetric representations of segments of the bronchial tree [13-17], for orotracheal geometries [18, 19], and for multigenerational bronchial tube models [20]. Researchers at MSU have simulated flow through asymmetric three-generation, planar and non-planar idealized bronchial tube models [21]. Figure 4

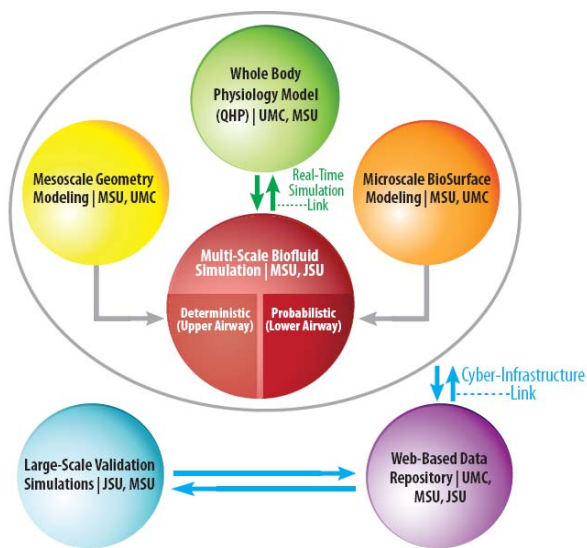


Figure 3 Collaborative framework for multiscale biosystem simulation.

illustrates the effects of simultaneous asymmetric and non-planar branching on the primary and secondary flows. To increase the realism of our lung flow simulations, we seek to couple our particle deposition simulations of the bronchial tubes with QHP to predict system-level physiological responses. The most difficult challenge is accurately predicting inhaled particle deposition for the entire human airway under realistic ventilation conditions. We will also investigate approaches for coupling high-fidelity CFD simulations for a realistic representation of the full upper airways with probabilistic deposition modeling for a simplified lower airway configuration.

Task 3: Modeling of Realistic Physiological Geometries.

To date, our CFD efforts have focused on simulations based on idealized representations of human anatomy. In the proposed effort, our emphasis will shift to more physically realistic models. For example, MRI and/or SPECT data will be employed to generate physiologically relevant geometrical models of the upper airways so that realistic simulations of flow and particle deposition can be performed [22, 23]. Adjunct components such as the orotracheal airway will be modeled for inclusion in simulations of the upper airway. Previous studies have demonstrated that a physically realistic representation of these geometrical details is critical for obtaining accurate distributions of airflow and inhaled particulates [20].

Task 4: Probabilistic Simulation of Airflow and Particle Deposition in the Lower Lung Airway. In contrast to deterministic CFD simulations, techniques developed by Martonen and colleagues [24, 25] estimate particle deposition throughout a completely resolved, highly complex lung geometry. This probabilistic approach estimates deposition rate through the mechanisms of inertial impaction, sedimentation, and diffusion. Ideally, a numerical simulation of particle deposition in lungs should combine high-fidelity, realistic simulation of the upper airways with low-cost, probabilistic-based models for the multitudinous lower airways. One recent example is Ma and Lutchen’s hybrid model [26], which combines fully resolved CFD simulation of the upper airways up to generation six with a 1-D transmission line model of the impedance of the small-scale airways. This model gives good prediction of overall lung impedance, but the work did not include a detailed investigation of small-scale flow and particle deposition. We will investigate methods for modeling and/or simulating airflow and particle deposition in the lower airways and develop methods for coupling them with the upper airway simulations. We will compare a number of approaches including empirical probabilistic modeling and reduced-order modeling using one-dimensional flow equations. We will investigate both Lagrangian-based particle tracking and Eulerian multiphase methods for the lower airways, including incorporation of realistic surface boundary conditions based on interfacial biological surface transport models.

Task 5: Micro-scale Physiochemical Modeling of Particle-Lung Tissue Interactions. Previous studies of particle deposition and clearance in the lung have considered steady-state conditions and mechanical parameters such as flow rates, particle size, airway diameter, and bronchial generation [27, 28]. Biological systems involve non-equilibrium conditions, non-covalent forces, fluidity, and structural flexibility [29, 30] and there is, hence, a strong need to incorporate particle composition into models for accessing particle transport in order to accurately predict deposition and clearance rates for inhalation toxicology and aerosol therapy applications [31, 32]. We will develop physiochemical transport models to describe particle interaction with biological surfaces and allow for linkages between mechanisms involved in lung clearance [33, 34]. Our models will incorporate particle properties including surface chemistry, size and surface area, aggregation, and diffusivity. They will utilize iterative-analytical theoretical modeling of gas, fluid, and particulate transport, and will provide an interface with simulations being performed at higher structure levels. These models are critical for resolving the “missing link” between CFD and QHP modeling.

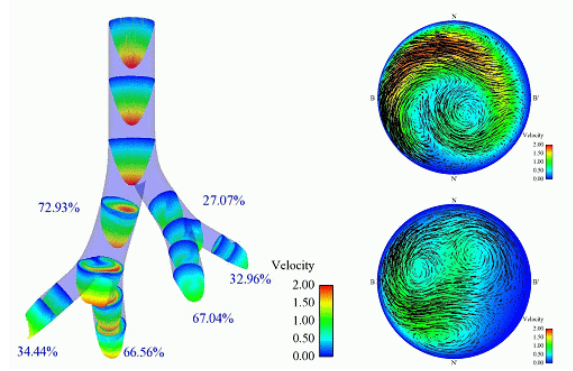


Figure 4 Illustration of CFD simulation of airflow in upper lung airway, showing velocity profiles and mass flow distributions (left) and in-plane secondary flow structures (right).

Task 6: Demonstration Problem—Physiological Impact of Inhaled Nanoparticles. While the focus of our effort is developing the multi-scale framework itself rather than any specific application, we will use nanoparticle inhalation as a demonstration problem of practical significance. Long-term and short-term exposures to nanoparticles such as metal oxides, asbestos, and diesel exhaust have been shown to induce deleterious effects on respiratory and cardiovascular function including acute blood pressure elevation, impairments in systemic tissue perfusion, and alterations in neural autonomic regulation. This task will employ the multi-scale model of integrative human physiology to simulate pathophysiological responses following NP inhalation.

Web-Based Data Repository. We will develop a web-based data repository to facilitate data and software transfer among BioSim members as well as to disseminate results to the research community at large. Information stored in this repository will include geometrical models, simulation results, and software. We will also develop a browser-based tool to visualize system-level simulation data. The repository will include a registration system and the capability to track the numbers of views and downloads, as well as password-protected areas that will be accessible only by BioSim members and their collaborators.

Large-Scale Validation Simulations. One of the key difficulties for simulating biological systems is the lack of available validation data. For example, detailed flowrate and particle deposition/absorption measurements taken *in vivo* from human subjects are difficult if not impossible to obtain. Most validation efforts for lung flow simulations in the literature have relied on experimental data obtained from simplified model geometries operating under steady-state conditions [35, 36]. While useful, such an approach does not address the effect of physiologically realistic geometries and fine-scale (lower airway) flow features. Though we will make use of these available datasets for our upper airway simulations, to validate our lower airway simulations, we will also perform companion deterministic (fully-resolved) CFD simulations of large sections of up to 16 generations of the lower bronchial tree. Such large-scale simulations require up to one billion computational elements and are therefore impractical for coupling with the multi-scale framework but are ideal for validating the probabilistic approaches that will be incorporated.

3.1.2 CompBio

The long-term CompBio intellectual focus is *Modeling Biological Networks*. The specific goal is to develop novel cyber-enabled algorithms to model and simulate complex biological networks supporting transformational research in data-sparse species of economic and environmental importance to the State. These algorithms will provide the computational framework to generate predictive models of emergent behaviors by integrating and mining disparate high-throughput data sets. This will build on existing statewide expertise and promote further inter-institutional and transdisciplinary research. Our approach is organized into three interrelated research components essential for building biological networks: 1) novel approaches for data integration and mining; 2) data provenance for biological modeling; and 3) modeling, reconstruction, and simulation of complex biological networks. The broader scientific impacts of this research will be demonstrated by applying the new algorithms for improved understanding of biological systems of critical importance for human health, food safety, biofuel production, biosecurity and the environment. Broader education and training impacts will be accomplished through support of one post-doctoral researcher, eight graduate students, and eight undergraduate students per year.

CompBio Research Activities: Figure 5 illustrates the connection among the research components where data mining and integration are used to extract knowledge essential for model building and data provenance is used to track data from experiments to models.

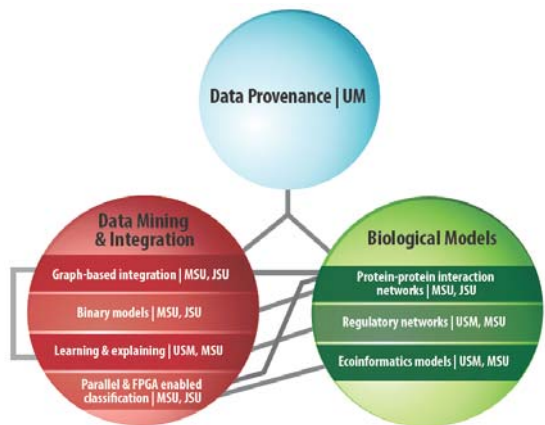


Figure 5 Collaborative framework for modeling biological networks.

Data Mining and Integration is an essential component of modern high-throughput biology. The enormous volumes and diversity of data generated necessitate new and novel ways of representing and integrating data from disparate sources for computational mining. The Gene Ontology (GO) has become the internationally-accepted standard for representing functional information about gene products [37], and MSU is the GO consortium member providing the major source of GO annotations world-wide for agricultural species [38-40] (www.agbase.msstate.edu). We have also pioneered use of GO in supporting transformational research to deliver value from functional genomics experiments from these relatively data-sparse species which are of great economic importance to MS [41-46]. However, although GO facilitates independent functional modeling of proteome or transcriptome datasets, the inherent lack of correspondence between these data types prevents comprehensive modeling (and therefore understanding) of gene regulation at these levels [47]. New methods for integrating functional genomics information (e.g. from microarrays, next generation sequencing, and proteomics) utilizing GO are essential.

Task 1: Graph Based Functional Integration of Data. S. Bridges and A. Perkins (MSU) will develop novel algorithms to effectively use GO to understand multiple levels of gene regulation by integrating transcriptome and proteome datasets at the functional level. Correspondences among the entities in the two datasets will be represented by abstracting to the functional level represented by GO terms and building a bipartite graph where edges represent semantic similarity of GO terms [48]. As part of the previous EPSCoR program, JSU developed binary codes for fast determination of ancestor-descendent relationships in the GO's directed acyclic graphs (DAGs) as well as methods for binary integration of high-throughput data [49]. Because computation of semantic similarity of GO terms for large datasets is computationally intensive, N. Meghanathan (JSU) will incorporate binary models for determining relationships between GO terms in DAGs and we will extract the relevant functional modules from this graph for building integrated gene/protein models. A. Perkins will extend our methods to include differential gene expression analysis based on next generation sequencing technologies. Y. Dandass (MSU) has successfully applied reconfigurable hardware for accelerating gene annotation pipelines [50] and these methods will be extended to cope with the vast amounts of data encountered with new sequencing technologies.

Task 2: Binary Data Models for Integrating Complex Biological Systems. R. Isokpehi (JSU) with MSU collaborators will lead development of a toolkit for extracting binary signatures, matrix construction, pattern search, and statistical evaluation of patterns. The availability of a wealth of multi-modal and multi-dimensional biological data provides an opportunity to develop novel algorithms to construct, search, evaluate and visualize binary-encoded models of complex biological datasets. When combined the binary values of variables form a binary signature for a label and a collection of these signatures becomes a binary matrix. Advantages offered by the binary integration of high-throughput data include computational efficiency and noise resilience [51, 52]. Despite the advantages of binary integration algorithms there are currently few software tools supporting binary data models.

Data Provenance (i.e. identifying the origin of data and tracking changes to it) is critical to complex computational workflows to ensure that: 1) data meets quality standards; 2) parameters and assumptions for model building are well documented for reproducibility; and 3) data sharing and collaboration are enhanced. Existing data lineage systems including Chimera [53], Trio [54], MyGrid [55, 56], CMCS [57, 58], and Open Provenance Model [59], are *ad hoc*, purely theoretical, or customized for a specific need. The primary challenge in data provenance for biological networks is to design a general model for data management that handles multiple granularities of data, grid environments, communication, user interface, and query requirements. UM will lead the research effort in data provenance and will collaborate with the MSU protein-protein interaction modeling group and the USM ecoinformatics group for proof-of-concept applications of their methods to real modeling problems. We will: 1) design and develop a flexible data provenance system for biological modeling; 2) evaluate alternative data models, workflows and methods for querying data provenance; and 3) test the new data provenance methods in the context of model building and refinement with collaborators at MSU, USM, and JSU. D. Wilkins and Y. Chen will use a service-oriented architecture (SOA) and data-centric model supporting both data

provenance archiving and sharing, with a particular focus on flexibility for the user. After evaluation with functional genomic data, the model will be extended to a grid-level scale.

Modeling and Reconstruction of Biological Networks from high throughput datasets is a challenging inverse problem because of its nonlinearity, high dimensionality, non-uniqueness, sparse and noisy data, and computational cost [60, 61]. The most widely used network inference approaches, such as probabilistic Boolean networks and Bayesian networks, can only be used to reconstruct small networks and also have low accuracy [62-64]. Researchers at MSU and USM have expertise in Bayesian networks [65-67], network inference based on channel transfer function estimation [68, 69] and feature extraction and classification from massive biological datasets [43, 45, 70].

Task 1: A New Hybrid Model for Learning Gene Regulatory Networks. C. Zhang, P. Ghosh, and J. Sun will investigate a new stochastic framework designed to model dynamic gene regulation. Their approach combines Bayesian learning and numerical optimization to reconstruct specific large-scale biological networks from high throughput time-series gene expression data. They will develop a multi-level discrete-event based bio-simulation platform based on their *in silico* models to simulate the complex biological processes and to study the interplay between gene regulation, signal transduction and metabolic reaction networks in genomic scales [71]. The proposed unique hybrid approach integrates computational modeling reconstruction and simulation and will improve the accuracy of inferred large scale networks. R. Isokpehi and B. Nanduri will evaluate the biological accuracy of the learned networks.

Task 2: Learning and Explaining Gene Interaction Networks. Real-world gene expression datasets are often sparse with few data points compared with the number of genes. It is difficult to infer reliable gene interaction networks from such sparse data. C. Yuan and N. Wang will develop algorithms to identify the most robust interaction relations and combine these to build robust gene interaction networks based on Bayesian model averaging methods [66, 72, 73]. The identified networks are rarely used for explanation or prediction [74]; C. Yuan and B. Nanduri will address this limitation by developing novel approaches for explaining the response to a given stimulus based on the learned networks [67].

Task 3: Protein-Protein Interaction (PPI) Networks for Non-Model Species. Computational prediction of protein-protein interactions in model species are typically derived from extensive high throughput datasets. A proportion of PPIs for non-model species will be shared with related model species. Current PPI prediction algorithms applied to sparse datasets are vulnerable to experiment-specific biases and noise. M. Ramkumar and N. Wang will develop new algorithms that utilize well documented PPIs from model organisms to offset the functional biases by estimating their transfer function and identifying the underlying interactions by inverting this function. Transfer function estimation methods to be evaluated include cross correlation, principal component analysis, and bias eliminated least squares. Identified interactomes extending systems biology to non-model species will be evaluated by B. Nanduri.

Task 4: Ecoinformatics Models from Surveillance Radar. Ecoinformatics is the science of gaining insights into the function of natural systems by using computational methods to integrate ecological and environmental data. Though ecoinformatics operates at a different scale from genomics, it also provides an opportunity to apply data mining, data integration, and data provenance methods for modeling and simulation and is equally relevant to the State's economic development. Embedded within the ~1.7 petabyte archive of data gathered by the national network of weather surveillance radars is one of the largest and largely untapped biological datasets in the world [75, 76]. USM has one of the few North American laboratories researching biological applications of radar. R. Diehl, who came to USM as an NSF Postdoctoral Fellow in informatics, was one of the first hires under the expiring EPSCoR RII. Dr Diehl (with C. Zhang) received one of our previous EPSCoR seed grants to collaborate on automating classification of biological radar targets. Drs Diehl (USM) and Zhang (USM) will now collaborate with Y. Dandass (MSU) to develop new highly-parallel data mining algorithms to identify biological targets within the radar data archive. These algorithms must be adapted to deal with large volumes of noisy sensor data where biological targets are not predictably distributed throughout data archive [50]. Data from these algorithms will in turn be the basis for individual-based models that reveal emergent animal behavior patterns and for testing data provenance techniques for tracking the data.

3.1.3 CompChem.

The long-term CompChem focus is *Modeling and Simulation of Nanoscale Chemistry*. The specific goal is to develop a systematic understanding of the relationships between the organization and properties of matter at the atomic, molecular, and supramolecular levels across size scales from approximately 1 to 100 nanometers. This understanding will dramatically improve our ability to design and synthesize controlled nanoscale objects with specific properties. The infrastructural goal is to develop an internationally recognized, extramurally funded, multi-institution network of scientists by establishing Mississippi's first *University & Industry Nanoscale Consortium (U&I-NC)* (see Figure 6). The U&I-NC will leverage expertise in computational chemistry and high-performance computing (HPC) as well as at the existing CREST Interdisciplinary Nanotoxicity Center (HRD-0833178) at JSU, and will network key groups from academia and industry in the State. Hybrid Plastics, Inc. (Hattiesburg, MS) which develops and markets a unique nanoscale chemical technology based on polyhedral oligomeric silsesquioxanes (POSS[®]), has agreed to participate in the consortium. Our research efforts will focus on: 1) developing new QSPR/QSAR models and integrated quantum mechanical (QM) computational methods for nano-materials; 2) applying state-of-the-art computationally-aided techniques to determine design principles for nanoscale chemistry that permit control of the size and properties of organometallic nanotubes (with nanopores), gold clusters, and supramolecular assemblies; and 3) improving our understanding of how biopolymer hydration affects molecular recognition and the interaction of small molecules with nanoscale biomolecules to design new classes of high-affinity binding ligands. The broader scientific impacts of this research will be demonstrated through our collaborative efforts with Hybrid Plastics, where our results will be used to predict properties (i.e. solubility, refractive index) and guide the synthesis of improved POSS[®] nanomaterials. Broader education and training impacts will be accomplished through support of one post-doctoral researcher, thirteen graduate students, and one undergraduate student per year.

We will address three separate but interrelated components for modeling and simulation of nanoscale chemistry.

Theoretical Characterization of Nanoscale Materials In chemistry, computational simulation and modeling are powerful tools in the laboratory providing insight into and quantitative predictions about complex systems. Although it is now possible to apply QM electronic structure techniques to nanoscale chemical systems, the discovery of design principles at the atomic, molecular, and supramolecular levels mandates the continued development of realistic, innovative and efficient models for these complex systems.

Task 1: Theoretical Characterization of Nanomaterials for Sensor Technologies. CompChem researchers will use electronic structure techniques to characterize a wide variety of nanomaterials with potential for sensor applications. To aid the design of Single Walled Carbon Nanotube (SWNT) sensors, we will employ QM computational methods such as those based on density functional theory (DFT), to study changes in the structure and electronic properties of SWNTs after various physicochemical changes, such as the chemisorption of hydrogen [77-79]. The same procedures will be used to examine modified SWNTs in which, for example, select C atoms are replaced with B and/or N atoms. We will also model plasmonic nanostructures for biosensing by computing changes in various optical responses in the presence of molecular adsorbates using time-dependent DFT methods [80-83].



Figure 6 Collaborative framework for modeling and simulation of nanoscale chemistry within the U&I-NC.

Task 2: Develop QSPR/QSAR Models for Nanomaterials. The U&I-NC will develop new computational methods to characterize nanoscale chemistry. These methodological projects span a wide range of techniques. At one end of the spectrum, QSPR/QSAR models will be created to predict the effects of nanoscale chemicals on human health and the environment, as well as their distribution and fate within the environment and biological organisms (i.e. nanotoxicity). A model of the solubility of fullerene C₆₀ in 122 solvents has already been developed by combining quantum chemical calculations and QSPR modeling in a genetic algorithm and multiple linear regression analysis (GA-MLRA)[84-86].

Task 3: Develop Integrated QM Methods for Metal Clusters. By coupling recently developed multi-centered (MC) approaches to integrated QM computations (e.g., QM:QM, QM:MM, ONIOM, etc.) with a traditional many-body decomposition of cluster energies, it is now possible to perform integrated QM calculations on atomic and molecular clusters. MC-ONIOM can now provide extremely accurate descriptions of weakly interacting molecular clusters [87-91] and will be used to study the forces and principles governing supramolecular assembly. In addition, MC-ONIOM will be modified to be applied to metal clusters, such as “magic”-sized gold clusters (*vida infra*), by evaluating higher-order terms from the many-body expansion, thereby enabling the characterization of these nanostructures with high-accuracy electronic structure techniques.

Computationally-Assisted Design, Synthesis and Characterization. This research component will provide direct support to enhance collaborations between computational and experimental chemists by coupling synthetic efforts at Mississippi universities and Hybrid Plastics with the computational and spectroscopic expertise of other U&I-NC members. Predictions about structure and properties will be followed up by synthesis and characterization. Three potentially high-impact applications have been initially selected: organometallic nanotubes containing nanopores, “magic”-sized gold nanoparticles, and the polyhedral oligomeric silsequioxanes (POSS[®]) at Hybrid Plastics, Inc.

Task 1: Nanopores in organometallic nanotubes. We have synthesized organometallic nanotubes containing nanopores [92]. These nanopores are direct analogs of cellular pores for which very few synthetic analogs exist. The structural characteristics and sources of the pores as well as the forces controlling the size of the nanopores are unknown.

Task 2: Magic-sized Gold Nanoparticles. Similar information is lacking about the extra stability associated with the “magic”-sized gold nanoparticles that we have also synthesized and characterized [93-98].

Task 3: Polyhedral Oligomeric Silsequioxanes (POSS[®]). At Hybrid Plastics, Inc., POSS[®] materials are finding wide application and are an emergent nanoscale technology. Yet methods to theoretically predict properties (i.e. solubility, refractive index) to guide synthesis for optimum productivity in the industrial setting do not exist.

Each of the above three material types must be better understood at a fundamental level to facilitate scientific progress and economic development. Members of the U&I-NC will provide this insight by characterizing these nanoscale systems using electronic structure methods and high-resolution spectroscopic equipment [77-79, 90, 99-104]. The team’s HPC access and resources will allow predictions that will benefit industry—particularly Hybrid Plastics—by reducing the number of synthetic options that must be evaluated.

Biomimetic Nanoscale Chemistry: This third research component will use computation and simulation to study complex nanoscale processes in nature such as biopolymer hydration, large-scale enzyme motion, and molecular recognition. Through the U&I-NC, the information obtained from these computational studies will then be used to develop nanoscale design principles and materials.

Task 1: Biopolymer Hydration. Modified camptothecins (CPTs) with hydrophilic functional groups can potentially provide new classes of ligands with extremely high binding affinities for the DNA/topoisomerase I interface. We will study the role of water in topo I-DNA interactions via computations and molecular dynamics simulations [105-109] of hydrated CPT analogs in the topo I/DNA/CPT ternary

complex. Existing expertise in water-soluble polymers and coupling of polymers to small molecules will be integral to this project [110-112].

Task 2: Carboxylesterase Inspired Biomimetics. Carboxylesterase (CE) inspired biomimetics have great potential because they could lead to engineered nanostructures that catalytically deactivate organophosphate nerve agents. These ubiquitous enzymes are responsible for the detoxification of xenobiotics. Structural dynamics of CEs are thought to be critical for substrate selectivity and catalytic activity but the mechanism is poorly understood. We will study the dynamics of CEs with a combination of experimental (fluorescence depolarization) and theoretical (molecular dynamics simulations) techniques in order to compare the fluctuations in molecular structure of these enzymes with their substrate conversion activities [113-116].

3.2 Focus Areas in Context of this RII

BioSim, CompBio and CompChem share the *central thematic link* of modeling and simulating biological and biologically-relevant complex systems. In years 3-5, we will also identify and develop *application links* by incorporating scientific and technological breakthroughs by the focus groups to address challenging multi-disciplinary problems that cannot currently be addressed effectively via computational modeling and simulation. It is difficult to anticipate the potential links and we hesitate to impose specific boundaries at the outset of the project. Instead, we will implement a funding mechanism to foster inter-group collaboration and research using \$1,095,000 (total) for seed-funding of these novel cross-cutting projects. A Request for Proposals will be issued annually and proposals will be peer-reviewed. See section 9.1 for more information about the review process and criteria for seed grant proposals. The focus areas will also coordinate education and outreach activities based on their research activities as outlined in section 7 and section 9.2. These activities include teacher workshops and statewide symposia.

3.3 Resources to Support Research Goals

BioSim. The significant hardware resources required for the project are currently available and listed in detail in the supplementary Facilities document of this proposal. Major systems include a 10-teraflop 2048 processor AMD Opteron cluster, a 384 processor Intel Xeon cluster with InfiniBand interconnect, a 1038 processor Intel Pentium III cluster, and a 600 core AMD Opteron cluster. Software to be further developed as part of this effort includes the QHP simulation tool at UMMC, as well as both commercial and in-house CFD solvers available at MSU and JSU. A key objective of this effort is development of a web-based collaborative environment and data repository. Funds have been requested to purchase website development software which is necessary to accomplish this goal. A part-time web design specialist will be hired at UMMC to assist in the development and coordination of the web tool.

CompBio. Available resources to be utilized in this project include computing laboratories, servers, and clusters described in the Facilities document, and existing high throughput datasets for economically important species. Funds are requested to support data collection for constructing ecoinformatics models and for additional cluster compute nodes, servers and storage capacity required for storing and processing massive amounts of data generated by high throughput methods.

CompChem. The proposed computational research will be carried out using local resources in the investigators' laboratories as well as the HPC resources at MCSR (see attached Facilities document). In year 1, \$88,713 will be used to acquire a significant upgrade to MCSR resources, most likely a solution based on the Intel Nehalem microarchitecture. In years 2-5, a total of \$47,955 has been allocated to ensure the continued availability of applications software packages such as Gaussian, MolPro, Amber, and Accelrys Materials Studio. For the most demanding computational chemistry applications, investigators will apply for time at national supercomputer centers and will continue to seek funding for additional resources for MCSR through the NSF CRIF and MRI programs.

3.4 Role and Intellectual Contribution of Each Lead Senior Participant

Scientific efforts in each research area will be coordinated at each institution by the following senior personnel: *BioSim*—D.K. Walters (lead investigator) at MSU; Hester at UMMC; Aliabadi at JSU; *CompBio*— Isokpehi (lead investigator) at JSU; Bridges at MSU; Moore at USM; Wilkins at UM; *CompChem*—Tschumper (lead investigator) at UM; Hill at JSU; McCormick at USM; Gwaltney at MSU. The intellectual contributions of senior investigators are summarized in Table 2.

Table 2 Intellectual Contributions of Senior Investigators

<i>Biological Systems Simulation</i>		
Hester	UMMC	Physiological function and modeling of cardiovascular and pulmonary systems
Coleman	UMMC	Principal developer of whole body physiology model QHP
Burgreen	MSU	Simulation and modeling of biological and biomedical systems
Thompson	MSU	CFD simulation of airflow and particle deposition in the lung
Walters (DK)	MSU	Multi-scale CFD simulation; turbulence and transition modeling
Walters (KB)	MSU	Surface chemistry characterization and biological surface modeling
Aliabadi	JSU	Large-scale HPC simulation; parallel algorithms
<i>Computational Biology</i>		
Bridges	MSU	Develop graph-based algorithms for data integration
Burgess	MSU	Senior biologist for GO & genetic networks in non-model biological systems
Perkins	MSU	Graph based functional integration of data
Dandass	MSU	Accelerating gene annotation pipelines with FPGAs and graphics processors
Nanduri	MSU	Systems biology in non-model biological systems
Ramkumar	MSU	Algorithms for protein-protein interaction for non-model species.
Isokpehi	JSU	Toolkit for extraction of binary signatures, matrix construction, pattern search
Meghanathan	JSU	Binary models for determining relationship between Gene Ontology terms in DAGS
Cohly	JSU	Evaluate computational inferences for experimental validation.
Wilkins	UM	Leader of data provenance research effort
Chen	UM	Major designer and developer of data provenance research
Moore	USM	Senior advisor for ecoinformatics research group
Zhang	USM	Modeling, reconstruction and simulation of complex biological networks.
Diehl	USM	Ecoinformatics research leader
Ghosh	USM	Multi-level discrete-event based bio-simulation platform
Sun	USM	Network alignment and complexity analysis.
<i>Computational Chemistry</i>		
Hill	JSU	Computational characterization of boron and nitrogen containing nanotubes
Leszczynski	JSU	Computational characterization of carbon nanotubes and metal nanoparticles
Leszczynska	JSU	Development of QSPR/QSAR models for nanoparticles
Shahbazyan	JSU	Computation of optical responses in plasmonic nanostructures
Gwaltney	MSU	Computational studies of large-scale molecular motion in biomolecules
McCormick	USM	Design of water-soluble polymers and coupling of polymers to small molecules
Dass	UM	Synthesis and electrochemical characterization of gold nanoparticles
Doerksen	UM	Computational characterization of biomolecule/ligand interactions
Hammer	UM	Spectroscopic characterization of nanoparticles
Hollis	UM	Synthesis of organometallic nanotubes
Tschumper	UM	Development of integrated QM:QM electronic structure methods
Wadkins	UM	Fluorescence depolarization experiments and MD simulations of biomolecules

3.5 Plan for Interactive Collaborative Research

Activities of the focus areas will be coordinated by a Steering Committee comprised of lead investigators and three rotating members (one from each group) designated as Research Coordinators for each focus area. The position of Research Coordinator will rotate annually to allow several individuals an opportunity to participate in a leadership position within the project and to ensure sustainability. The

Steering Committee will oversee the research progress of each group and will coordinate review and selection of cross-cutting projects (see section 3.2) that will link research outcomes for the three research areas. The Steering Committee will meet twice each year, at the annual EPSCoR state meeting and at the Annual Multi-Conference described in section 7. These meetings will provide a forum to meet and discuss collaboration across groups and possible cross-cutting projects. Other activities designed to foster collaboration at the student level are the student network described in section 7 and the student exchange program for graduate and undergraduate students described in section 9.2.

BioSim. Research activities within the BioSim focus area are tightly integrated. In addition to the primary model development effort, support activities include development of large-scale deterministic CFD simulations of the bronchial tree to validate probabilistic models of the lower airways and development of a web-based collaboration tool and data repository. Activities will be coordinated by quarterly video conferences between investigators at each institution, and yearly (or more frequently if necessary) face-to-face interactions between researchers.

CompBio. The Mississippi Computational Biology Consortium (MCBC), established under the current RII, will continue to meet twice per year with one meeting associated with the yearly EPSCoR state meeting and the other at the Annual Multi-Conference (see section 7). The MCBC Steering Committee will continue to meet monthly via video conference/groupware to plan activities and promote collaborative research. Web-based collaboration software will also be used by teams of investigators for collaborative research. All research projects in CompBio are cross disciplinary involving more than one Mississippi institution.

CompChem. MCSR currently offers workshops/courses/tutorials on computational chemistry, parallel programming, and other topics related to high performance scientific computing. The computational chemistry focus area plans to augment this existing State resource to include a Wiki dedicated to computational chemistry as well as a regular series of webinars on computational chemistry to share expertise with researchers, students and industry across the State.

The *U&I-NC* will meet at the annual EPSCoR state meeting and at the Southern School for Computational Chemistry and Materials Science (SSCC-MS). The SSCC-MS has been co-organized the past eight years with the NSF-CREST Computational Center for Molecular Structure and Interactions, the NSF-Partnership for Research and Education for Materials (NSF-PREM), and JSU. Funding in the amount of \$15,000 per year has been budgeted to assist in sponsorship of the annual SSCC-MS meeting.

3.6 Interactions with Other Groups and Organizations

BioSim. The current RII enabled several new collaborations. UMMC is working with NASA to use QHP to direct biological studies on future space missions and with Washington Hospital's Simulation Training Education Laboratory (SiTEL.org) to develop computer simulations for training physicians in burn patient care. MSU has established a collaboration with researchers at the US Food and Drug Administration (FDA) in cardiovascular device evaluation and blood damage modeling. Promising prospects for new collaborations exist with Cardiothoracic Surgery at the University of Alabama at Birmingham in the area of modeling ventricular function. Our ability to form and grow these external efforts will be significantly enhanced by the availability of our multi-scale simulation framework, which will provide a means of addressing problems that are of interest to these and other institutions.

CompBio. The current RII enabled us to establish research collaborations with UMMC and the Veterans Administration Hospital in Jackson, Mississippi in nosocomial infection and pneumonic bacterial disease, respectively. We have established a new collaboration with the USDA to build novel atlases of gene expression for cow and chicken. We have collaborated with the University of Arizona and Washington University medical schools and the University of Delaware on a \$5.6 million NIH proposal that was scored and we are pursuing the work needed to improve this score and resubmission. We are collaborating with the other GO Consortium members (www.geneontology.org/GO.consortiumlist.shtml) to expand the GO, increase functional annotations and provide tools for using the GO. Three universities collaborate with US Army Engineer Research and Development Center (ERDC) Environmental

Laboratory, working with the MSU Center for Environmental Health Sciences, we have published work identifying new mechanisms of pesticide toxicity. With the US Dept. of Energy we have sequenced the genomes of two novel bioenergy bacteria and identified the protein network that increases triglyceride accumulation under syngas conditions. Three of our previous RII faculty became Mid-South Computational Biology and Bioinformatics Society (MCBIOS) board members and one of our new investigators for this RII proposal (Dr Wilkins, UM) is the MCBIOS President. JSU's Center for Bioinformatics and Computational Biology is co-lead for the Bioinformatics and Computational Biology Working Group of the RCMI Translational Research Network, a NIH-NCRR Cooperative Agreement and established a Mentor-Protégé Agreement with Oak Ridge National Laboratory.

CompChem. JSU established the NSF sponsored Interdisciplinary Nanotoxicity Center (HRD-0833178, PI Leszczynski). Statewide interdisciplinary expertise will be pooled through the U&I-NC by networking key groups in the State such as the CREST center and the Mississippi Biophysical Consortium, which was founded in 2007 to help establish collaborations between researchers who are experts in the study of nanoscale properties of biological and biomimetic molecules. Money is also budgeted to support a researcher from a non-Ph.D. granting department at a Mississippi college or university. David Magers, a computational chemist at Mississippi College, will be funded in Years 1 and 2. The recipient in Years 3-5 will be selected on a competitive basis.

4 Diversity Plan

Mississippi has a very diverse population with 60% white, 36% black, 2% Hispanic, 1% Asian/Pacific, and approximately 0.5% American Indian (2000 U.S. Census) with African Americans underrepresented in our science focus areas at three of the four research institutions. Minorities and women are also inadequately represented at the faculty ranks. We have addressed these issues in the hiring of five new EPSCoR faculty members in the computational science. They include Isokpehi, a minority faculty member at JSU (an HBCU) and Nanduri, a female faculty member in the College of Veterinary Medicine at MSU. We initiated a major effort to retain and nurture our own graduate students. Successful examples include African American Glake Hill, who received his Ph.D. at JSU and is now an assistant professor at JSU and project member of the expiring RII, and Nan Wang, an MSU female PhD student working in computational biology, who is now a USM tenure track faculty member. Both Hill and Wang are investigators on this RII. Other successes include the following:

- Individuals from underrepresented group received seed grants
- Female graduate students specializing in bioinformatics taught at the annual Bioinformatics for High School Teachers and College Faculty
- One female graduate from JSU began PhD program in Computational Medicine at Cornell University
- One female graduate from JSU was trained to operate high-end genome sequencers at National Biodefense Analysis and Countermeasures Center.
- One female African-American from JSU is a post-masters fellow in Computational Biology at Division of Biosciences, Oak Ridge National Laboratory.
- JSU, enabled by EPSCoR RII funds, has attracted Department of Homeland Security funding to establish a Bioinformatics in Biodefense Career Development Program (<http://compbio.jsums.edu/projects/bbcdp/>). Current students in the program are African-Americans.
- MCSR provided computational capabilities for researchers at Mississippi's HBCUs.
- MSU established collaborations with six HBCUs in Mississippi and Alabama resulting in an NSF URM proposal highly rated, but not funded, and currently under revision for re-submission.
- A larger number of students were provided computational sciences opportunities through the development of new and enrichment of existing courses at post-secondary level.

Building on our previous successes, our diversity plan will continue our efforts to improve recruitment of underrepresented minorities in computational sciences and increase the number of underrepresented graduate/undergraduate students. We will nurture, train and retraining our own minorities while attracting new ones into faculty positions, will impact instruction and career knowledge of computational sciences

in secondary schools with majority African American student populations, and will focus on transitioning students from JSU and other minority serving institutions into graduate programs at our four state research institutions.

Strategies include utilizing start-up packages targeted for recruiting and retaining faculty underrepresented in STEM disciplines. Through workshops for secondary teachers we will incorporate the computational sciences into classroom instructions while introducing career pathways in the computational sciences. We will use 25% of our assistantships for students from underrepresented groups.

As part of our effort to increase the number of underrepresented minorities in graduate programs, we will partner with the Science Diversity Center (SDC) at JSU to enable researchers to maximize the progress and leadership of minority and underrepresented students and faculty. SDC is an NSF sponsored cyberoffice program to improve STEM workforce participation by working with minority-serving institutions on research proposals, collaborative opportunities and cyberinfrastructure associated with teaching and networking. Leveraging this state resource will facilitate the creation of a diverse community of minority scholars.

Additional strategies include: 1) establishing a forum for female researchers to implement mechanisms for attracting female high school students to pursue studies in computational simulation and modeling; 2) providing competitive fellowship/scholarship training support for students from underrepresented populations to ensure full-time commitment to computational sciences; 3) providing travel funds to women and underrepresented populations to participate at professional conferences in computational sciences; and 4) providing targeted funding opportunities to underrepresented students and faculty to participate in the international exchange program where Mississippi students and faculty travel to research institutions in other countries.

Milestones and metrics for diversity are located in section 8.

5 Workforce Development

Traditionally Mississippi has had a labor-based economy. Consistent with the America Competes Act, the strategy for Mississippi's economic development is to grow a highly skilled and knowledge-based economy [117]. *Because our overall EPSCoR effort is fundamentally aimed at research and research infrastructure, our workforce development goals are tightly integrated with our research goals.*

Our goal is to increase the workforce in the computational sciences—particularly the areas addressed in this project—by bringing together researchers, teachers, entrepreneurs, and industries. We will implement activities to provide crucial technical skills at all levels that will have broad impacts for job creation and increasing the skill quality of the workforce. Activities include professional development of secondary school teachers and community college faculty; secondary curriculum enrichment and development; transition of students from secondary schools to two year colleges to four-year institutions and graduate school; and linkage of university research programs to entrepreneurs and small businesses. The outcome will be a demographically diverse cadre of graduates at multiple educational levels, possessing marketable skills in computational science, qualified to provide manpower for technology-oriented industries that will foster the transition from an industrial to a knowledge-based economy in Mississippi.

Of the roughly 3M population of Mississippians 1.3M individuals are in the workforce. Unfortunately only 5.8% of the workforce have graduate or professional degrees. Furthermore only 17% have bachelor degrees. Mississippi has the lowest national wage [118]. To reverse this trend—from labor workforce to highly skilled workforce—we will leverage several successful and existing programs at Mississippi institutions aimed at enhancing the numbers and diversity of the State's scientific and technical workforce. These include programs specifically targeting under-represented groups, such as the Louis Stokes Mississippi Alliance for Minority Participation (LSMAMP), the Science Diversity Center (SDC) at JSU, the MSU/IMAGE Summer Bridge Program (SBP), and the Alliance for Graduate Education in Mississippi. Other programs that target broader demographic distributions while focusing on the STEM workforce in particular include the Cooperation in Research and Education in Science and Technology (CREST) program in computational chemistry at JSU and the CSEM and S-STEM scholarship programs

at MSU. A current program addressing both of these goals is the LSMAMP “Bridge to the Doctorate” program, which to date has led to 19 minority students enrolling in STEM Ph.D. programs following their baccalaureate degree from JSU.

Professional development for secondary teachers and community college faculty and curriculum enrichment and development will increase exposure and interest in computational science and engineering among high school and community college students in Mississippi. We will accomplish this through teacher/faculty workshops and recruiting visits to high schools and community colleges. Our model for the teacher workshops is the existing NSF program “Industry Education Partnerships: A Model for the Teacher Professional Continuum,” which provides internship opportunities and workshops to expose teachers to the activities of industry participants. Evaluation data shows that this effort is sustained well beyond the workshop. Details of the professional development workshops are provided in the section 9.2.

Transitioning STEM Students from Two-Year Colleges to Four-Year Universities. The goal of this activity is to facilitate the transfer of students at two-year community colleges to four-year research universities. We will do this through three different mechanisms: recruitment visits by EPSCoR faculty to in-state community colleges, involvement of community college faculty members in our yearly teacher workshops, and providing undergraduate research assistantships to community college graduates who enroll at four-year universities in STEM disciplines. We will focus on minority students, by setting aside at least 25% of undergraduate assistantships for members of under-represented groups. This effort represents a new domain that complements the networks that have been developed and will be developed between secondary and university teachers, and addresses an aspect of the workforce pipeline that has not previously been a major focus of existing workforce development activities in the state of Mississippi.

Transitioning STEM Students from Undergraduate to Graduate School. The goal of this activity is to increase the number of students graduating from four-year Mississippi universities who attend graduate school in computational science and engineering. The three focus areas in this effort have each requested funding for graduate student support at multiple institutions. We will target Mississippi students for these assistantships, since these students are more likely to remain in the state and supplement the technical workforce after receiving their graduate degrees. Because JSU is a minority-serving institution, we will specifically focus on transitioning undergraduates there to computational science and engineering graduate programs at JSU and at other state institutions (MSU, UM, USM).

Linking Computational Science Research with Industry Partners. We will work to increase post graduation opportunities through partnerships with small businesses in the State. We will use the SBIR and STTR program to establish linkages between research institutions and private employers, strengthening economic competitiveness and creating high technology jobs for graduating students. We will sponsor two SBIR/STTR workshops per year in cooperation with MS-FAST/MTA on a rotating basis at each of the four research institutions. The objectives of these workshops are to directly support improvements to the research infrastructure, R&D capacity, and high-technology commercialization opportunities in the State of Mississippi.

Metrics and milestones for workforce development are listed in section 8.

6 Cyberinfrastructure Plan

“Investments in interdisciplinary teams and cyberinfrastructure professionals with expertise in algorithm development, system operations, and applications development are also essential to exploit the full power of cyberinfrastructure to create, disseminate, and preserve scientific data, information and knowledge” [119]. Connectivity and interaction through cyberinfrastructure (CI) will enable our small and geographically disperse group of faculty to develop a larger, virtual community building strong and competitive research teams to address large multidisciplinary research areas. This RII, consistent with our State’s vision for science and technology, will directly impact three major areas of CI development, all relying heavily on HPC calculation and simulation that can only be performed with the most powerful computers available today. These areas are summarized below.

Collaborative teams and virtual communities. The current EPSCoR makes extensive use of cyberinfrastructure for the development of interdisciplinary teams and virtual organizations to advance our research, including strong interactions between Mississippi's HBCUs and the other research universities. Each focus area is developing a virtual community through cyber-enabled consortia, linked via an umbrella website encompassing the activities of all personnel and institutions involved in our EPSCoR effort and through collaboration software. We will host web-based colloquia on state-of-the-art computational research and make them available to students and faculty at the other state institutions. We will incorporate video conferencing, webinars and other cyber-enhanced asynchronous work environments such as wiki pages, email, and the scientific equivalent of social networking sites.

Management and dissemination techniques for algorithms and data. The ability for users to access research results, data, software, teaching tools, and on-line courses is essential for the dissemination of information. The MCBC website will continue to serve as a portal for dissemination of results, and researchers will develop new ways of representing data that enable integration of data. The Mississippi BioSim Cluster website will be enhanced to include a browser-based database for viewing simulations, data, publications, and other related information generated from this effort. The QHP model and its CFD interface will be ported such that QHP/CFD can run in a web-based Unix-only environment. The QHP software will be divided into a Unix engine to solve its equations and into a separate platform-specific program to provide visual display of QHP results. We will also develop a web browser-based tool to visualize system-level simulation data online.

High performance computing access. The Mississippi Center for Supercomputing Research (MCSR), established in 1987, provides high performance computing support for research at Mississippi's eight publicly funded institutions of higher learning at no cost to the institutions, supporting the computational needs of the entire EPSCoR program. MCSR is a contributing member to the regional SURAGrid, which links HPC resources at universities throughout the southeastern US and beyond. In the 2008 fiscal year, researchers at Mississippi's three historically black colleges and universities (Jackson State University, Alcorn State University, and Mississippi Valley State University) accounted for well over 50% of the CPU hours consumed at the MCSR. We will make extensive use of MCSR facilities for performing the research tasks of this effort. We will further increase inter-institutional access to other in-state HPC resources through the development of our collaborative research projects.

Cyberinfrastructure to enhance communication is described in section 7.

7 Outreach and Communication Plan

Our goal is to develop a diverse, well-prepared, internationally competent, and globally engaged STEM workforce. The effectiveness of these strategies will be measured as described in Section 9. Under our current EPSCoR grant, each research area initiated *practices that facilitate communication, collaboration and network building*. We will expand collaborations among both faculty and students that cross university and disciplinary lines by addressing cross-cutting scientific issues in modeling and simulation of complex systems. We will initiate an international exchange program, establish statewide research consortia and a student network, and enhance communication with NSF and other jurisdictions.

Our international exchange program will foster international collaborations among scientists, grow our network and give students the opportunity to gain the skills needed in our highly interconnected global scientific communities and economies. We will fund travel by Mississippi undergraduate and graduate students and faculty to research institutions in other countries. Preliminary international contacts in South Africa, Australia, Europe, China and Viet Nam will serve as a base enabling our faculty to take advantage of international collaborative opportunities early in their career and become active members of the international research communities. Students, many of whom have never travelled outside the US, will experience the global nature of research and establish international collaborations upon which they can build throughout their careers. By the conclusion of this grant, Mississippi universities will be competitive for international collaborative programs sponsored by NSF, USDA, and NIH.

Under the expiring RII, the computational biology research focus area established the *Mississippi Computational Biology Consortium* (MCBC)—a statewide collaboration among MSU, JSU and USM. The MCBC will be extended to include other Mississippi institutions and serves as a model for consortia in the other research areas (the *Mississippi BioSim Cluster*, and the *University & Industry Nanoscale Consortium*). Specific strategies will be implemented to increase cross-university collaboration and cross-consortia collaboration among scientists and students. The steering committee of each consortium will meet at least quarterly via video conference/web-based collaboration software to promote collaborative research and to plan activities and joint meetings. A major goal will be to increase our national and international research profile by involvement in regional, national, and international organizations.

A joint meeting of the three consortia will be held twice per year—at the annual EPSCoR meeting in the spring and at the Annual Mississippi Modeling and Simulation Multi-Conference in the fall. The Education/Outreach Coordinator and Science Coordinator will assist each host university in organizing the conference. Although the conference will include specific tracks for each research areas, a major focus will be crosscutting activities including a single keynote address, specific scientific tracks and working groups that cut across the research areas (i.e. data provenance, data mining, nanomaterials), unified student presentation/poster sessions with awards for best posters and presentations, and career advancement sessions for students. To increase the impact of our research in the State, we will actively recruit students and faculty from other Mississippi educational institutions (such as Mississippi University for Women, Mississippi Valley State University, Tougaloo College, and Alcorn State) to participate in the meetings and work with us on collaborative research projects.

At a focus group meeting at our last statewide EPSCoR meeting, our graduate and undergraduate researchers asked for more interaction with students at other universities and suggested the use of social networking sites such as FaceBook and MySpace for intra-student communication. Although these sites are not widely used in the scientific community [120, 121], they are widely used by our students and we will use these mechanisms to establish a student-centric *Modeling and Simulation Student Network*. The Education/Outreach Coordinator will work with an undergraduate student and the Research-Education liaison to establish and run this part of our network. We will also explore the utility of initiatives such as Small World virtual networks [122], which takes advantage of Web 2.0 ("read/write Web") services. In this model, users not only consume online information but also produce it through collaborative interactions. This is important because although social networks like Facebook are popular their impact is largely confined to social and leisure use has not had a significant impact on practicing laboratory scientists [120].

We will establish a *student exchange program* among our research groups. Students participating in this program will spend at least one week in the laboratory of a faculty member at another institution working on a specific collaborative project. In addition to our own students, we will recruit students from historically female and minority institutions in the state to participate in the program.

In addition to the video conferencing approaches that we are currently using, we will obtain and deploy web-based teaming and collaboration software for improved communication among researchers, students, and with NSF program managers. Universities will continue to routinely bring NSF staff to campus. MSU takes new faculty in STEM disciplines to NSF to meet with program managers. A goal is for each faculty participant to serve on at least two (2) NSF, NIH or USDA peer-review panels.

8 Evaluation and Assessment Plan

The evaluation will 1) formatively study, using a systematic structure, the quality of the implementation of this RII and project progress toward meeting milestones and intended outcomes (NSF 02-057), and 2) summatively assess, both annually and at the end of the grant, the effectiveness and overall impact of project components on improving discovery and learning, developing a nationally and internationally competitive, diverse Mississippi STEM workforce, facilitating science-based economic development in Mississippi and expanding scientific literacy of Mississippi citizenry (NSF 97-153). Evaluation findings will be used to enhance the project by increasing the sources of data that will contribute to the

administration revision and delivery cycles. Some of the formative evaluation findings (effective strategies, minority inclusion, strengths and weaknesses of materials and activities, lessons learned) will inform the summative evaluation. Communication is critical to effective evaluation. In addition to annual reports, the External Evaluator will report formative evaluation findings quarterly to the PI and shorter-loop feedback will be reported informally by email and telephone.

The Internal Evaluator, Dr. Maxine Harper, is Interim Director of UM’s Center for Educational Research and Evaluation. Her responsibilities will be related primarily to the Education and Workforce Development activities at the schools and universities. Working with the external evaluator, the internal evaluator will ensure proper planning and implementation of data collection tools and data analysis. The Internal Evaluator will also observe some of the education activities and will be responsible for tracking undergraduate and graduate students who are part of RII programs. She will also attend project meetings as necessary per the project director.

The External Evaluator, Dr. Rose Shaw, is accomplished at evaluating multiple-site, collaborative projects. Shaw taught math 20 years, has a PhD in Applied Statistics, MS in Mathematics and BS in Mathematics and Composite Science (emphasis: Biology). She has 18 years experience evaluating NSF STEM and infrastructure improvement projects including GK12, LSC, CETP, IGERT, EPSCoR RII, NUE, BD, ADVANCE, ITEST and LSAMP.

The RII leadership team and the evaluators will meet within the first five months of funding to review, align and finalize logic model aligned evaluation (inputs, activities, outputs, and anticipated outcomes) and results-based evaluation (goals, objectives, performance measures, milestones and metrics), along with administrative evaluation-utilization pathways to ensure maximum use of evaluation findings. The External Evaluator will work with the PI and component leads on rigorous outcome evaluation designs (e.g., randomized pre/post, quasi-experimental). Outcome evaluation will focus on the use of psychometrically sound assessment instruments (e.g., MOSART). Formative and process evaluation instruments will be developed by the PI, co-PIs, Internal Evaluator, and the External Evaluator; surveys will be templated for longitudinal analysis. Formative and process evaluation data will be gathered using (web-based and paper-and-pen) surveys, telephone interviews, email, and on-site observation and interviews. The MS EPSCoR office and the Internal Evaluator will coordinate tracking of undergraduate and graduate students from groups targeted by this RII. Evaluation observations will use the Horizon Research, Inc. Classroom and Professional Development Observation protocols. The annual summative evaluation form will be submitted to the PI by the External Evaluator within 60-days of the end of each project year. The evaluation timeline is given in Table 3.

Table 3 Evaluation and Assessment Timeline

Type	Activities	Timeline	Responsibility
Formative & Outcome	Collect baseline milestone and metric data	First five months after funding	Project team leaders; External Evaluator, Mississippi EPSCoR
Formative & Outcome	Collect metrics	Annually	Mississippi EPSCoR and External Evaluator
Outcome	Meet with MS-AMP to align metrics, coordinate data collection	First five months; annually	PI, External Evaluator, RII leadership, Internal Evaluator
Summative	Data trend analysis and reporting to PI	Annually within 60 days of completed collection	External Evaluator
Formative	Surveying, (formal and informal) interviewing and observation	Ongoing	PI and RII leadership, Internal Evaluator and External Evaluator
Formative, Outcome and Summative	External panel of researchers	Years 2 and 4	PI and RII leadership
Process	Use evaluation and assessment data to improve and refine components	Ongoing	Mississippi EPSCoR, PI and RII leadership

Evaluation will collect a combination of qualitative and quantitative measurements and judgments (effective strategies, strengths and weaknesses, lessons learned) about the program’s implementation that will be used to improve the quality of performance, processes, and outputs. Standard qualitative methods

(organization, meaningful reduction, cross-case analysis, themes, and trends) will be used to analyze qualitative data. Quantitative data will be analyzed using descriptive statistics and frequency distributions charts (with bar and line graphs illustrating disaggregated longitudinal enrollment, participation) and association tests (e.g., Chi-square and correlation). The annual quantitative metrics will be used to assess and evaluate project components.

Table 4 Summary of Mississippi NSF RII Milestones

RII Component	End of Year 1	End of Year 2	End of Year 3	End of Year 4	End of Year 5
Computational Biology	Demonstrate classification of ecoinformatics training data.	-Demonstrate graph-based integration;	-Demonstrate pilot data provenance model; -Demonstrate binary integration capability	-Demonstrate hybrid Bayesian model and simulation with sparse data; -Demonstrate PPI algorithm. -Demonstrate FPGA accelerated data integration.	-Demonstrate data provenance with different types of models via the grid; -Validate ecoinformatics model.
Biosystems Simulation	-Bring web-based data repository online -Demonstrate female version of QHP	-Demonstrate probabilistic lower airway model -Demonstrate UNIX version of QHP model	-Demonstrate combined upper/lower airway CFD model	-Demonstrate offline coupling of CFD and QHP model - Demonstrate full web-based multi-scale modeling framework.	-Apply model to demonstration problem— inhalation exposure to nanoparticles
Computational Chemistry	-U&I-NC membership – 15 -Demonstrate collaborations- 3 co-published papers or patents -Demonstrate polymer-ligand attachment -Demonstrate QSPR/QSAR models	-Demonstrate collaborations- 6 co-published papers or patents -Demonstrate controlled nanopore simulation and experiment -Demonstrate models for POSS properties	-U&I-NC membership - 22 -Demonstrate collaborations - 9 co-published papers or patents & -Pre-proposals submitted for Center Grant support -Demonstrate Au-nanoparticle synthesis and simulation	-Pre-proposals invited for Center Grant full application -Demonstrate collaborations - 9 co-published papers or patents -Demonstrate new POSS predictions by synthesis & characterization -Demonstrate QM methods for nanoscale applications -Demonstrate computation and measurement of molecular dynamics of H ₂ O in ligands & enzymes	-U&I-NC membership - 30 -Demonstrate collaborations - 12 co-published papers or patents -Full proposals submitted for NSF or other Collaborative Center Grant and/or funded Research Center grant -Market a new POSS material

The Mississippi EPSCoR data collection system will be used to gather the quantitative outcome metrics that will be used to evaluate discovery, learning, research infrastructure and stewardship dimensions. Table 4 summarizes the research milestones. The following research metrics focus on scholarly output, collaboration and research infrastructure.

- The average production of scholarly output by faculty members supported by this NSF EPSCoR grant will be 2 journal articles and 2 conference presentations per year.
- NSF-funding for CompBio, BioSim, and CompChem will increase by 5% each year.
- Non-NSF grant funding for the three research teams will increase by 5% each year.
- The average dollar amount of grants funded for the three research teams will increase by 2% each year.

- At least 4 peer-reviewed publications per year will involve faculty authors from more than one Mississippi research university.
- During the last 2 years of the grant, at least 3 peer-reviewed publications per year will involve faculty authors from more than one of the three research areas.
- At least 3 IGERT (Integrative Graduate Education and Research Traineeship Program) proposals will be submitted. At least 1 will be funded by the end of the 5 years.
- All untenured faculty supported on the EPSCoR grant will submit an NSF CAREER Award proposal (or a similar proposal to another agency) with at least 2 funded after 5 years.
- At least three proposals will be submitted to 1) Partnerships for International Research and Education, and 2) International Planning Visits and Workshops or a similar program, with 2 funded in 5 years.
- The number of faculty participating in CompBio, BioSim and CompChem research will be increased by four by the end of the 5 years.
- Critical instrumentation valued at \$1,000,000 or more will be obtained through proposal submissions to programs such as MRI, CRIF, and IMR.

Milestones and metrics for all other categories are given in Table 5. In the area of diversity, our goals are to increase the number of underrepresented minority U.S. citizenry in STEM undergraduate majors consistent with MS LSAMP targets and to increase by 10% the percentage of women and the disabled of U.S. citizenry in undergraduate, graduate and post-doctoral STEM majors at all four universities.

Table 5 Education, Outreach, and Workforce Metrics and Milestones

Metric	Milestone	Timeline
# secondary teachers attending research workshops	15/yr	Yrs. 1-5
# attending from highs schools with 50% African American enrollment	8/yr	Yrs. 1-5
# recruitment visits by EPSCoR faculty to high schools	3/yr	Yrs. 1-5
# community college teachers attending research workshops	5/yr	Yrs. 1-5
# recruitment visits by EPSCoR faculty to community colleges	3/yr	Yrs. 1-5
#UG researchers presenting research results at conferences	4/yr	Yrs. 1-5
#UG researchers co-authoring peer-reviewed publications	2/yr	Yrs. 1-5
# UG researchers recruited from community colleges	6	Yr. 5
# MS UG students transitioning to EPSCoR grad projects	6	Yr. 5
# MS African American UGs transitioning to EPSCoR grad projects	3	Yr. 5
# SBIR/STTR workshops	2/yr	Yrs. 1-5
#faculty and students will be involved in international collaborations	4/yr	Yrs. 1-5
#publications of EPSCoR faculty with international co-author	2/yr	Yrs. 1-5
#students and faculty attending EPSCoR annual meeting and Multi-conference	50/yr	Yrs. 1-5
#students participating in Student Network	20/yr	Yrs. 1-5
#students participating in Student Exchange	8/yr	Yrs 1-5
#students and faculty using collaboration software	70/yr	Yrs 1-5

9 Sustainability Plan

Sustainability will occur with our leverage of State and federal investments, including this RII, to raise our level of competitiveness and national and international prominence in three key interrelated research areas. We have used the expiring RII to build a cadre of talented young researchers to build a critical mass of expertise across the state. Our new focus on building infrastructure enable new RII hires and existing faculty to develop and leverage their research skills to build large transdisciplinary teams with collaborations Statewide, nationally and internationally. We will impact the workforce by increasing the pipeline of students moving into computational sciences related careers. This project will result in a skilled, collaborative network of researchers who will successfully compete for extramural funding in project research and related areas.

9.1 Seed funding and emerging areas

Up to six competitive seed grants of \$36,250 per year will be awarded to young faculty and/or experienced faculty changing fields consistent with our research goals. Funds will be used to develop innovative projects and gather preliminary data to increase competitiveness for extramural funding. Grants will require multidisciplinary collaborations among investigators at different institutions. Proposals will be solicited from participating institutions and reviewed by a panel chosen by the EPSCoR Steering Committee and comprised of external reviewers. Criteria include scientific merit, relevance to modeling and simulation of complex systems, and potential for building collaborations leading to external funding.

To increase Mississippi's competitiveness in attracting new and outstanding faculty, funds are allocated to provide start-up funding for new tenure-track or tenured researchers. These funds provide the resources needed to establish a scholarly research program that will lead to increased external research funding. A pool of \$218,100 per year, up to six awards of \$36,250, will be available to the institutions for recruitment and retention of faculty. The MRC will control the pool allowing institutional flexibility to respond quickly to new opportunities for high risk informative research in emerging areas.

9.2 Education and Human Resources Development

Education and human resource development are integrated throughout our proposal. We will continue to develop human capital in the faculty ranks and student populations and increase the pipeline in STEM areas by supporting and mentoring faculty (previously discussed) and by conducting education activities for secondary teachers and graduate and undergraduate students. Current RII activities for secondary and community faculty included conducting three summer workshops in computational biology for secondary teachers and community college instructors. Experience with these workshops points to the importance of having researchers involved in development and delivery of workshop materials. A major goal was to enable participants to introduce computational biology tools and databases to their students. Researchers also introduced teachers and faculty to careers in computational biology and make them aware of research opportunities for undergraduates. We will leverage NSF's investment by offering workshops to include topics in and involve researchers from all three research areas. A non-residential workshop will be held each summer at a different research university. Teachers and community college faculty will be recruited from the surrounding area with at least 50% participation by those from schools with majority African American students. Because workshops at MSU, USM, UM and JSU will geographically cover most of the State except the Mississippi Delta, the final workshop will be held at Mississippi Valley State University, an HBCU located in the Delta.

Our education and research goals are tightly integrated and address both graduate and undergraduate education. To increase the pipeline of students, particularly those from Mississippi, pursuing graduate degrees in STEM fields, an undergraduate research program, initiated during the current RII, will be expanded. Students will in research laboratories with an assigned graduate student mentor during the academic year and/or the summer. Students will be recruited from our own institutions as well as other state universities including Mississippi University for Women, Mississippi Valley State University, Tougaloo College, Rust College, and Alcorn State University increasing gender and racial diversity of the pool of students. To develop and sustain a network that supports nationally/internationally competitive research programs, we must attract highly qualified graduate students. We will fund Graduate Research Assistants in all three research areas.

9.3 Post RII plans and extramural funding

Our post RII vision is a highly competitive, nationally and internationally recognized cadre of researchers in modeling and simulation of complex systems. We will develop multi-institutional, transdisciplinary, collaborative teams who can respond to and compete for large highly competitive funding.

The science coordinator and Science Executive Committee will identify opportunities for large, collaborative proposals and will direct resources to assemble teams that include appropriate university and industry partners. We will be positioned to succeed in securing major awards from NSF (ERC, STC, MRSEC, and MRI), NIH, DARPA, NASA, and DHS. Sustainability will include expanded involvement

with DoD, proposed collaborations with the DoE laboratories and establishment of an active network of collaborations with U.S. and foreign partners. High performance study of new materials has the potential to contribute valuable input to specific DoD, DoE, and EPA needs such as environmental studies or to provide insight at the molecular level concerning toxicity of current and new nanomaterials.

Previously we discussed the attraction of industry to our State as a result of university research capabilities and potential opportunities for economic growth in our research focus areas. We will further develop relationships with appropriate industries as research applications emerge.

10 Management Plan

The project management organization is shown in Figure 7. The management team will be led by PI/PD Sandra H. Harpole (W/F), associate vice president for research. She has 21 years of academic experiences and has directed numerous NSF grants. She will be responsible for overseeing all aspects of the project, reporting to NSF, and ensuring that the project proceeds on schedule and meets goals and milestones. She will be assisted by Teresa Gammill (W/F), project administrator who will manage the day-to-day operation of the project and will report directly to the project director.

The project management team is guided by the Mississippi EPSCoR State Committee which includes the Mississippi Research Consortium (MRC) which meets monthly and government and business leaders. Members include Representatives Angela Cockerham (B/F); Haley Fisackerly, (W/M), President/CEO, Entergy; Gray Swoope (W/M), Executive Director, MDA; Carl Hagstrom (W/M), V P/Chief, Hybrid Plastics; and MRC members Felix Okojie (B/M), CRO, JSU; Kirk Schulz (W/M), CRO, MSU; Alice Clark (W/F), CRO, UM, and Cecil Burge (W/M), CRO, USM. The EPSCoR Committee is chaired by the chair of the MRC, a position that is rotated among the four research institutions every two years.

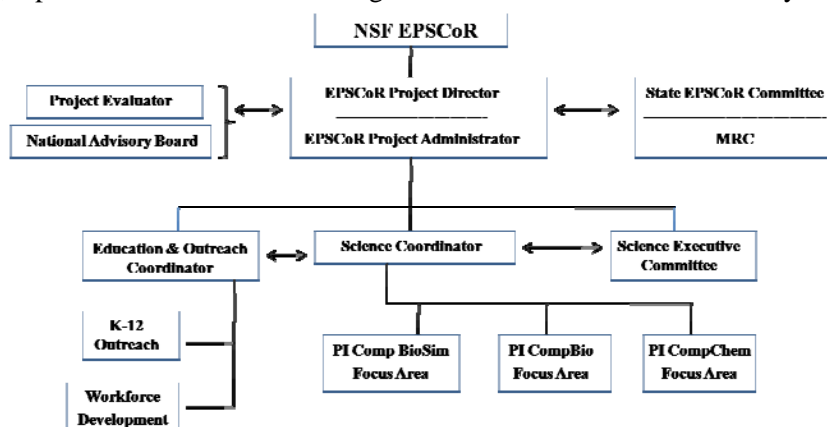


Figure 7 Organization Chart for MS EPSCoR

The National Advisory Board (NAB), to meet twice yearly, will provide direct input to the research accomplishments and education and outreach to the PD and the individual researchers and recommend mid-course modifications. Members include Parker Antin (W/M), University of Arizona; Lisa Grable (W/F), North Carolina State University; Jerry Hobbs (W/M), American Institute of Physics; Karen Johnston (F/W), North Carolina State University; Michael Khonsari (W/M), Louisiana State University; Vincent McKoy (W/M), California Institute of Technology; N. Radhakrishnan (B/M), North Carolina A&T State University, and David Silvernail (W/M), University of South Maine(W/M).

The evaluators assisted in developing the evaluation metrics and will collect and track data and provide both formative and summative reports to the PD and the NAB. Rose Shaw (W/F), Metrica-Greeley, CO, will serve as external evaluator assisted by an internal evaluator, Maxine Harper (W/F, Disabled), UM.

New to our management plan are the science coordinator and education and outreach coordinator positions. Susan Bridges, Professor in Computer Science and Engineering at MSU will provide leadership in the coordination and implementation of the science areas, assist in developing statewide collaborative opportunities, assist in the coordination of reports and provide updates to the PD pertaining to the

research areas. She will chair the science executive committee made up of the science area PI and faculty members from each of the research areas who will serve on a rotating basis.

The outreach coordinator to be hired is responsible for coordinating the education and outreach program working collaboratively with EPSCoR researchers to recruit, advertise, and coordinate teacher workshops and student internships and to develop/improve/revise curricula associated with education/outreach activities. The PD in collaboration with the State EPSCoR Committee and coordinators reviews and makes recommendations for any mid-course adjustments.

The Mississippi EPSCoR office will coordinate technical assistance for all institutions in assisting with the planning of proposals, developing university-industry-government collaborations, developing faculty as mentors, and enhancing interdisciplinary collaborations. All workshops and presentations will be made available to faculty at all state institutions through invitations for participation and cyber opportunities. A calendar will be maintained on the Mississippi EPSCoR website and presentations will be placed on the website. Examples include presentations by program officers from NSF and other agencies, a grant writing workshop each year by a nationally known expert, and SBIR/STTR workshops. An expert on mentoring faculty and students will be invited to present a workshop in the first year of the project. Staff from each university's office of research and the sponsored research office will meet once each year to plan and coordinate technical assistance activities. The PD, science coordinator, education and outreach coordinator, and the PIs from each of the three science focus areas will work together to identify funding opportunities for faculty. To ensure continuity and sustainability of leadership, we will gradually move junior faculty into leadership positions throughout our management.

Financial Management: MSU will serve as Project Fiscal Agent for the Mississippi EPSCoR, facilitating rapid and efficient communication and ensuring effective coordination of fiscal matters relating to components at other institutions. MSU will subcontract with JSU, UM/UMMC, and USM. The PD, with the MRC, will use available financial data to evaluate expenditure trends, to identify potential problems, and to maintain the overall schedule and funding level.

MSU Controllers Office as well as staff in the PD's office will track all invoices received from subcontractors, monitoring expenditures to budgeted amounts for each subcontract. The PD will monthly to the chief research officers at each of the four research institutions comparing budget consumed to the amount of time elapsed.

Table 6 Summary Table of Requested NSF Support

AWARDEE	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
MSU (incl. seed grants & startups)	1,776,179	1,725,348	1,784,883	1,772,049	1,743,315	8,801,774
Subcontracts to Participating Institutions						
UM	792,655	777,861	763,304	783,554	746,211	3,863,585
JSU	687,827	700,308	753,373	697,315	737,639	3,576,462
USM	354,733	370,814	322,502	369,418	350,666	1,768,133
UMMC	363,708	400,567	375,938	377,664	422,169	1,940,046
MC	24,898	25,102	0	0	0	50,000
Total Subs	2,223,821	2,274,652	2,215,117	2,227,951	2,256,685	11,198,226
Total Project	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	20,000,000