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NEESgrid: A Distributed Virtual Laboratory for Advanced Earthquake Experimentation and Simulation

Project Execution Plan

Tom Prudhomme[1] **Kyran D. Mish**[2]

[1] National Center for Supercomputing Applications,
University of Illinois at Urbana-Champaign

[2] Center for Computational Engineering,
Lawrence Livermore National Laboratory

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1.0 Project Execution Overview

The Project Execution Plan (PEP) presents the top level technical, cost, and schedule baselines for the "NEESgrid: A Distributed Virtual Laboratory for Advanced Earthquake Experimentation and Simulation," project, hereafter referred to as "NEESgrid," submitted in accordance with National Science Foundation (NSF) proposal CMS-0117853. This project is a component of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), a Major Research Equipment (MRE) project at NSF, and is also part of the National Earthquake Hazards Reduction Program. This project will design, construct, implement, test, and make operational a high performance Internet network that enables a truly synergistic national simulation resource for research and education that will support collaborative experimentation, modeling, and simulation for the earthquake engineering community.

The focus of NEES systems integration is to seamlessly integrate tools that will enable earthquake engineering simulation, both physically and numerically, to develop increasingly complex, comprehensive, and more accurate models of how the infrastructure responds to earthquake loadings, e.g., tsunami effects, soil response; buildings, bridges, and lifelines response; nonstructural response, etc., through large-scale/near full-scale structural and soil models, extensive data bases, and advanced and integrated simulation and visualization codes. Systems integration will provide a common access framework for connecting to 20 or more NEES earthquake engineering research equipment sites. Each site will feature teleobservation and teleoperation capabilities; tools supporting publication to and use of a curated data repository; access to computational resources and open source analytical tools; and collaborative tools supporting experiment planning, execution, analysis and publication. Therefore, NEESgrid will integrate a scalable, extensible system.

This PEP sets forth the organization, systems, and plan by which the project participants will manage the NEESgrid project. The PEP for NEES system integration will be reviewed and revised, as required, to incorporate lessons learned, changes in baselines (technical scope, cost, and schedule), and new project development and/or other arrangements among the participants. Revisions, as they are issued, will be acknowledged by all participants, and will supersede in their entirety previous versions. The first such revisions will be incorporated into the PEP at the end of the second quarter (Q2) of operation. These revisions will reflect new information on user and performance requirements collected through outreach efforts conducted during the first quarter of operations. New information on requirements will assist the project participants in determining the order in which to undertake the development and deployment efforts in the plan, managing risk, and ensuring that the integration effort meets its objectives and deliverable schedule.

The following project management elements are included in this document:

- Project description (Section 2),
- Project organization (Section 3),
- Project work breakdown structure (WBS, Section 4),
- Project cost elements (Section 5),

- Project implementation elements (Section 6)
- Project standards required for contract management (Section 7), configuration control (Section 8), and appropriate technical standards for documentation, software development, and other essential components of this project (Section 9), and
- Reporting and review requirements (Section 10).

To provide additional detail in support of the narrative document, appendices are included with this execution plan:

- Appendix A. Glossary of terms to establish a common vocabulary among NSF, earthquake engineering and information technology participants in NEES SI project management,
- Appendix B. Detailed table describing the Work Breakdown Structure for the project,
- Appendix C. Summary of the NEES equipment site awards to date, and
- Appendix D. Gantt chart summarizing extensions and improvements to the Project Execution Plan during the first quarter (Q1) and second quarter (Q2) of the NEESgrid Project.

1.1 NEES Project Overview

The NEES Program is a MRE project in the NSF Directorate for Engineering, Division of Civil and Mechanical Systems. The goal of NEES is to provide a networked, national simulation resource of geographically-distributed, shared-use next generation experimental research equipment installations, with teleobservation and teleoperation capabilities. This national resource will provide the infrastructure and framework to shift the emphasis of earthquake engineering research *from* current reliance on physical testing *to* integrated experimentation, computation, theory, databases, and model-based simulation. NEES will integrate experimental facilities, computational resources and tools, collaborative communications technologies and tools, and curated data repository system, developed to facilitate collaboration and broad community participation in earthquake engineering research and education. Through NEES, the earthquake engineering community will be catalyzed to utilize its advanced experimental capabilities to test and validate more complex and comprehensive analytical and computer numerical models that will improve the seismic design and performance of our nation's civil and mechanical systems. NSF plans that NEES construction will be completed by September 30, 2004, and will be operational through September 30, 2014.

The integration, networking, and shared-use access of the NEES equipment sites is effected through a NEES Systems Integration (SI) award, which develops the high-performance system that will enable the development, integration, and operation of all components of NEES. The SI component has been awarded to the University of Illinois, Champaign-Urbana (UIUC), and the Phase 1 NEES equipment sites are listed in Appendix C.

NSF plans to spend a total of $81.8 million by September 30, 2004 under NEES to enhance the earthquake engineering research infrastructure in the United States and to build a high performance Internet network connecting the equipment facilities to the broadest possible user

base. The current equipment awards, totaling $45 million over four years, will fund construction, expansion and modernization of equipment at 10 universities that will include capabilities for remote observation and operation. NSF plans to grant a second set of equipment awards in Spring/Summer 2002. All components of NEES, including equipment sites and systems integration, must be completed by September 30, 2004.

The scope of this project management document is limited to the systems integration component of NEES, but where appropriate, a larger view of the NEES MRE is taken.

2.0 Science Plan

This section outlines the core scientific and engineering objectives of the NEES Systems Integration project. Because success of the overall NEESgrid enterprise requires successful component efforts in a wide range of physical science, social science, and engineering venues, these individual aspects of the overall NEES effort are outlined below.

2.1 Introduction

NEES system integration provides a synergistic, collaborative access and use framework linking individual NEES experimental equipment sites and community resources (data, models, simulation codes and other software tools) to be shared by the broadest definition of the earthquake engineering community. The general intent of the SI project is to remove distance and location near major experimental facilities as barriers to research progress, innovation, and education in earthquake engineering, thus providing opportunities for full earthquake engineering community participation in the multi-facets of NEES, as well as K-12 academic infrastructure and the general public.

NEESgrid serves three classes of earthquake engineering researchers and practitioners, namely:

- The structural engineering community, generally concerned with the behavior of above-ground or buried structures (e.g., high-rise buildings, bridges, thin-shell dams, tunnels) subjected to seismic loads,
- The geotechnical engineering community, generally motivated by the response of foundations and soil masses (e.g., earth dams, soil liquefaction, slope stability) during earthquakes, and
- The tsunami community, concerned with the prediction and mitigation of tsunamis, which occur in response of earthquakes occurring on the ocean floor.

NEESgrid must readily handle the similarities and differences of each of these communities, so that the development of new cross-disciplinary communities of earthquake engineers can be fostered while preserving the unique and productive attributes of these existing communities.

2.2 Objectives and Scope

Constructing a large-scale distributed system such as NEESgrid poses many challenges from the information technology perspective. NEES is a national simulation resource for a diverse user

community, each component with its own set of specific application requirements. Viewed from the perspective of an integrated system, NEESgrid must be able to scale up to tens of experiment sites, hundreds of user sites, and thousands of users geographically distributed across the entire country, and eventually, internationally. Applications that use NEESgrid will be written in a variety of programming languages and may incorporate commercial software. Further, there may be stringent performance requirements in terms of response time (teleobservation and teleoperation), the data volumes that the system must handle, and the amount of computation needed to support advanced simulation studies.

Experience in designing, building, and maintaining large-scale distributed systems supports the approach taken in this plan: identify and exploit common needs across NEESgrid applications and produce system elements that can be reused from application to application, eliminating the need to start from scratch every time a new application is developed.

The NEESgrid design is based on distributed systems technology that is referred to as Grid technology. Grids follow the principle of layered system architectures, a principle that has proven particularly successful in the design and development of the Internet. At its lowest level, a grid consists of a core set of services with well-defined protocols that form the foundation for constructing higher level and more application-specific tools and services. This layering addresses our requirements for common NEES infrastructure while supporting the development of higher-level capabilities to support the applications of specific earthquake engineering domains.

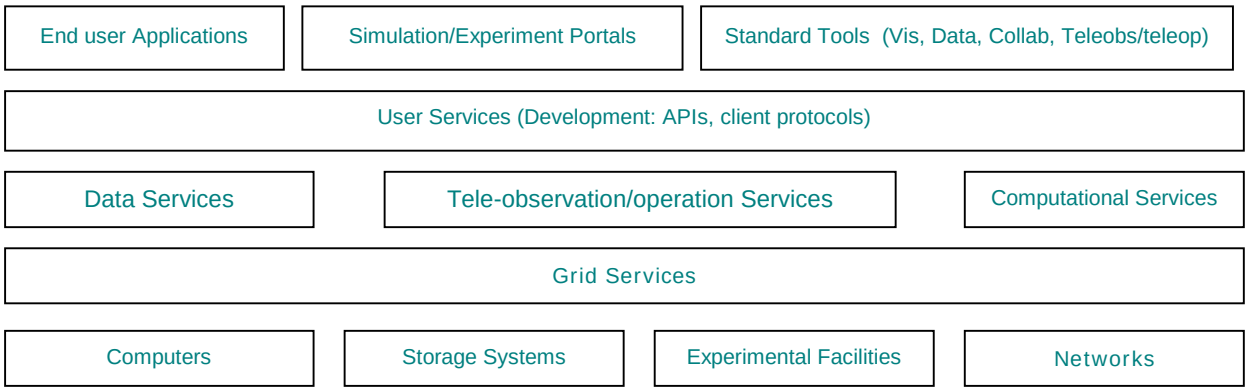

Figure 1. Main elements of the NEESgrid system architecture.

Figure 1 shows the structure of the NEESgrid system architecture. Common with other Grid based systems, the NEESgrid architecture is layered. At the foundation is a core set of common Grid services. Building on these basic services are more specialized collections of services that address requirements in data management, teleobservation/teleoperation, computation, and collaboration. Each individual collection forms a *Services Package* that is installed on Grid resources. Each services package is used in turn to construct the higher-level end-user services and tools (teleobservation/operation, collaboration, simulation, and information management) that are required by the NEES community.

The major elements of this architecture are:

- *Core grid services* that provide basic security, information, and resource management functions which are used by virtually all services packages,
- *Teleobservation and teleoperation services* that provide standard protocols for exchanging control and status information between equipment sites and remote sites. The services in this package are used to construct the high-level teleobservation and teleoperation tools discussed in the following section.
- *Computation and simulation services* that include access to compute resources and simulation codes. These services are used to construct the high-level simulation services and tools described in the following section.
- *Data management services* that manipulate the management of data files and are used to build the information management environment

The details of the system architecture will be optimized for earthquake engineering community requirements based on input from earthquake engineers prior to and during the design, development, and deployment of NEESgrid. This input will be obtained through an ongoing user requirements analysis, coupled with direct interaction with the NEES equipment sites, application developers, engineering members of the NEESgrid team, and through other NEESgrid outreach activities.

An implementation of the NEESgrid architecture results in several specific sets of interfaces, services and software components. For end users, there will be programming interfaces and tools that use underlying NEESgrid services and protocols to perform application-specific functions. These interfaces and tools are the primary means by which the high-level system capabilities described in the next section are implemented. Equipment sites as well as compute and storage resource providers will be able to implement services and interfaces that provide access and control of the physical resources located at their sites. Finally, management services will be defined to support the operation and maintenance of the NEES system.

This project will develop and refine working prototypes during the second year of operation, and will achieve a fully operational NEES System by September 30, 2004. The prototypes will include NEES equipment sites that have become operational with sufficient lead-time to be incorporated into the prototypes. Acceptance tests will be conducted for all operational components of the NEES System, including the connections to individual equipment sites to enable teleobservation and teleoperation, connections to high performance networks and existing high performance computers and data stores, and all software integrated into the NEESgrid pool of resources. This resource pool includes both software developed by the NEESgrid team and other codes in general use by the earthquake community, for example, OpenSees, which are integrated into portals and code repositories supported by NEESgrid.

2.2.1 Scientific Scope and Objectives

The scientific purpose of the NEESgrid effort consists of two broadly-defined components, one involving the physical sciences that govern the response of physical systems to earthquakes, and the other involving the social science principles that form the underpinning of community-

building and collaborative research. In addition to these components, the systems integration effort forms the bond that links these two scientific components. Through NEESgrid, scientific understanding is improved by leveraging the collective knowledge of the community, the social science understanding of the nature of collaborative work, and the ability of information technology to facilitate collaborative knowledge sharing. By integrating three disciplines to create the underlying architecture of NEESgrid, the overall benefit to the earthquake engineering community is maximized. The integrated system is by design more powerful, useable and appropriate to the needs of the community than any other combination of the components implemented independently of one another.

2.2.2 Technical Scope and Objectives

The technical objectives of the NEESgrid effort are:

- Deploy a prototype national simulation resource at selected early adopter equipment sites and "pioneer" users at the beginning of year 2 of operations; the initial prototype including basic grid access to shared resources, a teleobservation environment, collaboration tools including data visualization capabilities, a database of commonly used simulation codes with a simple portal interface for execution, and data/metadata definitions for creation of experimental and simulation datasets; these capabilities being based upon the integration of functional software previously tested in other environments and modified to meet the specific requirements of NEESgrid.

- Refine the prototype with a series of updates and software releases to an extended base of collaborating partners during the second year of operations; adding system software extensions to improve functionality at the user interface level (top level) of the architecture; and creating the data repository, extending the capabilities of the collaboration and visualization environments, demonstrating the functionality of a high performance framework for multi-physics simulation, and completing the generalized passive teleparticipation management system.

- Engage in full scale deployment during the third year of operations with formal software releases to provider (equipment) sites and clients (end users); adding specific new capabilities, as formal software updates, enhancing the facility with which end users use advanced simulation capabilities; populating and curating the data repository; integrating more advanced visualization tools into the collaboration environment; and adding active control capabilities (as appropriate) to the teleparticipation management system.

- Fully document the system, information services, outreach and management systems used in NEESgrid; and facilitate the transition to the NEES Consortium on September 30, 2004.

To meet these objectives, the NEESgrid SI team will work as collaborative virtual teams, including community participants, in well defined parallel efforts coordinated by the technical team leaders with the overall project managed to meet deliverable specifications by the NEESgrid management team. The development and deployment effort will use the spiral model which entails rapid deployment of a working system followed by iterative improvement in active partnership with end users, leading to the release of a validated and tested software system with features appropriate to the end user community. The specific technologies defining NEESgrid

that will be integrated, improved, modified or developed *de novo* are summarized in Table 1 below.

Table 1. Baseline System Scale and Capability Specifications

Functionality	*Capabilities or Capacity of NEESgrid*
System Design and Development	
Extensions to Globus Information Service	Framework for publishing resource configuration and status information for users to discover type and availability of grid resources.
HotPage Tools	CGI scripts that are used to construct web based portals.
Remote Job Submission Tools	Specialized job submission and monitoring tools that exploit knowledge of NEESgrid architecture and the structure of the simulation framework to improve usability.
Broker that Allows for Automatic Dispatch of Simulation Runs	Delivers simulation tools, data and an appropriate computing platform to an end user as an integrated unit.
Ingest Tool to Populate Repository and Metadata Catalog	Enables the publication of data to the central NEES repository or to local repositories set up by individual institutions or sites.
Secure Remote Storage Management Tools	Storage management tools that deal with issues such as quotas, setting access controls, managing temporary storage space, consistence checking with meta-data catalog, etc.
Secure Interfaces to Tele-Observation/Control Protocols	Integrates NEESgrid security into the basic interfaces used by the teleoperation and teleobservation management systems.
Neespop Services	Combination of existing Grid services and a small number of new services configured and packaged for NEESpop use supporting connection of equipment provider sites to NEESgrid.
Configuration and Specialization of Core Services	Modify Grid tools to accommodate specific including configuration of a certificate authority, tools for obtaining user and resource credentials, and construction of an integrated NEESgrid wide information service.
Specialization of Community Access Service for NEES Community	Configure framework for specifying and enforcing access control policies for subcommunities within NEES.
Deployment, Operations, & Support	
Equipment Provider Sites Connected to NEESgrid	NEESgrid software systems will be deployed to all Phase 1 and Phase 2 NEES equipment awardee sites by project completion; additional sites may be connected based on availability of project personnel.
Training Systems	Online training for site administrators and NEESgrid users; in-depth training available on-site at NCSA on computational parallelization and optimization of simulation codes.
Help Desk Services	NCSA will maintain a phone/email help desk facility for NEESgrid during the SI project.

Data Storage Resources for Repositories	NCSA maintains over 4 TB of active storage which can be accessed by the NEES community during the system integration project, and which will be used to host the NEES centralized data repository.
High Performance Computing Resources	Multiple teraflops of NSF-funded computing capacity are managed by the PACI partnerships on behalf of the national computational science community. A peer review process to support research proposals allocates these resources. Users and equipment sites may connect additional resources to NEESgrid for use by the community that can be managed and allocated separately.
Data Storage for Experiments	Limited only by the local storage at the experiment site (nominally 100GB), which can be increased by the site. Our requirements analysis demonstrated a wide variation in data generated per experiment, from <1 MB to >30 MB, based on current usage.
Point of Presence (NEESpop) Hardware and Software	Dual 1GHz+ processors, 1 GB memory, 100 GB local disk, GigE NIC, including all Grid system software plus specific extensions to support site inventory and access controls (see above).
NEES Site Connectivity Levels	Gigabit Ethernet (1 Gb/s) on-site with a minimum of 155 Mb/s (OC3) to external networks (Internet). NCSA maintains OC48 (2.4 Gb/s) network connectivity to its onsite resources used by NEESgrid.
NEESgrid.org Community Web Server	The community website is maintained as part of the NCSA server farm which includes 24/7 system support and high volume internet access.
Information Services	
Collaboration and Visualization Environment	Supports Electronic notebooks; thin client access to experimental data, simulation data, metadata, simulation code databases, data visualization tools (VTK), visualization pipeline, side-by-side. simulation/experimentation visualization (based on SPARC) and an integrated framework (CHEF) for up to 20 users to collaborate simultaneously.
Teleobservation and Teleoperation Environment	Browser-based interface managing up to 16 simultaneous video streams, supporting data acquisition into electronic notebooks, real time (or near real time) visualization of up to 50 sensor inputs during experimentation, integration of data capture in electronic notebooks with analysis tools using the collaboration/visualization environment.
Management of and Access to Central and Distributed Data Repositories	Data repository curation and user interface for information services will be managed by APIs developed by the NEESgrid Data Management Team which call upon underlying data services incorporated in to Globus (above).
Computational Simulation System and Requirements	Computational resources available to NEESgrid users far exceed current levels of usage. OpenSees is being ported to NCSA's HPC platforms to support more rapid analysis of larger scale problems. The simulation framework based on Terascale, LLC, technology will support the analysis of computational problems involving subsystems with different physical bases and different timescales. These two components of NEESgrid will be incorporated into a portal environment and are expected to increase HPC resource utilization, which will be monitored.

2.2.3 Project Scope and Objectives

The NEES System will give researchers remote access to a curated repository of experimental and simulated datasets, user-developed simulation software, and models for use in model-based simulation and visualization. The SI project team will work extensively with the earthquake engineering research community, under the coordination of the NEES Consortium Development awardee and the NEES Consortium, when established, to define procedures for collecting, processing, retrieving, and disseminating data sets and user-developed simulation software and will implement these procedures to produce the curated repository for the NEES System. The SI team will be responsible for curating and operating this data repository through September 30, 2004.

The NEES System will form an integrated, networked national simulation resource that facilitates collaboration among scientists and engineers, including educators, students, practitioners, and public sector organizations, both within the U.S. and abroad. There is expected to be continued growth in the size of the NEES user community and in the community's utilization of NEESgrid. Users will continue to require new levels of connectivity and communications, mass storage, speed, system memory, and systems integration services. The SI project team will be expected to plan for and monitor these changes in usage at each NEES equipment site and throughout the NEES System. To incorporate the experimental, collaborative, computational, modeling, and archival needs of the earthquake engineering research community, the SI team, under direction of the NEES Consortium Development awardee and NEES Consortium, when established, will be expected to interface extensively with this community through outreach and training activities to design, promote, and facilitate use of the NEES System through September 30, 2004. The SI team will also be required to monitor and assess the performance of the NEES System and its use through September 30, 2004.

Developing the NEES System includes establishing the configuration of the three main software layers: the *programming interfaces* for NEES equipment at the host equipment sites; the *middleware* needed to facilitate networked collaboration, including database query and retrieval interfaces; and an *application development and operation environment*, including a networked numerical simulation capability. Software, including embedded software and processors, for the NEES research equipment will have to be adapted to enable teleobservation and teleoperation participation during experimental testing. System designs must be flexible to adapt to and support both the changing external networking and data storage environments and the evolving requirements of the NEES collaboratory.

2.3 Project Description

This project develops and makes operational NEESgrid, a national-scale distributed virtual laboratory for advanced earthquake engineering. NEESgrid will be an Internet-based virtual laboratory, national in scope, that links together diverse institutions and resources to enable teleobservation, teleoperation, collaboration, data access, and the coupling of experiment, simulation, and data. Our goal is to enhance the effectiveness of the earthquake community by reducing barriers to the sharing and integrated use of scarce resources, whether expensive equipment, datasets, simulation codes or human expertise. NEESgrid comprises the following components:

Experimental facilities enhanced with *collaborative technologies* to enable collaborative planning and teleobservation of experiments as they are taking place, *network management* to enable remote archiving and integration of experimental data with simulation capabilities, and *control interfaces* to enable teleoperation where appropriate.

Information Management systems that enable the curation and sharing of data and metadata located in centralized and distributed repositories, including storage systems at experimental facilities and other remote sites, enhanced with data management software to enable rapid and controlled publication of and subsequent remote access to experimental and simulation data.

Simulation systems and associated software repositories that enable a wide range of earthquake engineers to exploit powerful simulation codes at high speeds, whether on centralized supercomputers or on high-end clusters at user sites.

User sites, with *NEESgrid-enabled user desktops* that provide individual users with access to the experimental, collaborative, simulation, and data archive capabilities of the entire collaboratory.

Support node(s), which maintain *online knowledge bases* that contain tutorial and other information concerning the effective operation of the many components of the NEESgrid collaboratory and which operate *help desk(s)* that provide access to assistance with the technologies that underlie the NEESgrid collaboratory, whether collaborative tools, data archives, or the underlying networks.

Our goal is to produce, via effort in three principal areas, an operational national simulation resource that can be turned over to the NEES consortium for subsequent operation during FY 2005 – FY 2014.

- *Development and ongoing refinement of a set of detailed user requirements* that identify both functionality and performance needs in each of a set of key areas. An expert team with extensive experience in understanding the needs of scientific communities will perform this requirements analysis, working in close collaboration with the earthquake community, the NEES Consortium Development Team and, in particular, with sites funded under the NEES Earthquake Engineering Research Equipment solicitations (Phases 1 and 2).

- *Definition and integration of a set of hardware and software technologies* to be deployed at each of the NEES Equipment sites, coupled with a collaborative framework for accessing NEESgrid resources and services. This infrastructure will leverage existing grid infrastructure developed and deployed by members of the NEESgrid team and will also exploit existing NSF-funded compute and storage resources at NCSA.

- *Development of a support infrastructure* including online knowledge bases and help desk capabilities, with the goal of ensuring that the NEESgrid collaboratory is directly usable by all earthquake engineers.

We will achieve this goal through the delivery of software to provide desired capabilities in the areas of data (including a curated data repository), instruments (teleobservation and teleoperation), collaboration, computation, grid and user services, and a software framework that facilitates the development and/or incorporation of community-based end user applications.

3.0 Institutional Roles and Responsibilities

This section provides information on organizations participating in the project, their roles and responsibilities. The System Integration project is one of three integral components of the NEES program.

3.1 Institutional Roles

The key organizational participants are:

1. The University of Illinois at Urbana-Champaign
2. The National Science Foundation Division of Civil and Mechanical Systems

The legal entity for the cooperative agreement pertinent to the operation of the NEESgrid Project is The Board of Trustees of the University of Illinois, Champaign, Illinois. The University of Illinois at Urbana-Champaign (UIUC) is responsible for the execution of this project. The UIUC Office of Grants and Contracts has responsibility for the managing the execution the NEESgrid project Cooperative Agreement, on behalf of the University of Illinois. The NEESgrid Principal Investigator (Project Director) reports directly to the Executive Director, National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign. The Project Director in turn has appointed a full-time Project Manager.

Within the National Science Foundation (NSF), the Division of Civil and Mechanical Systems (CMS) has responsibility for the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) and general oversight monitoring of all awards under NEES. The NSF NEES Program will provide project funds, pending availability of funds, and provide general oversight monitoring.

3.2 Responsibilities

3.2.1 University of Illinois at Urbana-Champaign

The University of Illinois at Urbana-Champaign will utilize existing expertise in its Department of Civil and Environmental Engineering (UIUC-CEE) and the National Center for Supercomputing Applications (NCSA) to complete the design, development and implementation of NEESgrid. In addition, UIUC will subcontract certain aspects of the effort to other nationally recognized organizations. The subcontracting organizations are:

1. The University of Michigan (UM)
2. The University of Chicago (for Argonne National Laboratory, ANL)
3. The University of Southern California (USC)
4. Terascale, LLC

Each of these subcontracting organizations is responsible for the completion of specific tasks as described in the WBS. The effort subcontracted to the University of Michigan will be carried out by the Center for Research in Electronic Work (CREW), a unit of the School of Information. The Mathematics and Computer Science Division of Argonne National Laboratory will carry out

the effort conducted under the auspices of The University of Chicago. The Department of Civil and Environmental Engineering (USC-CEE) and the Information Sciences Institute (ISI) will conduct work subcontracted to the University of Southern California.

The responsibilities of UIUC in the overall management and conduct of the NEES Systems Integration project are to:

1. Develop and submit to NSF major technical scope, cost, and schedule baselines to be used in the design, development, and implementation of the NEESgrid project.
2. Prepare the Project Execution Plan for NEESgrid, keep it current, and submit any subsequent revisions to NSF for review and approval.
3. Manage the project in accordance with the specifications in the WBS
4. Conduct an annual review and interim design reviews of the NEESgrid project.
5. Conduct project design reviews per the project schedule with active participation by members of the earthquake engineering community.
6. Prepare and transmit to NSF required quarterly and annual reports documenting fiscal and programmatic details of the project.
7. Prepare and disseminate technical reports on the NEESgrid web site per the project schedule documenting NEESgrid progress.
8. Monitor and report use of the web site by the earthquake engineering community.,
9. Manage subcontract relationships to ensure timely adherence to schedules and report requirements required by NSF.

3.2.2 National Science Foundation

The responsibilities of NSF in the overall oversight of the NEES System Integration project are to:

1. Approve major technical scope, cost, and schedule baselines to be used in the design, development, and implementation of the NEESgrid project.
2. Approve the Project Execution Plan and any subsequent revisions.
3. Review the NEESgrid Project on an annual basis and perform other reviews as necessary.
4. Participate as an observer in all NEESgrid project major design reviews.
5. Review performance against approved technical specifications, budget levels, and schedule milestones, and provide oversight with the awardee to make necessary changes or take corrective action.
6. Review and approve quarterly interim progress reports and annual progress reports submitted by the awardee.

3.3 Internal and External Advisory Committees

The NEESgrid Project is complex and needs both internal and external advisory mechanisms to ensure 1) timeliness and technical quality in system integration activities, 2) relevance and usability of the interfaces and resources provided to the community, and 3) effective synergy with the other NEES program components. Functional relationships among project components (management, technical and outreach), advisory groups and the community at large are depicted in Figure 2 below.

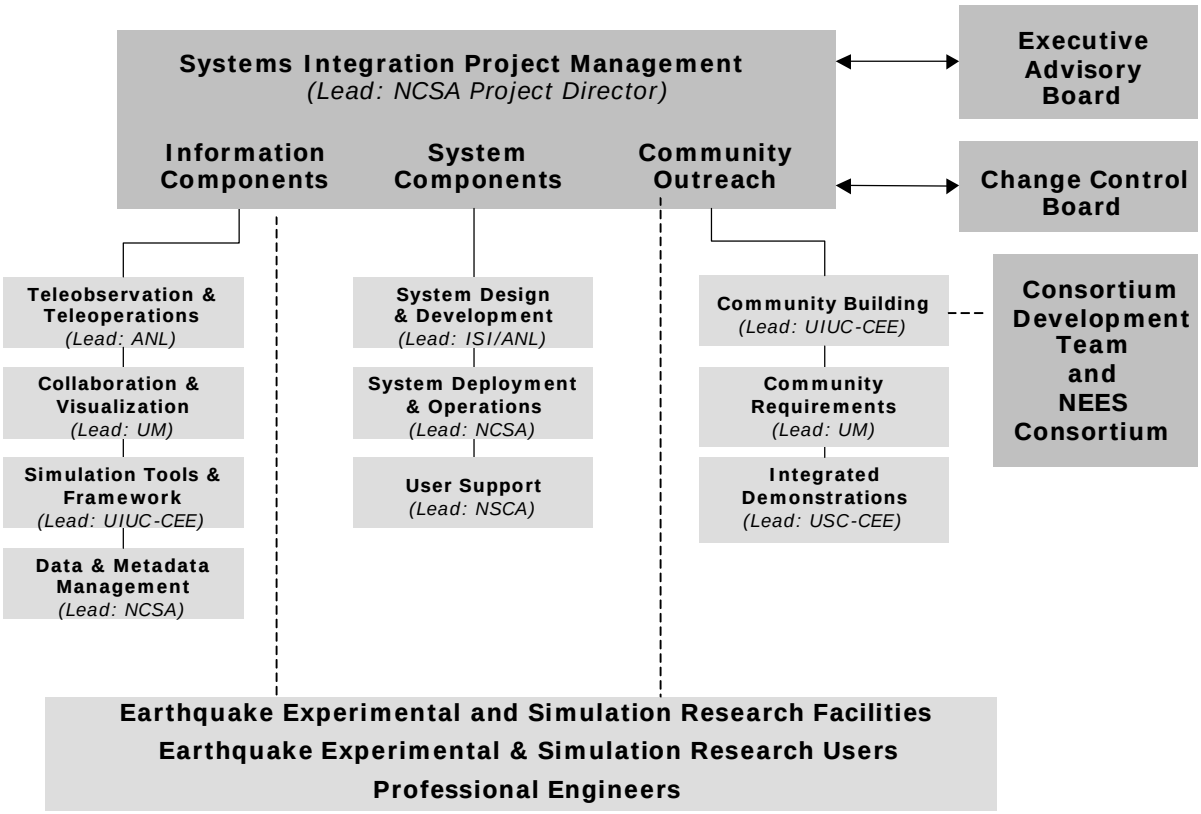

Figure 2. Functional project organizational chart including SI project leads, and SI project relationships with advisory boards, the NEES Consortium Development Team and the earthquake engineering community. Note: The dotted lines denote collaborations and input from external community sources.

The NEES System Integration project is lead by an eight-member Management Team. This team is composed of the project principal investigators, a senior member of the earthquake engineering research community and the full-time Project Manager. The Management Team is lead by the Project Director and serves as the decision-making body for NEESgrid. In cases where consensus among the members of the Management Team is not possible, the Management Team advises the Project Director in whom final authority for decision-making rests. The Project Director also coordinates formal communication between the NEESgrid Project and the earthquake engineering community and between the NEESgrid project and NSF.

The technical and outreach project teams each report to the Management Team and are responsible for completing NEESgrid deliverables in the areas of information services, system components, and community outreach. In addition, the community building team (part of the outreach effort) serves a special role to manage the relationship between NEESgrid and the NEES Consortium Development Team to ensure that our activities are consistent with the interests of the community. The Management Team combined with the technical and outreach team leaders comprise the *internal advisory group* for the NEESgrid project.

An Executive Advisory Board (EAB) advises the Management Team. Currently the EAB includes four leaders from the earthquake engineering community and three leaders representing the information sciences or information architecture communities. The EAB will be expanded in the first quarter of project activity to include additional earthquake engineering end user representation and information technology expertise. In addition, representation by the NEES Equipment Site Council and the NEES Consortium Development Team will be added to the EAB during the first quarter.

The role of the EAB is to actively participate in formal and informal project reviews to make recommendations for positive change or improvement in project scope or direction to the Management Team. The EAB will participate in semi-annual informal internal project reviews, and in annual NSF program reviews. Finally, the EAB will advise the Management Team on an ad hoc basis on topics of specific interest to individual EAB members or to members of the Management Team.

A Change Control Board (CCB) has been established to provide a formal approval mechanism for making changes to the WBS, including changes to design or configuration specifications for NEESgrid components. Initially, the CCB will have four members, including the Project Director, the Project Manager, one member of the EAB with earthquake engineering expertise, and one member of the EAB with information technology expertise. In reviewing changes proposed by the Management Team, the CCB may solicit advice and other input from members of the EAB, the technical team leaders, members of the information technology community-at-large and members of the earthquake engineering community-at-large. NSF approval is required for changes to the WBS to be made. The CCB will meet as needed, upon request by the Management Team.

3.4 Project Communications

The NEESgrid Project is conducted as a cooperative effort involving NSF/CMS and UIUC. For the NEESgrid Project to progress rapidly, all parties need to be fully informed of progress, plans, issues, problems, solution, and achievements in a timely manner.

NEESgrid project communications include the following three components:

- Internal project communications,
- Communications with the NSF NEES Program Office, and
- Communications with the earthquake engineering community and the general public.

Internal project communications internally includes Management Team and technical team leader meetings, staff meetings for each technical team, communication with the EAB and its

members, communication with the CCB, and staff meetings of the project Management Team. Typically, these communications will be handled using electronic mail and attachments, but other electronic media may be used. Meetings will be summarized electronically to capture issues presented, discussion comments and actions taken. All meeting summaries and internal electronic communications regarding the NEESgrid project will be archived to document the issues, the decisions taken, and the internal management or decision-making processes followed in executing the project. Communications between the management team and the CCB will be handled separately from other communications, and a formal record will be kept documenting changes to the WBS requested by the Management Team, CCB meeting summaries, and actions taken. Overall, the definitive source for information on policies and procedures for project participants is the NEESgrid Project Manager.

Project communications with NSF includes various reports, as described in Section 10, and listed in Table 6. In addition, changes to the WBS approved by the CCB will be formally submitted to NSF for approval. In general, the Project Manager will provide quarterly updates to NSF on the master NEESgrid Project Execution Plan (in MS Project 2000 format) to assist the NSF program office with maintaining their master project plan for all components of the NEES program. Action on and transmittal of formal communications are performed promptly. On most issues, informal communication between NSF and UIUC will have occurred prior to formal communications to minimize surprise and delay and maximize success.

A community website, www.neesgrid.org, has been established to serve as the primary communications interface with the earthquake engineering community, researchers and practitioners, and other parties interested in the NEES program. All project communications materials prepared by the NEESgrid team will be made available on this website. In addition, the community website will be used to host online events, such as webcasts, and will host an online discussion forum for community members wishing to participate. Finally, this website will provide links to all system and client software, portals, analytical tools, and repositories.

The standards used in the development of materials for the website, and for print and other media, will be those used by the NCSA Communications Division for development and dissemination of NCSA program materials. NCSA has a long history of creating high quality printed materials, state-of-the-art websites, and actively promoting scientific successes in the popular press.

3.5 Records Management

Records are divided into program documents and materials, and financial records. All program documents and materials will be archived in electronic form and maintained at the NEESgrid project management office at NCSA for the duration of the project. Program documents and materials include all official correspondence (electronic or paper format) among NEESgrid participants, between the NEESgrid Management Team and its advisory boards, and between the NEESgrid Management Team and NSF. The WBS and all changes proposed and approved by NSF are included in these materials. All program documents and materials will be made available to NSF upon request during the life of the project, barring intellectual property or other concerns that will be discussed with NSF on a case-by-case basis. Upon completion of the project, copies of these materials will be provided upon request to the NEES Consortium as

documentation for the detailed progress of NEESgrid implementation during the systems integration phase of the NEES national simulation resource.

The Office of Grants and Contracts (OGC) at the UIUC will maintain all financial records. The OGC is responsible for financial accounting and adherence to regulations and acceptable business practices for the entire University of Illinois system. The OGC will comply with reasonable requests for financial information regarding NEESgrid made by NSF.

4.0 Project Work Breakdown Structure

A Work Breakdown Structure (WBS) has been developed to describe and account for all components of the project. The NEESgrid project is organized in several levels of increasing detail (see details in Appendix B). The project WBS defines the technical content of the project and is the basis for project management, cost estimating, scheduling, project cost and schedule control, and human resource requirements. In this section, the first three levels of the WBS are defined.

Level 0 is the entire project. At level 1, the project is divided into four components representing the primary division of labor: (1) System Components, (2) Information Services, (3) Community Outreach, and (4) Management. While the project is managed as an integrated whole, each of these four components is presented in a separate Figure for clarity (Figures 3 through 6).

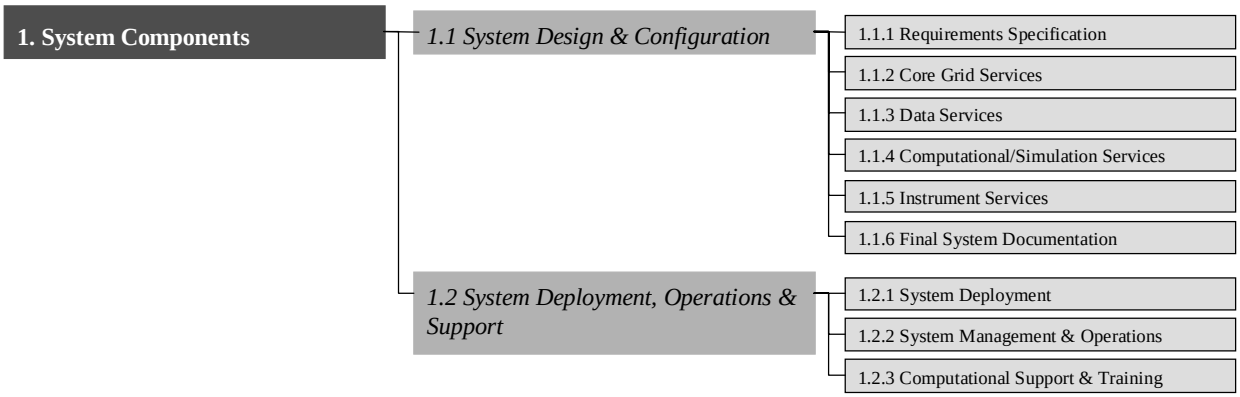

Figure 3. Work Breakdown Structure for NEESgrid: System Components

In level 2, the primary activity areas are defined. Each level 2 activity is assigned to a technical, outreach or management team, and each team has a team leader. For the System Components in Figure 3, there are two teams representing WBS level 2 activities: System Design and Configuration; and System Deployment, Operations and Support.

Level 3 identifies key deliverables for each technical, outreach or management team effort, and 43 separate deliverable items are identified in the WBS. For System Design and Configuration there are six key deliverables, as shown in Figure 3. System Deployment, Operations and Support includes three key deliverables (Figure 3).

Finally, WBS level 4 elements represent milestones with completion dates leading to accomplishment of each deliverable task. Appendix B describes all WBS activities for levels 1

through 4, including team leadership (level 2) and deliverable (level 3) assignments with cost data to level 3.

Information Services (Figure 4) are divided into four level 2 technical team efforts: Teleobservation and Teleoperations, Collaboration and Visualization, Simulation Tools and Framework, and Data and Metadata Management.

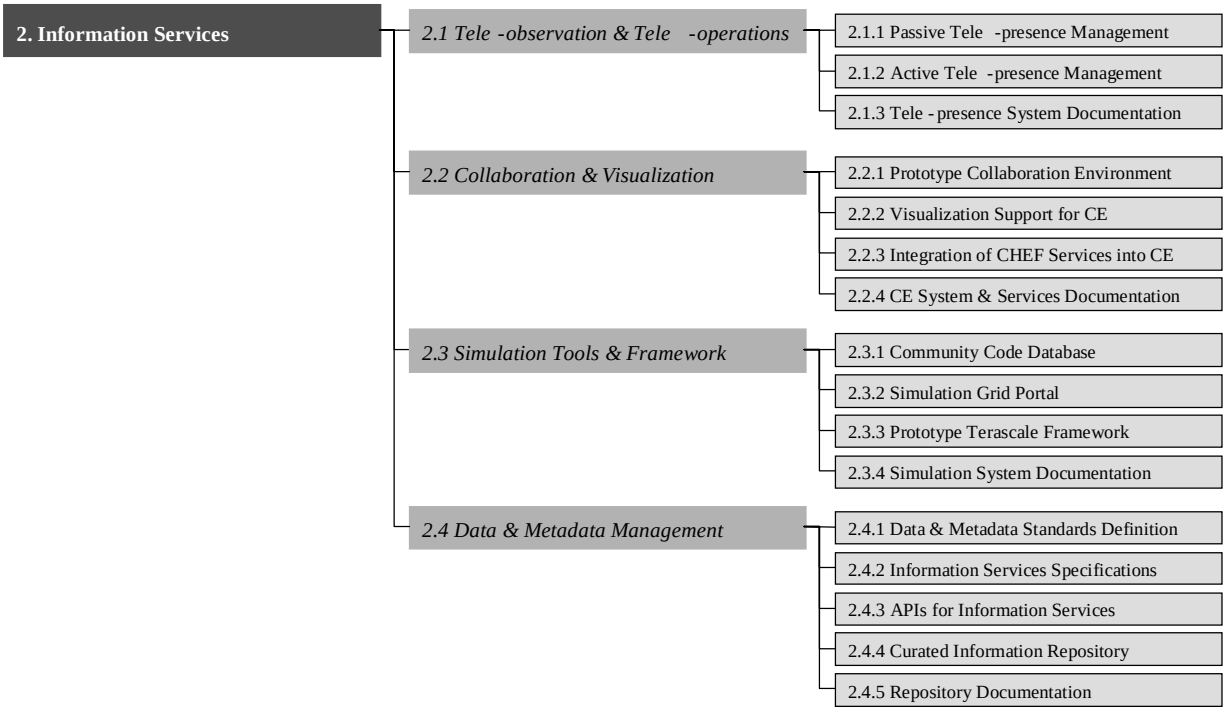

Figure 4: Work Breakdown Structure for NEESgrid: Information Services

Three primary activities are included under Community Outreach in Figure 5: User Requirements Assessment, Community Building. and Integrated Demonstrations.

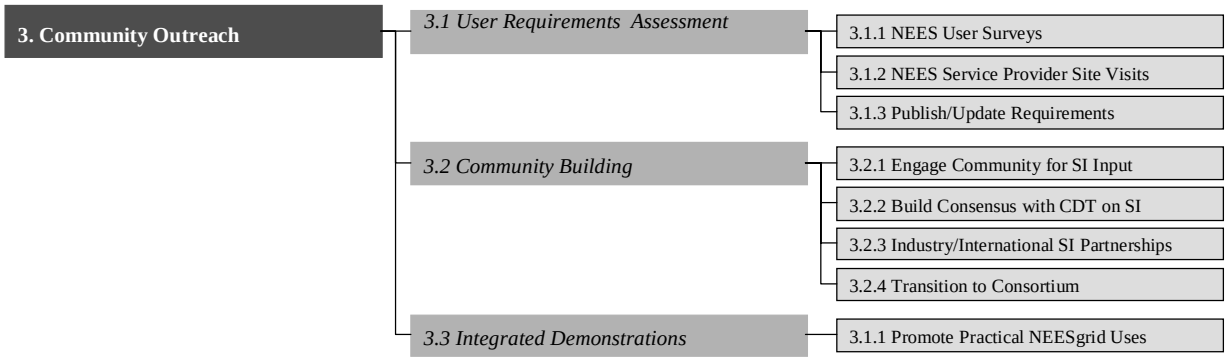

Figure 5. Work Breakdown Structure for NEESgrid: Community Building

Management (Figure 6) is divided into NEESgrid Management, Operational Management, and Assessment and Evaluation teams.

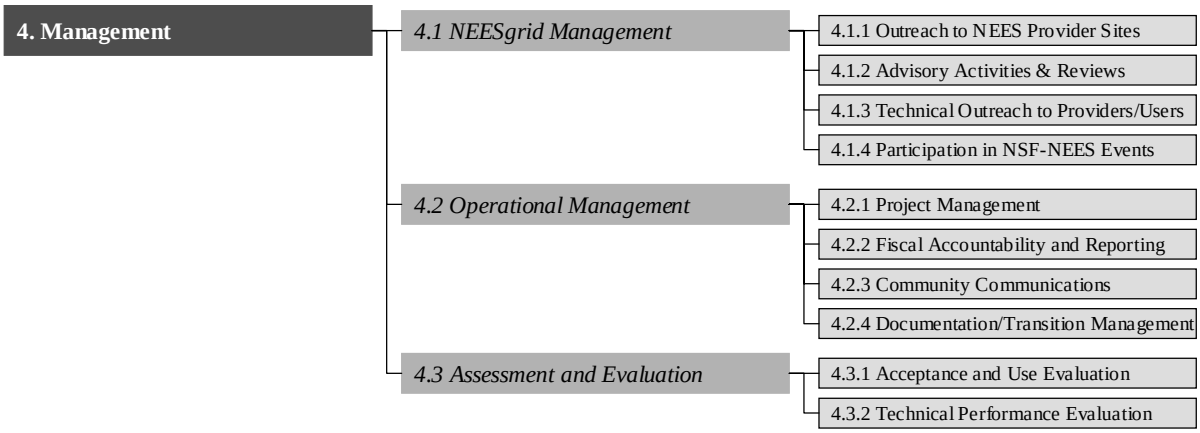

Figure 6. Work Breakdown Structure for NEESgrid: Management

The schedule baseline summarized in Table 2 identifies the major activities essential for completion of the NEESgrid project. The baseline integrates and optimizes the activities related to design, procurement, development, construction, testing, and operation of NEESgrid; and it reflects the major activities and funding baseline presented in Section 5. To develop this baseline, separate networks were prepared for each WBS level system schedule. Schedule interfaces with other WBS elements will be formally identified in Q2, and the entire database will be used to evaluate critical path(s).

Table 2. Major NEESgrid Project Milestones (WBS level 4) and Timeline

WBS	*Milestone/Deliverables Description*	*Completion Date*
1.1.1.2	System Specifications and Planning Documents Published	9/30/2001
3.1.3.1	User Requirements Specifications Published	10/1/2001
2.4.1.3	Data and Metadata Standards Published	9/30/2002
2.3.2.1	OpenSees Portal for Simulation Completed	12/31/2002
2.1.1.2	Passive Teleparticipation Management System Prototype Completed	3/31/2002
1.2.1.4	NEESpop Prototype Deployed	4/1/2002
2.2.1.3 2.2.2.2	Collaborative Environment with Visualization Pipeline Prototype Completed	6/30/2002
2.4.4.2	Establishment of Curated Data Repository	6/30/2003
2.1.2.5	Active Teleoperations Management System Completed	6/30/2004
2.3.3.5	TeraScale Multi-Physics Simulation Framework Prototype Completed	6/30/2004

2.2.3.7	CHEF Environment for Collaborative Visualization Integrated into NEESgrid	6/30/2004
1.2.1.5	NEESgrid System Completed and Deployed to NEES Equipment Sites	6/30/2004
4.2.4.2	Successful Transition of NEESgrid to Consortium	9/30/2004

4.1 Work Plan (WBS Levels 1 and 2)

The Work Breakdown Schedule (detail in Appendix B) for this project is divided into five levels. Level 0 is the whole project, level 1 represents the major activity categories, level 2 captures the activities of the project teams, level 3 identifies deliverables for the project teams, and level 4 identifies the milestones to complete in accomplishing the deliverables assigned to each project team. The responsibilities assigned to project teams in each level 1 component are given in the following four sections.

4.1.1 System Components

System Components include all system design, development, deployment, operations and support activities in NEESgrid. This effort comprises two project teams: 1) System Design and Configuration and 2) System Deployment, Operations and Support. The System Design and Configuration team is responsible for specifying system requirements to meet defined user needs. This team is assigned the tasks related to configuring or modifying existing middleware, or in certain cases developing new required components, to meet those requirements. Upon completion, the software products from this team are transferred to the Deployment, Operations and Support Team. The deployment component of this team is responsible for packaging, testing, validating and distributing the NEESgrid System and client software releases and updates. The operations component is responsible for establishing, monitoring and troubleshooting NEESgrid System components including computing, storage and network resources. The support component is responsible for training and consulting for system support personnel at provider sites and users of NEESgrid services. In addition, the support component provides consulting support for optimization and parallelization of simulation and numerical analysis codes that might experience improved performance running on grid-accessible HPC platforms.

4.1.2 Information Services Components

Information Service Components include all integration activity in developing high level end user interfaces for NEESgrid users. This effort comprises four project teams: 1) Teleobservation and Teleoperations (Telepresence), 2) Collaboration and Visualization, 3) Simulation Tools and Frameworks, and 4) Data and Metadata Management. Each of these teams will work closely with the system design and development team to ensure functionality and interoperability of their tools and interfaces with the underlying middleware tools and services in NEESgrid. They will also work with the systems deployment and operations team to assist them in packaging their work products into the NEESgrid client software for testing and distribution.

The Teleobservation and Teleoperations team is responsible for delivering a passive telepresence management system supporting participation NEES experiments by remote users, and an active

teleoperations management system supporting remote control of experiments, as appropriate given safety and performance issues.

The Collaboration and Visualization team is responsible for delivering a collaboration environment supporting experimental design and data analysis, including data visualization tools and visualization pipelining when required.

The Simulation Tools and Framework team is responsible for delivering a web-accessible database of user codes, a user portal environment for executing simulation codes using grid resources, and a prototype, multiphysics framework for computational simulation based on TeraScale technology.

The Data and Metadata Management team is responsible for establishing data and metadata standards for the NEES repository, for establishing a curated repository and for populating the repository with data from the community.

4.1.3 Community Outreach Components

The Community Outreach components of NEESgrid are responsible for the effective communication between the NEESgrid team and different levels within the earthquake engineering community. This effort comprises three components.

Our user requirements analysis component is focused on assisting the system specification definition activity with user requirement specifications that are determined through direct interaction with the different segments of the earthquake engineering community.

The community building effort is focused on developing active partnerships with the Consortium Development team, NEES Consortium, the NEES equipment sites (through direct contact coupled with a partnership with the NEES Site Council), and with specific industrial partners that are important to the systems integration aspects of NEES.

The integrated demonstration effort is focused on engaging pioneer researchers in the field to use NEESgrid in their work both to learn the benefits of NEESgrid and to teach it to other researchers.

4.1.4 Project Management and Operations

Three activities are included in our management effort.

The NEESgrid Management Team and Executive Advisory Board component includes top level management and decision making for the project, plus the internal and external review activities that actively involve the EAB.

NEESgrid Project Management and Operations includes the day-to-day adherence of project teams to delivery schedules, fiscal management and reporting to NSF and communications with the earthquake engineering community.

The Project Assessment and Evaluation effort collects, analyses and publishes reports summarizing usage statistics, community valuation and validation, and technical performance results from semi-annual and annual reviews.

5.0 Cost Baseline

This section provides an overview of cost estimates, baseline funding agreements, contingency management and project staffing.

5.1 Basis of Cost Estimate

Estimated costs for this project are based on 1) personnel, equipment, travel and services required to perform the tasks necessary for completion of the milestones and deliverables in the WBS; and 2) knowledge of management and support costs gained from prior experience conducting projects of this complexity, scope and magnitude.

Personnel costs for staff currently employed by UIUC or one of its subcontractors are based on actual salary, fringe benefit and indirect cost rates for that individual and institution. For personnel to be recruited, an average salary for each position to be filled was used to estimate cost, specific to the institution with responsibility for completion of the task.

5.2 Funding Profile

Table 3 provides overall baseline funding estimates for the entire project for each of the WBS level 1 components with contingency funds as a separate cost component.

Table 3. NEESgrid Cost Baseline for Full Project (2001-2004) to Level 1

WBS L 1	*Description*	*Total Cost ($M)*
1	Systems Components: Design, Development, Deployment, and Support	
2	Information Services Components	
3	Community Outreach and Partnership Development	
4	Management	
	Contingency	
	Total	

Table 4 documents the funding obligations to UIUC and its subcontractors for each year of the project to level 1 of the WBS, with contingency funds included in the numbers for each level 1 project component.

Table 4. Project Obligation Profile Including Contingency to Level 1

WBS L 1	*Description*	*Year 1 7/1/2001 to 6/30/2002*	*Year 2 7/1/2002 to 6/30/2003*	*Year 3 7/1/2003 to 6/30/2004*	*Year 4 7/1/2004 to 9/30/2004*	*Total*
1	System Components: Design, Development, Deployment, and Support					
2	Information Services Components					
3	Community Outreach and Partnership Development					
4	Management					
	Totals by Project Year					

5.3 Contingency Management

A contingency budget item is estimated for each WBS element at the lowest possible level on the basis of a technical risk assessment for each item. All contingency funds are to be retained by NEESgrid Project Management in a separate central account.

Application of contingency funds for a particular task will be initiated by a formal request, initiated by the appropriate task leader and submitted to the NEESgrid Project Director or Project Manager. The scope of allowable requests and the details of the formal request process will be determined as part of the initial Project Execution Plan developed in Q1 and Q2 of the Systems Integration process (see Appendix D). All requests for application of contingency funding will undergo formal review by the NEESgrid Change Control Board, and the board will make its recommendations to the NEESgrid Project management. The designated Project Controls Manager in association with the Project Director shall issue a written decision memorandum on the request.

The granting of contingency funds is recorded as a change in the NEESgrid Cost Baseline. Appropriate record-keeping mechanisms for tracking, auditing and evaluating contingency funding will be developed as part of the Project Execution Plan, and these mechanisms will be established upon revision of that plan in Q2. The specific composition and responsibilities of the Change Control Board will be developed in that plan.

Application of contingency will be reported at WBS level 3 in the quarterly and annual reports to NSF and will be tracked against allocation and against the project earned value. NSF will be notified of any contingency allocation in excess of $50,000; otherwise all contingency allocations will be reported in the quarterly and annual progress reports.

5.4 Staffing

Wherever possible, each of the technical, outreach and management team leaders is using existing staff to fulfill task obligations to NEESgrid. This strategy allows us to initiate the project with minimal staffing dependencies, and allows us to more exactly estimate costs. Certain key activities will require the recruitment of new staff, most notably a Project Manager and post-doctoral staff for the Telepresence and Simulation and Data teams. However, qualified candidates for some of these positions have already been identified and can be recruited immediately upon receipt of a Notification of Award from NSF. In all, the team leaders with open positions are confident that all positions will be filled before the end of the second quarter of operations.

6.0 Implementation Plan

6.1 Schedule Baseline

Table 5 describes major project milestones leading to the successful completion of this project. Entries are organized by level 1 WBS component, and each item includes level 3 or level 4 WBS numbers linking it back to the complete WBS in Appendix B.

Table 5. Major NEESgrid Project Milestones

WBS	*Milestone Description*	*Date*
0 – Full Project	NSF Project Funds Received by UIUC	7/1/2001
1 System Components 1.1.1, 1.1.2.1, 1.1.2.2, 1.2.1.1	Core grid services and grid information services integration completed and incorporated into deployment package for testing with early adopters	6/30/2002
1- System Components 1.1.5.1, 1.2.1.1	Instrument services integration completed and incorporated into deployment package for testing with early adopter sites	6/30/2002
1 – System Components 1.1.3.1, 1.1.3.2, 1.2.1.1	Data services integration completed and incorporated into deployment package for testing with early adopters	6/30/2002
1- System Components 1.1.4.1, 1.2.4.2, 1.2.1.2	Remote job submission and portal services integration completed and incorporated into deployment package for testing with early adopters	6/30/2003
1- System Components 1.1.5.2, 1.1.5.3, 1.2.1.3, 1.2.1.4	Complete grid integration of NEESpop services deployment to equipment sites	6/30/2004
2- Information Services 2.1.1	Passive telepresence management system completed and integrated into NEESgrid	6/30/2003
2- Information Services 2.1.2	Active teleoperations management system completed and integrated into NEESgrid	6/30/2004
2- Information Services	Prototype thin client collaborative environment	6/30/2002

2.2.1.3, 2.2.2.2	with visualization pipeline completed	
2- Information Services 2.2.3.7	Integrated CHEF architecture implemented on NEESgrid	6/30/2004
2- Information Services 2.3.1.3, 2.3.2.1	Community simulation code database implemented with grid-enabled OpenSees user portal	12/31/2002
2- Information Services 2.3.3.5	TeraScale simulation framework prototype completed	6/30/2004
2- Information Services 2.4.1.3	Data and metadata standards published	9/30/2002
2- Information Services 2.4.2, 2.4.3, 2.4.4.1, 2.4.4.2	Data repository with curation and management system established	6/30/2003
3- Community Outreach 3.1.3.1	Initial User Requirements Specifications completed and published	10/1/2001
3- Community Outreach 3.1.2.1	Initial meetings with all NEES sites completed and report published on neesgrid.org	12/31/2001
3- Community Outreach 3.3.1.4	First integrated demonstration completed and posted on neesgrid.org	4/1/2002
4- Management 4.2.1.1	Establish project management team and systems including expanded EAB	9/30/2001
4- Management 4.1.2.3	Conduct first annual review with NSF demonstrating adherence to project management principles and systems	4/1/2002
4- Management 4.2.4.2	Complete transition of system and documentation to the Consortium	9/30/2004
0- Full Project	Project Completed	9/30/2004

6.2 Critical Path Analysis

The current WBS for the NEESgrid project does not contain sufficient information (e.g., component dependencies, technology milestones, risk-mitigation strategies) to develop a robust and reliable critical path analysis at this date. To ameliorate this constraint, two initiatives will be begun within the NEESgrid project upon award (described in the Project Management Planning Q1-Q2 schedule in Appendix D):

(1) In Q1, the NEESgrid Project team will gather and develop the remaining data required for a formal critical path method (CPM) analysis and an associated PERT analysis, and

(2) In Q2, the NEESgrid Project team will re-factor (as appropriate) the project's core components to facilitate the maximal decoupling of effort.

The first task will provide a schedule that is optimal for all deterministic project tasks, while the second will help mitigate schedule and budgetary risk arising from non-deterministic project

tasks. Taken together, this strategy will achieve the primary goal of a critical path analysis: developing an optimal schedule that maximizes progress while minimizing risk.

Both PERT and CPM will be utilized as project network idealizations, because the NEESgrid effort has substantial deterministic components (where CPM is intended for use) and non-deterministic tasks (where PERT is better-suited to determining critical tasks).

The formal project network analysis will be a key milestone of the Q2 NEESgrid project management deliverable, and this analysis will undergo one iterative refinement as risk mitigation data is gathered during the development of the final Project Execution Plan. Efforts on the part of the individual PI's (e.g., identifying key technical personnel who can provide needed data for the PM plan) have already begun, but completion of this task must necessarily occur after the award date, as many of these efforts are of substantial complexity, and could not be reasonably accomplished under the scoping study award.

7.0 Subcontract Management

This section describes the subcontracts required to execute this project and specific reporting requirements imposed upon the subcontractors necessary to assist the Project Management team in its activities.

7.1 Subcontracts

The execution of this project requires expertise and other resources from three academic institutions in addition to the University of Illinois at Urbana-Champaign. These institutions are:

- The University of Michigan (School of Information),
- The University of Southern California (Information Sciences Institute and Department of Civil and Environmental Engineering), and
- The University of Chicago (contractor for the Argonne National Laboratory, Division of Mathematics and Computer Science).

The University of Illinois Office of Grants and Contracts will execute subcontracts with each of these institutions that will describe the terms and conditions governing the conduct of activities undertaken by employees of each subcontracting institution. The University of Illinois has extensive experience negotiating and managing subcontracts resulting from large NSF-funded projects, and specifically has active subcontracts with each of the institutions described above.

In addition to subcontracts with these academic institutions, the University of Illinois will execute a subcontract with Terascale, LLC, to procure the services of their two top scientists to assist the simulation effort under NEESgrid

7.2 Reporting requirements

The key aspect of the subcontracting relationships negotiated for NEESgrid partners that is different from the norm for academic contracting is the need for additional and more frequent

reporting of financial and technical information to the Project Manager at UIUC. To effectively use modern project management techniques, including project management software applications, information from the UIUC business office, and from the subcontractors is essential and will be included in the terms and conditions of the subcontracts.

During Q1 of project activity, we will develop a template for financial information keyed to the WBS categories to be communicated in electronic from the UIUC and subcontractor business offices to the NEESgrid project management office. Information included in this template will be used to update financial data in the Project Execution Plan (maintained in MS Project 2000 at NCSA) on a weekly basis.

In addition, on a monthly basis the project management office at NCSA will receive from each project technical and outreach team leader an updated project plan (in MS Project 2000 format) including partial progress against milestones and deliverables, keyed to the WBS. These documents will be incorporated into the NEESgrid master project plan to enable active assessment of overall project performance, changes in risk profiles, changes in project networks, and calculation of earned value, e.g., on a monthly basis.

8.0 Baseline Control

A mechanism for controlling baselines and specifications is presented in this section.

8.1 Overview

The project baseline includes a technical baseline (Section 4), a cost baseline (Section 5) and a schedule baseline (Section 6). All three aspects will evolve and be measured and controlled by the NEESgrid Project Management Team, as the project progresses. The cost and schedule baselines presented in Sections 5 and 6, respectively, are based on the technical baseline and proposal CMS-0117853 submitted to NSF.

If necessary (e.g., due to significant changes to the funding profile), UIUC or NSF may initiate and propose rebaselining the project at any time. Rebaselining involves updating cost and schedule plans to reflect the best current estimate for the current, approved configuration given the currently projected funding profile. The revised baseline will then be used to track subsequent cost and schedule performance estimates. Cost estimates are based on only the most up-to-date baseline and approved technical scope.

The cost and schedule baselines will be implemented and controlled through the following measures:

- All project work will be defined, organized, and implemented in accordance with the WBS.
- Project performance will be measured against cost and schedule baselines at level 2 of the WBS.
- A procedure will be employed to control changes and will be developed by Q2.

The NEESgrid Project management will exercise technical control by:

- Organizing work according to the WBS.
- Maintaining the controlled technical baseline to specific technical objectives and to establish design specifications and criteria for the component systems.
- Creating system designs that meet the design criteria and satisfy the cost and schedule constraints.
- Reviewing proposed designs (using both technical and fiscal criteria, and with review performed under the aegis of the associated advisory or control board) prior to issuance of subawards.
- Implementing the institutional QA plan and establishing specific QA plans as required by Q2 as part of the risk mitigation strategy.
- Implementing a change control system by the end of Q2.
- Implementing procedures to assure the proper authorization and technical integrity of the statements of work, procurement documents, and accompanying documents by the end of Q2.
- Supervising the development of component systems and testing them at appropriate points (e.g., upon delivery for deterministic components, or during walkthroughs for higher-risk components) to assure that design specifications and criteria are met.

Baseline management for mature technology components is effected through the project's configuration management component, with a formal mechanism utilized for (1) identifying areas where change is required, (2) characterizing the events that cause changes to be desired, (3) outlining the process for effecting the change, and (4) gaining the required authority (e.g., from the funding agency, or from a technical advisory board) for realizing the change. The various components of baseline management are presented below.

There are three primary areas where baselines must be identified and managed in this project:

- Business baselines, which will be in the form of a cooperative agreement between NSF and UIUC and as subcontracts between UIUC and subaward organizations, which may require more formal approval to create or modify,
- Technical baselines, which are expressed as agreements outlining the technical work to be performed (e.g., the WBS expression of the roles and responsibilities of the collaborating organizations), and
- Schedule baselines, which detail the sequence and duration of the various component tasks that define the overall systems integration project.

In each of these venues, a baseline modification procedure will be developed during Q2, as part of the Change Control Process and Project Execution Plan development process.

8.2 Risk Management Plan

During Q1 of the NEES SI award, the standard risk management technique of weighted-value calculations will be used on each WBS project element in order to assess the cost of technology risks, so that high-risk elements can be mitigated using appropriate risk containment measures such as technology portfolio diversification.

A formal risk assessment of all project components will be developed in Q2 of the project, and this risk assessment will be used to develop the NEESgrid Systems Integration Risk Management Plan during Q2. Along with a critical path analysis of the project's components, and a formal change control/change management/configuration management plan, these more detailed baselines will represent the framework for managing the NEESgrid SI project to a successful completion.

We have developed a high level assessment of risk elements in our technical plan, which is summarized in Table 6, below. These risk elements will be formally analyzed during the Q1-Q2 assessment process, and will likely change, but the following list is intended to demonstrate that the process of identifying potential risk components in NEESgrid has been initiated.

Table 6. Initial assessment of potential risk elements in NEESgrid

Technical Team	Potential Risks	Mitigation Strategies
System Design & Development	Globus middleware technology not sufficiently mature to meet early SI deliverables	Deploy feature-limited B2B technology Deploy limited Globus solution that meets needs
System Deployment	NEES site network infrastructure support not complete or unable to support NEESpop services	Work with institutional network administrators to provide sufficient capability, capacity and QoS
Teleobservation & Teleoperations	Potential I/O demand (audio, video, sensors) exceeds limits of current configuration for remote use Data acquisition and control software not able to be shared (e.g., MTS software)	Evaluate more structured use of COTS solutions Work with vendors to improve performance of legacy systems and resolve intellectual property issues
Simulation Framework	Risk inherent to integration of new technology (i.e., Terascale Framework)	Deploy a more conventional framework, i.e. OpenSEES
Data/Metadata	Insufficient resources to address data/metadata requirements of NEES community	Identify critical requirements and scale back effort Try more structured approach to data management using COTS Reallocate NEESgrid resources
Collaboration & Visualization	Risk inherent to integration of new technology (i.e., CHEF)	Modify scope to incorporate selected tools supporting computational simulation visualization, 3D data visualization, and animation

8.3 Change Control

Change control is effected by maintaining a centralized repository of information that represents the current state (e.g., progress, financial health, configuration, etc.) of the project, the various directions that individual components are working in, and other project management information (e.g., contingencies, portfolio diversification strategies). This centralized repository serves both as a means to provide a uniform view of the project for all the project participants, and as a history of the project's evolution, both planned (e.g., schedule baselines) and unplanned (e.g., change management).

The project Management Team will prepare a formal change control plan as a subtask in our Project Execution Plan, described in Appendix D. The change control plan will be based on standard configuration management practices, and this change control document will be delivered at the end of the second quarter of the project as part of the overall Project Execution Plan package. The configuration management plan will define and describe several relevant areas of change control for this project, including:

- Which components utilize sufficiently mature technology to permit effective use of configuration management principles,
- The circumstances under which emerging technology components are deemed sufficiently mature to warrant identification under the configuration management plan,
- Appropriate mechanisms to assess risk and impact (technical, financial, and schedule) of proposed changes to the project baselines, and
- Appropriate mechanisms to identify, characterize, process, and authorize changes to the various project baselines.

8.4 Funding Control

The NEESgrid Project maintains a project obligation plan that is revised as required to adapt to changes in the funding profile. The total obligation plan is the sum of individual plans prepared by task in the WBS.

Each fiscal year during the project, it is expected the NSF, pending availability of funds, will approve a specified amount of the funding for the NEESgrid Project. This funding will be provided to UIUC following the annual site visit merit review and based on progress to date and plans for the next year. These plans will include risk assessment and contingency plans based on risk. In the interest of optimizing progress and project success, it is the policy of UIUC to obligate all funds in the year they are received to perform activities or to procure items included in the approval baseline.

A parallel accounting structure that allows funds to be allocated to specific WBS elements has been created. This structure provides a system by which the different types of funds (NSF and UIUC) can be allocated and tracked.

Based on weekly updates from UIUC and its subcontractors, monthly reports of expenses and obligations are generated for use by the project Management Team. In addition, UIUC tracks open purchase requisitions as well as bid prices and current negotiations for major subcontractors about to be placed. The aggregate cost may be more or less than planned either because tasks have not been performed according to the original schedule, or actual costs have been more or less than estimated. This cost experience is reported quarterly to the NSF.

If towards the end of the fiscal year, the total obligations fall short of the available funds, the NEESgrid Project Director will have the management freedom to accelerate priority tasks for procurements planned for the subsequent fiscal year. This process does not change the total project contingency since the estimated for all tasks has not been changed.

If the cost trend is unfavorable, i.e., planned tasks are requiring more funding than estimated, the NEESgrid Project Director will act to reduce costs by exploring and implementing cost-saving alternatives. Total costs for all work planned for the fiscal year will be compared with the funding available. If the total estimate for the planned work exceeds the available funding, the Project Manager will coordinate with the technical and outreach team leaders to identify and prioritize tasks or procurements that can be rescheduled for the subsequent fiscal year while minimizing the impact on project milestones. Any significant impacts on major project milestones will be discussed with the NSF NEES Program Director.

Rescheduling project tasks to manage the required funding does not directly affect contingency since the estimate at completion for the task remains the same. Contingency is affected by changes in the estimate at completion reflecting cost overruns or underruns. Contingency may also be affected slightly by the change in escalation rate when a task is rescheduled to a different fiscal year.

On an annual basis, the NEESgrid Project prepares a revised estimated of the cost to complete the project. This estimate is based upon updated cost information from subawards, approved changes to the technical baseline, cost-saving plans and approaches developed by the NEESgrid Project Director in the collaboration with the Project Manager and Management Team, and on known or projected revisions to the funding profile. With this information, NSF will evaluate the progress and scope of the project. If the estimate-to-complete exceeds the current funding baseline, the Project Director will develop a plan, approved through the Change Control Board, to enable NEESgrid Project completion and submit this plan to NSF for approval.

8.5 Performance Measurement and Corrective Actions

The performance of all project technical, outreach and management teams will be measured by their adherence to the plan, meeting all approved milestones according to the agreed upon timelines and within the allocated budgets. In addition, the Project Manager will monitor progress toward milestones, and evaluate on a monthly basis if any project components are at risk. The Project Manager will bring present this assessment to the Management Team for discussion and action, if appropriate. If action is required, a change request will be prepared by the management team and proposed to the Change Control Board.

8.6 Meetings and Reviews

Internal management meetings will occur on a weekly basis during the term of this project. The purpose of these meetings is to monitor project performance at each level in the WBS and to identify as early as possible any changes in risk profiles or other aspect which might require a change in the technical, cost or schedule baselines. Due to the distributed nature of NEESgrid participants, we will use H.323 video teleconferencing technologies and services to support remote participation in management functions.

Internal management meetings include:

- Management Team meetings, conducted by the Project Director,
- Technical Team Leader meetings, conducted by the Project Manager, and
- Technical Team meetings, conducted by the Technical Team leaders. The technical teams and their leaders are defined at level 2 in the WBS.

The Executive Advisory Board meets formally on a semi-annual basis, coinciding with the internal reviews conducted each October and the annual NSF project reviews conducted each April. In addition, on an *ad hoc* basis members of the EAB will be invited to join meetings of the Management Team or the technical teams to contribute their expertise and perspectives. Again, we will use H.323 video teleconferencing technologies and services (VTC) to enable this *ad hoc* participation. Having the Management Team, the technical team leaders and the EAB accessible by VTC allows the Project Director and Project Manager the freedom to meet informally with any combination of these participants regardless of location.

The Change Control Board serves to consider proposals by the Management Team for changes to project baselines. It is not scheduled to meet on a regular schedule, but stands ready to consider any proposals made as soon as a meeting of its members can be arranged. This process will be facilitated through the use of VTC supporting remote participation in CCB meetings.

We anticipate frequent interactions with the NSF NEES Program Office, and the cognizant NEES Program Director, or her designee, will be invited to participate in the weekly management team meetings. It is essential to the success of the project that an open line of communication is maintained between NSF and the Project Director/Management Team. In addition, on an annual basis NSF will convene a formal project merit review to perform a detailed evaluation of project performance, project management, desired or necessary changes to project baselines, and other assessment reports prepared by the NEESgrid Project participants. Participants in the annual reviews will include external reviewers invited by NSF, the NEES Program Director and other NSF staff, the NEESgrid Project Director, NEESgrid Project Manager, Management Team, and other NEESgrid Project staff.

In all areas of software development or NEESgrid components with high technological risk, walkthroughs will be performed sufficiently early in the systems integration process to insure that no project failure modes exist within these high-risk project venues. Such early walkthrough meetings will be one of the most important mechanisms for creating the baseline risk assessment project management documents in calendar year 2001.

9.0 Standards, Quality Assurance, and Safety

Relevant standards for the systems integration project are presented in this section, including background material on software project management and software quality assurance, two topics which are more tightly related in the abstract world of software development than they are in more concrete projects such as construction or manufacturing.

9.1 Standards

Codes and standards proven through established engineering and software practice to be appropriate to the system under consideration will be incorporated into performance specifications for the design of each major system of NEESgrid. An integral part of the preliminary design of each major system will be the selection of the appropriate codes and standards to govern design, development, testing and operation of the system. This selection is subject to review by UIUC through the design review process. The selection of codes and standards will be tailored for each major system specification in accordance with the function of the system and accumulated engineering experience with similar systems development projects.

When established codes and standards are not applicable or available, a NEESgrid Project Standard or Specification will be formulated by the appropriated standards subcommittee, based on the best technical information available, and communicated to project participants.

In the realm of software and digital content generation (e.g., from data gathered at experimental sites), existing industry standards will be utilized where feasible. Software development models will follow established industry practice (e.g., CMM), and data models generated for archiving and retrieval of experimental and simulation data will utilize established standards appropriate to the content (e.g., XML).

In all cases, preference will be given to deployment of COTS technology, either as an initial prototype implementation intended to mitigate risk, or as a long-term solution intended to minimize costs. The use of COTS technology will also permeate the project management components of this project, and new development (e.g., tools to harvest university accounting systems for the purpose of automating the process of tracking costs during the project lifecycle) will be minimized in scope wherever feasible.

9.2 Quality Assurance

Ultimately responsibility for the guidance and oversight of quality assurance (QA) at UIUC rests with the Project Director. Formulation and implementation of the QA program is the primary responsibility of the NEESgrid Project management.

It is the policy of UIUC that all activities be performed at a level of quality appropriate to achieving the scientific, technical, operational, and administration objectives of the NEESgrid system. This concept is adhered to in design, development, test, calibration, operation, procurement, finance, personnel, security, and other activities. Concept, design, programmatic, and administrative reviews are an essential component of QA at UIUC.

The QA objectives are to implement the checks and balances required for achieving the scientific, technical, operational, and administrative objectives of NEESgrid.

Because of the substantial expenditures on software development present in the NEESgrid effort, formal software quality assurance (SQA) principles will be applied to all software components of NEESgrid. A risk-based graded approach will be used in developing SQA plans for each software component, so that the more critical the software, the more detailed the level of SQA required in the software Project Execution Plan. For example, the middleware components of Globus permeate many aspects of the NEESgrid architecture, so these components must be held to higher standards of SQA, as the risk to the overall project is higher if these middleware components fail. For earthquake engineers writing simulation code, the risk is low, and less stringent SQA measures will be required.

Example models for appropriate SQA principles include those from the Software Engineering Institute (SEI) at Carnegie Mellon University, or software development policies and procedures developed by the IEEE. In each case, software components will be developed in accordance with a flexible software project management plan that will be written jointly by the individual PI's and by the NEESgrid Project Management Team.

10.0 Reporting and Reviews

10.1 Reporting Schedule to NSF

Table 6 lists periodic reports due to NSF during the course of the NEESgrid project and the due dates for these reports. The following subsections describe the reports required by NSF.

Table 6. Reporting Schedule to NSF

Type of Report	Due Date Each Year
Quarterly Interim Progress	June 30
Quarterly Interim Progress	September 30
Quarterly Interim Progress	December 31
Annual Progress	March 31
GPRA - Performance Data Report – Estimate	TBA
GPRA – Performance Data Report – Actuals	TBA

10.1.1 Quarterly Interim Progress Reports

The NEES grid project quarterly interim progress report will be prepared and submitted to NSF via FastLane. The quarterly interim progress report will cover baseline technical scope, cost, and schedule progress during the quarter just completed minus one month, e.g., the quarterly report due on September 30 will cover the months of June, July, and August.

This report is prepared in accordance with the Cooperative Agreement and at a minimum will consist of the following:

- Summary of work accomplished during the reporting period, including major technical accomplishments and interactions with other NEES program awardees.
- Progress toward technical baseline achievement.
- Financial status report and other financial information, including actual or anticipated underruns or overruns.
- An assessment of project status relative to the baseline schedule and milestones.
- Change Requests approved by the Change Control Board during the reporting period and their affect on key milestones, contingency, or technical performance parameters.
- Changes in organizational structure or personnel.
- Summary of risk management during the reporting period, including a review of current or anticipated problem areas, use of contingency funds, and corrective actions taken.
- Status of action items affecting NEESgrid/NSF responsibilities.
- Any other actions requiring NSF notification.

The financial information in the quarterly report will include a summary at the reporting level of the WBS level 2, of costs and obligations and a comparison with available funding. The forecast and actual completion of project level milestones will also be compared with the planned milestone completion dates presented in this plan. Performance data will include comparisons of "earned value" for work completed with a time-phased budget baseline and with actual costs accumulated to provide a "dollar" measure of the ahead or behind schedule position and the overrun/underrun status of each reporting level of the WBS. This data will be presented graphically to show trends at the top level of the WBS. A narrative "variance report" will discuss the causes and corrective actions to address significant variances from the Project Execution Plan.

10.1.2 Annual Progress Report

In lieu of a fourth quarterly progress report, the NEESgrid project annual progress report due on March 31 will be submitted via FastLane, and include all information that would be submitted in the quarterly progress report in the form of an annual progress report. The annual reporting period will be the March 1 – February 28. The annual report will be prepared in accordance with the Cooperative Agreement and will contain, as a minimum, the following information:

- Summary of overall progress, including results to date, and comparison of actual accomplishments with the proposed goals of the period.
- Summary of work performed during the succeeding year, and any other pertinent information.

- Technical, financial, schedule, risk management, and contingency allocation information similar to that given in the quarterly progress report will be included in the annual report, including progress against baselines, summarized for the annual reporting period.
- Summary of changes to the NEESgrid technical, cost, and schedule baselines, approved in the NEESgrid Change Control process.
- Indication of any current problems or favorable or unusual developments.

The annual report will discuss past year achievements in terms of technical scope, cost, and schedule and compare these achievements against those in the Project Execution Plan. Significant staffing changes, costs, and schedules will be presented for each WBS level 2 and comparisons will be made to the Project Execution Plan cost and schedule baselines.

Changes to the NEESgrid technical, cost and schedule baseline, approved in the NEESgrid Change Control process, will be identified and these changes may represent modifications to the cost and schedule information presented in this Project Execution Plan. Any other changes in the Project Execution Plan will be similarly considered in the Change Control process, as the Project Execution Plan is a controlled document with the overall NEES project baseline. These changes will be fully reported in the annual progress report review and approval by NSF in accordance with the terms and conditions in the Cooperative Agreement. The annual progress report will include an estimate of funds remaining unobligated at the end of the annual reporting period and the plan to spend these funds during the next period. The annual progress report will include a statement of the NEESgrid project calendar for the next project year for meetings of advisory committees, workshops, and internal and NSF reviews.

10.1.3 GPRA Reporting

As a requirement under the Government Performance and Results Act (GPRA), NSF is required to report on the Federal Performance Goals for Facilities. The awardee is required to submit, via FastLane, Performance Data Reports related to the GPRA performance goals. This may include the collection and submission of specific data related to the NSF GPRA requirements, including information on costs, project schedule, and annual project milestones. The Awardee will be required to submit estimates for the current fiscal federal year on a date TBA by NSF and actuals for the preceding fiscal federal year fiscal year are due approximately 6 months later.

10.1.4 NSF Reviews

NSF will conduct annual reviews of the NEESgrid project, covering technical and management issues. NSF will provide the project with the review protocol and criteria prior to the review, with adequate time to agree on the agenda and to prepare the necessary presentation material. There will be continuity of membership on these review committees.

A formal design review of the Project Management component of this Systems Integration effort will be carried out by NSF during the third quarter of this award. The purpose of this review is to insure that all additional project management documents (e.g., formal risk assessments, critical path analysis for the project as a whole and for each major project component) are adequate to insure the successful completion of the project within the schedule and budget allocated to the project team.

10.2 Project Documentation

The NEESgrid project activities for technical, outreach and management teams will be fully documented using a variety of mechanisms. First, the neesgrid.org website supports email archiving, and all project related email will be archived on the site server. In addition, text summaries of weekly meetings conducted by the Project Director, the Project Manager and the technical or outreach team leaders will be posted to the server via email. A copy of the Project Execution Plan, including all revisions and updates will be maintained on the website. All reports generated by the project team will be posted to the website.

Copies of all technical specification and other documentation will be maintained by the team leaders and updates will be posted to the website quarterly. All software products and training information will be distributed via the neesgrid.org site.

10.3 Technical Reports

As part of the NEESgrid project it is expected that technical reports will be generated to document the implementation and performance of new concepts in software engineering for complex science and engineering communities. Copies of all technical reports generated by the NEESgrid Project team will be posted on the website. In addition, we will be working with the earthquake engineering community participants in NEESgrid to assist them in posting research reports to the website, as it is intended that the website become a community resource that continues during 2004-2014 under management by the NEES Consortium.

Baseline: a baseline is a formal agreement between the consumer (i.e., the customer) and the producer (i.e., the supplier) of a project element, and represents a documented decision that is fixed unless a change is requested by either the supplier or the customer, in which case the process of change control begins.

Business Baseline: a formal business agreement outlining the specification of some business-related project element, e.g., funding level or scope of work. Business baselines are often implemented as legal contracts, so that changing a business baseline commonly requires formal contract modification procedures.

Change Control: a documented process applying technical and management review and approval of changes to technical, schedule and cost baselines. Along with configuration identification at the beginning of a project and configuration audit at a project's conclusion, this process represents the way in which the project baseline is modified in a disciplined manner during the execution of a project.

Configuration: the composition of a system or of a system component as identified by the (e.g., number, type, version, etc) of its component parts.

Configuration Item: a collection of hardware, software (or both) that is identified as appropriate for configuration management (e.g., because the item represents relatively mature technology) and that is treated as a formal component of the configuration management process.

Configuration Management: the aspect of project management intended to identify a configuration item, facilitate (i.e., detect need, review, and implement) changes to that item, perform quality assurance tests to insure satisfaction of appropriate service metrics, and formally document the various states and changes of that item.

Configuration Management Plan: the written plan establishes the detailed procedures to be followed in carrying out the configuration management of a project.

Contingency: a collection of resources (e.g., temporal, financial, physical) used to mitigate risk by application of redundancy. A financial contingency represents funding that is banked to provide a project surplus in case of cost overruns. A schedule contingency represents extra time included in the project plan to accommodate tasks that may take longer for completion, or where task schedule slips cause project scheduling problems (e.g., for tasks on the critical path).

COTS: An acronym for Commercial Off-The-Shelf, which represents commercially available and hence inherently mature technologies.

Critical Path: the sequence of tasks in a project that controls the overall progress of the project. Alternatively, the critical path in a deterministic project plan is the sequence of tasks for which there is no temporal contingency for the overall project duration (i.e., any delays in tasks on the critical path will result in schedule slip).

Earned Value: the sum of the budget (estimated cost) for completed work, including schedule work packages and the portion of level-of-effort work completed. Earned Value is the quantitative expression of the fraction of the project completed.

Estimate to Complete: the cost estimate developed to represent a realistic appraisal of the cost estimate of the remaining work in a project.

Incremental Development Model: a model for design, development, and deployment of technology that begins with a prototype demonstration (generally of limited function), followed by cycles of continuous product improvement (termed "churn") that eventually results in a product that both meets the required specifications and permits more rapid adoption of improved technology. Incremental models are inherently more difficult to control and review, but are an excellent means to mitigate risk in areas where technological change is fast-paced.

Integrated Project Schedule: the comprehensive combination of all schedules in a project, including all subprojects, subsystem schedules and contracted work schedules.

Milestone: finite defined events in a project schedule that constitute start, completion of a task or occurrence of an objective criterion for accomplishment. Milestones are discretely measurable; the passage of time itself is not sufficient to be a milestone. Milestones should be associated with a schedule date so that it can be determined when the milestone is to occur.

Performance Measurement Baseline: the combination of the cost estimate for every element in the Work Breakdown Structure with the scheduled tasks in the Integrated Project Schedule. This procedure a detailed, time phased budget plan for all work to be accomplished during project execution against which the project performance is measured.

Risk Management: the aspect of project management oriented towards identifying potential project risks, characterizing their probability of occurrence, determining the impact of the identified risks, and making appropriate decisions to mitigate the risk in order to minimize the likelihood of project or component failure.

Schedule Baseline: a formal agreement outlining the schedule of a project element, e.g., a task outline with component initiation/completion dates. Effective use of schedule baselines requires both sequence and duration information for each component task, but also a set of dependencies that relate the various tasks, as well as a set of synchronization events (e.g., milestones) that provide observable measures of overall project progress.

Spiral Development Model: a synonym for incremental development model

System Requirements: the documented set of specifications by which the system to be delivered is identified, characterized, decomposed (into subsystems which may require their own component system requirements documents), and evaluated. The systems requirements document is commonly obtained by the translation of the user requirements document into appropriate systems engineering concepts.

Technical Baseline: a formal agreement outlining the technical content of the project, e.g., a task list or a work-breakdown structure. While schedule baselines (e.g., Gantt charts) provide information about *when* project elements are developed or deployed, technical baselines (e.g., a WBS) provide information about *what* elements are deployed, and *how* those project components are developed.

User Requirements: a high-level project document that characterized the needs of the customer in a form that is accessible to that customer. User requirements thus constitute an important project baseline, but are generally expressed in a form that will require translation (into a systems requirements document) before they can be effectively utilized in the project management process.

Walkthrough: a project quality-assurance process characterized by informal reviews of high-risk technology components (typically software modules) that are examined sufficiently early in their developmental process to identify the areas of greatest risk. Code walkthroughs are common mechanisms to insure that all components of a software project are sufficiently feasible to permit efficient implementation, and these procedures are widely used to mitigate risk in software project management.

Waterfall Development Model: a model for design, development, and deployment of technology that is readily utilized for deterministic projects where the rate of change of underlying technology is slow compared to the lifetime of the project. Waterfall models are often unsuitable (e.g., risk-averse, or overly expensive) when the processes under development are inherently non-deterministic (e.g., research or other creative enterprises) or when technology improvements obviate design or implementation decisions embedded in the static waterfall model.

Work Breakdown Structure (WBS): a graphical or outline view of the various project components so that the overall project is decomposed into various tasks (for a functional WBS), or into various assemblies (for a system WBS). Many governmentally-funded projects utilize a standard WBS format embodied (with examples) in MIL-STD-881A.

Appendix B. Work Breakdown Structure (WBS) for NEES-SI

WBS Level	*Description*	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
1.0	**System Components: Design, Development, Deployment, Operations and Support**	**ISI**	**Carl Kesselman**		
1.1	**System Configuration and Design**	**ISI/ANL**	**Carl Kesselman and Ian Foster**		
1.1.1	***System Requirements Specification***	***ISI/ANL***	***Kesselman/Foster***	***7/1/2001***	***12/31/2001***
1.1.1.1	Requirements Definitions				9/30/2001
1.1.1.2	System Specifications and Planning Documents				12/31/2001
1.1.2	***Core Grid Services***	***ANL***	***Steve Tuecke***	***1/1/2002***	***6/30/2003***
1.1.2.1	Integration of Core Grid Services				6/30/2002
1.1.2.2	Information Services Extensions				6/30/2002
1.1.2.3	Community Access Control Extensions				9/30/2002
1.1.2.4	Packaging, Testing and Release				6/30/2003
1.1.3	***Data Services***	***ISI***	***Ann Chervenak***	***1/1/2002***	***6/30/2004***
1.1.3.1	Data Publication Tools				6/30/2002

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
1.1.3.2	Data Storage and Management Tools				12/31/2002
1.1.3.3	Data Repository Management Tools				12/31/2003
1.1.4	***Computational and Simulation Services***	***ANL***	***Bill Allcock***	***1/1/2002***	***6/30/2004***
1.1.4.1	Core Resource Management Services				3/31/2002
1.1.4.2	Portal Tools				6/30/2003
1.1.4.3	Remote Job Submission Tools				6/30/2003
1.1.4.4	Software/Resource Broker Services				6/30/2004
1.1.5	***Instrument Services***	***ANL***	***Bill Allcock***	***1/1/2002***	***6/30/2004***
1.1.5.1	Information Services for Instrument Sites				6/30/2002
1.1.5.2	Instrument Resource Management Services				12/31/2002
1.1.5.3	NEESpop Services				12/31/2003
1.1.6	***Final Documentation***	***ISI/ANL***	***Kesselman/Foster***	***1/1/2004***	***9/30/2004***
1.1.6.1	System Documentation Completed				9/30/04
1.2	**Deployment, Operations and Community Support**	**NCSA**	**Rob Pennington**		
1.2.1	***NEESgrid Deployment***	***NCSA***	***Randy Butler***	***7/1/2001***	***9/30/2004***

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
1.2.1.1	Package and test NEESPOP for deployment to Equipment Sites				6/30/2002
1.2.1.2	Package and test Client Package for distribution to NEESgrid Users				6/30/2002
1.2.1.3	Document NEESgrid Administration into Draft NEESgrid Administration Guide				6/30/2003
1.2.1.4	Deploy NEESPOP to NEES Equipment Sites				6/30/2004
1.2.1.5	Establish Distribution Service for NEESgrid Client Package				9/30/2004
1.2.2	***NEESgrid Systems Operations***	***NCSA***	***Rob Pennington***	***7/1/2001***	***9/30/2004***
1.2.2.1	Production system design requirements				9/30/2001
1.2.2.2	NEESgrid interfaces to existing infrastructure				6/30/2002
1.2.2.3	Begin support production services over NEESgrid				7/1/2002
1.2.2.4	Begin support Helpdesk and monitoring services				1/1/2003
1.2.2.5	System and administrative documentation				9/30/2003
1.2.2.6	System transition				9/30/2004
1.2.3	***Computational Support and Training***	***NCSA***	***John Towns***	***7/1/2001***	***9/30/2004***
1.2.3.1	Begin training for NEES sys admins				1/1/2002
1.2.3.2	Begin training for NEESgrid users				1/1/2003

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
1.2.3.3	Migrate first targeted applications to HPC Platforms (2 per year, 3 years)				6/30/2002
1.2.3.4	Online technical resources for NEESgrid administrators and users				6/30/2003
1.2.3.5	Begin email/phone HPC consulting services for system users migrating/optimizing codes				7/1/2003
2.0	**Information Services Components**	**UIUC**	**Dennis Parsons**		
2.1	**Tele-observation and Tele-operations**	**ANL**	**Nestor Zalucek**		
2.1.1	***Passive Telepresence Management System***	***ANL***	***Nestor Zalucek***	***7/1/2001***	***6/30/2003***
2.1.1.1	Resource Requirements Definition				9/30/2001
2.1.1.2	Prototype Platform				3/31/2002
2.1.1.3	Generic user Interfaces				9/30/2002
2.1.1.4	Ethernet Appliance Usability				9/30/2002
2.1.1.5	Labview Protocols				12/31/2002
2.1.1.6	Generalized DAS Protocols				3/31/2003
2.1.1.7	Generalize Client Interfaces				6/30/2003
2.1.1.8	Grid Integration				6/30/2003
2.1.2	***Active Telepresence Management System***	***ANL***	***Zalucek***	***7/1/2003***	***6/30/2004***

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
2.1.2.1	Resource Requirements Definition				9/30/2003
2.1.2.2	Compatibility Testing				3/31/2004
2.1.2.3	Remote Labview Active Protocols				6/30/2004
2.1.2.4	Generalized Active Protocols				6/30/2004
2.1.2.5	Grid Integration				6/30/2004
2.1.3	***Final Documentation***	***ANL***	***Zalucek***	***7/1/2004***	***9/30/2004***
2.1.3.1	Telepresence Documentation Completed				9/30/2004
2.2	**Collaboration and Visualization**	**UM**	**Joseph Hardin**		
2.2.1	***Prototype collaborative environment***	***UM***	***Joseph Hardin***	***7/1/2001***	***9/30/2003***
2.2.1.1	Identify candidate tools				10/31/2001
2.2.1.2	Identify early adopter users				10/31/2001
2.2.1.3	Deploy tools to first adopters				6/30/2002
2.2.1.4	Test and evaluate usability of tools				9/30/2003
2.2.2	***Visualization support for Collaboration tools***	***UM***	***Joseph Hardin***	***7/1/2001***	***6/30/2004***
2.2.2.1	Synchronized video and numeric data viewer				6/30/2002
2.2.2.2	Prototype visualization pipeline				6/30/2002

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
2.2.2.3	Integration of video/data viewer into CHEF				6/30/2004
2.2.2.4	Integration of visualization pipeline into CHEF				6/30/2004
2.2.3	***Adaptation of the Comprehensive Collaborative Framework (CHEF) for collaborative visualization applications and services on NEESgrid***	***UM***	***Joseph Hardin***	***7/1/2001***	***6/30/2004***
2.2.3.1	CHEF adaptation requirements analysis				6/30/2002
2.2.3.2	CHEF adaptation functional specification				6/30/2002
2.2.3.3	CHEF adaptation broker and interface architecture modifications				6/30/2002
2.2.3.4	CHEF adaptation Grid integration				6/30/2003
2.2.3.5	Testing adapted CHEF with early adopter users				6/30/2003
2.2.3.6	CHEF adaptation software release				9/30/2003
2.2.3.7	CHEF adaptation full deployment on NEESgrid				6/30/2004
2.2.4	***Final Documentation***	***UM***	***Joseph Hardin***	***7/1/2004***	***9/30/2004***
2.2.4.1	Collaboration/Visualization Documentation Completed				9/30/2004
2.3	**Simulation Tools and Frameworks**	**UIUC**	**Dennis Parsons**	**7/1/2001**	**9/30/2004**

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
2.3.1	***Database of community simulation codes***	***UIUC***	***Dennis Parsons***	***7/1/2001***	***12/31/2001***
2.3.1.1	Survey existing application codes				9/30/2001
2.3.1.2	Metadata design for existing codes				11/30/2001
2.3.1.3	Implement code database and integrate into NEESgrid web site				12/31/2001
2.3.2	***Grid portal for simulation codes***	***UIUC***	*Dennis Parsons*	***1/1/2002***	***3/31/2003***
2.3.2.1	Deploy a grid scheduler for existing applications (OpenSees)				12/31/2002
2.3.2.2	Develop interfaces to data repository for existing applications				3/31/2003
2.3.3	***Prototype software framework for scalable, distributed simulation applications***	***Terascale, LLC***	***Lee Taylor***	***7/1/2001***	***6/30/2004***
2.3.3.1	Initial demonstrations and user requirements				12/31/2001
2.3.3.2	Data interface development				6/30/2002
2.3.3.3	System identification module development				3/31/2003
2.3.3.4	Distributed simulation module development				12/31/2003
2.3.3.5	Grid integration and final demonstrations				6/30/2004
2.3.4	***Final Documentation***	***UIUC***	***Dennis Parsons***	***7/1/2004***	***9/30/2004***

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
2.3.4.1	Simulation Framework Documentation Completed				9/30/2004
2.4	**Data and Metadata Management**	**NCSA**	**Joe Futrelle**	**7/1/2001**	**9/30/2004**
2.4.1	***Publish recommended standards for data and metadata models and representations***	***NCSA***	***Joe Futrelle***	***7/1/2001***	***9/30/2002***
2.4.1.1	Characterize EE community use of data and metadata, and future requirements				1/31/2002
2.4.1.2	Distribute preliminary metadata standards, data models and representations for review				5/31/2002
2.4.1.3	Publish recommended NEESgrid standards for metadata, data models and representations				9/30/2002
2.4.2	***Specification for NEESgrid information services***	***NCSA***	***Joe Futrelle***	***7/1/2001***	***9/30/2002***
2.4.2.1	Characterize existing data services (e.g. IRIS) on the internet				9/30/2001
2.4.2.2	Develop current and anticipated requirements for NEESgrid information services				1/31/2002
2.4.2.3	Develop information acquisition and access architecture				6/30/2002
2.4.2.4	Review proposed information architecture against metadata and data models				9/30/2002

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
2.4.3	***Develop APIs for information acquisition, management and access***	***NCSA***	***Joe Futrelle***	***2/1/2002***	***9/30/2002***
2.4.3.1	Develop core set of common APIs to support information acquisition and access				6/30/2002
2.4.3.2	Review metadata/data models and information service architecture against proposed APIs				9/30/2002
2.4.4	***Curated information repository***	***NCSA***	***Joe Futrelle***	***10/1/2001***	***6/30/2004***
2.4.4.1	Survey existing data storage and access tools (e.g. RDBMS's, tertiary storage, etc.)				9/30/2002
2.4.4.2	Implement scenarios with components built to API's and Grid proxy/broker scheme				6/30/2003
2.4.4.3	Acquire EE data from community				6/30/2004
2.4.5	***Final documentation***	***NCSA***	***Joe Futrelle***	***7/1/2004***	***9/30/2004***
2.4.5.1	Data Management Documentation Completed				9/30/2004
3.0	**Community Outreach and Partnership Development**	**UM**	**Tom Finholt**		
3.1	**User Requirements Assessment**	**UM**	**Tom Finholt**		
3.1.1	***User Surveys***	***UM***	***Tom Finholt***	***9/1/2001***	***4/30/2004***

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
3.1.1.1	Publish year 1 user survey				4/30/2002
3.1.1.2	Publish year 2 user survey				6/30/2003
3.1.1.3	Publish year 3 user survey				4/30/2004
3.1.2	***Site Visits***	*UM*	***Liz Wierba***	***7/1/2001***	***3/31/2004***
3.1.2.1	Publish report on initial visits to representative NEES provider and user sites				12/31/2001
3.1.2.2	Publish report on initial visits to NEES Phase II awardee sites				3/31/2003
3.1.2.3	Publish report on follow up visits to all sites previously visited				12/31/2003
3.1.3	***Publish and update NEESgrid User Requirements Analysis on neesgrid.org***	***UM***	***Tom Finholt***	***10/1/2001***	***4/30/2004***
3.2	**Community Building**	**UIUC**	**Dan Abrams**		
3.2.1	***Engage EER community to collect SI input***	***UIUC***	***Dan Abrams***	***9/1/2001***	***4/30/2004***
3.2.1.1	Establish a videoteleconferencing infrastructure supporting improved communications with NEES equipment sites and other members of the community				9/30/2001
3.2.1.2	Present SI accomplishments at EER annual meetings				9/30/2004

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
3.2.1.3	Meet with NEES Equipment Site PIs to facilitate implementation of NEESgrid				6/30/2004
3.2.1.4	Interact with emerging EQE researchers in model-based simulation and promote their work on neesgrid.org				6/30/2004
3.2.1.5	Provide online resources documenting the uses of NEESgrid by members of the EQE community				9/30/2004
3.2.2	***Build consensus with CDT on SI issues***	*UIUC*	***Dan Abrams***	***10/1/2001***	***9/30/2004***
3.2.2.1	Quarterly and informal update meetings with CDT Board				9/30/2004
3.2.2.2	Presentations at CDT-led workshops				9/30/2004
3.2.3	***Outreach to industry and international partners in the EQE community***	***UIUC***	***Dan Abrams***	***7/1/2001***	***9/30/2004***
3.2.3.2	Promote SI concepts to international EQE communities by presenting at conferences				9/30/2004
3.2.3.3	Interact with equipment manufacturers to discuss common NEES SI issues related to their equipment				12/31/2001
3.2.4	***Facilitate NEESgrid transition to Consortium***	***UIUC***	***Dan Abrams***	***4/1/2003***	***9/30/2004***
3.2.4.1	Define operations and maintenance and estimate costs for NEESgrid for CDT				9/30/2003

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
3.2.4.2	Plan and facilitate transition to Consortium				9/30/2004
3.3	**Integrated Demonstrations**	**USC**	**Jean-Pierre Bardet**		
3.3.1	***Promote practical examples of the uses of NEESgrid***	***USC***	***Jean-Pierre Bardet***	***7/1/2001***	***6/30/2004***
3.3.1.1	Begin testing individual SI components to demonstrate usability to EER community				7/01/2001
3.3.1.2	Begin conducting experiments using NEESgrid				1/1/2002
3.3.1.3	Begin monitoring usefulness and success of collaboration enabled by NEESgrid				1/1/2002
3.3.1.4	Begin publishing results on NEESgrid.org				4/1/2002
4.0	**Management**	**NCSA**	**Tom Prudhomme**		
4.1	**NEESgrid Management**	**NCSA**	**Tom Prudhomme**		
4.1.1	***Outreach to NEES equipment sites***	***NCSA***	***Tom Prudhomme***	***7/1/2001***	***9/30/2004***
4.1.1.1	Conduct visits to representative NEESgrid resource provider sites				12/31/2002

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
4.1.1.2	First quarterly informal progress reports to NEES facilities				1/1/2002
4.1.2	***Advisory Activities and Program Reviews***	***NCSA***	***Tom Prudhomme***	***7/1/2001***	***6/30/2004***
4.1.2.1	Establish expanded Executive Advisory Board				9/30/2001
4.1.2.2	Conduct first semi-annual and ad-hoc program review with EAB				1/1/2002
4.1.2.3	Conduct first annual program review with EAB and NSF reviewers				4/1/2002
4.1.3	***Technical Outreach to resource providers and NEESgrid users***	***NCSA/LLNL***	***Kim Mish***	***7/1/2001***	***12/31/2001***
4.1.3.1	Conduct integration workshop				9/30/2001
4.1.3.2	Establish virtual working groups				12/31/2001
4.1.4	***Participate in NSF-sponsored NEES events***	*NCSA*	***Tom Prudhomme***	***7/1/2001***	***9/30/2004***
4.2	**NEESgrid Operations**	**NCSA/LLNL**	**Kim Mish**		
4.2.1	***Project Management***	***NCSA/LLNL***	***Kim Mish***	***7/1/2001***	***9/30/2004***
4.2.1.1	Build project management team				9/30/2001

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
4.2.1.2	Establish Project Execution Plan and procedures				9/30/2001
4.2.1.3	Begin monitoring/managing progress against deliverables, risk and project performance				10/1/2001
4.2.1.4	Prepare first quarterly status report for NSF documenting progress against deliverables				10/1/2001
4.2.1.5	Prepare first semi-annual and annual progress report for use in program reviews				1/1/2002
4.2.2	***Fiscal Accountability and Reporting***	***NCSA/LLNL***	***Kim Mish***	***7/1/2001***	***9/30/2004***
4.2.2.1	Begin managing fiscal reporting by subawardees				7/1/2001
4.2.2.2	Prepare first semi-annual financial report required by NSF				10/1/2001
4.2.2.3	Prepare first financial report for semi-annual and annual reviews				1/1/2002
4.2.3	***Communications and Community Outreach***	***NCSA/LLNL***	***Kim Mish***	***7/1/2001***	***9/30/2004***
4.2.3.1	Complete design and development of community website				12/31/2001
4.2.3.2	Post and promote program information				7/1/2001
4.2.3.3	Begin support, maintain and promote NEESgrid application portals installed on website				1/1/2002

WBS Level	Description	Organization(s) Responsible	Person(s) Responsible	Start Date	Completion Date
4.2.4	***Final Documentation and Transition Management***	***NCSA/LLNL***	***Kim Mish***	***1/1/2004***	***9/30/2004***
4.2.4.1	Management Documentation Complete				9/30/2004
4.2.4.2	Complete Transition of NEESgrid to the Consortium				9/30/2004
4.3	**NEESgrid Assessment and Evaluation**	**UM**	**Tom Finholt**		
4.3.1	***Evaluation of NEESgrid Acceptance and Use***	***UM***	***Tom Finholt***	***10/1/2001***	***9/30/2004***
4.3.1.1	Post first data summary from site visits and surveys on website				10/1/2001
4.3.1.2	Prepare first annual evaluation report on acceptance, valuation and use of NEESgrid by EQE community				1/1/2002
4.3.1.3	Post first quarterly usage summary on website				10/1/2001
4.3.2	***Technical Performance Evaluation***	*UM*	***Tom Finholt***	***1/1/2002***	***3/31/2004***
4.3.2.1	Prepare first annual evaluation report on progress against technical deliverables				1/1/2002
4.3.2.2	Prepare first annual evaluation report on technical focus, direction and resource allocation related to impact on community				1/1/2002

Equipment Category	Award No.	PI	Institution	Title
Shake Table Research	0086612	Bruneau, Michel	SUNY Buffalo	Versatile High Performance Shake Tables Facility towards Real-Time Hybrid Seismic Testing
Shake Table Research	0086624	Buckle, Ian	University of Nevada, Reno	Development of a Biaxial Multiple Shake Table Research Facility
Centrifuge Research	0086555	Dobry, Ricardo	Rensselaer Polytechnic Institute	Upgrading, Development and Integration of Next Generation Earthquake Engineering Experimental Capability at Rensselaer's 100 g-ton Geotechnical Centrifuge
Centrifuge Research	0086566	Kutter, Bruce	University of California, Davis	A NEES Geotechnical Centrifuge Facility
Tsunami Wave Tank	0086571	Yim, Solomon	Oregon State University	Upgrading Oregon State's Multidirectional Wave Basin for Remote Tsunami Research
Large-Scale Lab Experimentation	0086611	Bruneau, Michel	SUNY Buffalo	Large-Scale High Performance Testing Facility towards Real-Time Hybrid Seismic Testing
Large-Scale Lab Experimentation	0086602	French, Catherine	University of Minnesota	A System for Multi-Axial Subassemblage Testing (MAST)
Large-Scale Lab Experimentation	0086621	Moehle, Jack	University of California at Berkeley	Reconfigurable Reaction Wall-Based Earthquake Simulator Facility
Large-Scale Lab Experimentation	0086592	Shing, P. Benson	University of Colorado, Boulder	Fast Hybrid Test Platform for the Seismic Performance Evaluation of Structural Systems
Field Experimentation and Monitoring	0086605	Stokoe II, Kenneth	The University of Texas at Austin	Large-Scale Mobile Shakers and Associated Instrumentation for Dynamic Field Studies of Geotechnical and Structural Systems
Field Experimentation and Monitoring	0086596	Wallace, John W.	University of California, Los Angeles	Field Testing and Monitoring of Structural Performance

ID	Task Name
1	**Develop Task Dependencies**
2	Collect Dependencies
3	Initial SI Sequence
4	Milestone: WBS w/ Dependencies
5	**Develop Technology Portfolio**
6	Collect Risk Data
7	Classify Component Risks
8	Milestone: Risk Classification
9	**Develop Project Network**
10	Refactor Project Components
11	Initial Critical Path Analysis
12	Initial PERT Analysis
13	Milestone: Initial CPM and PERT Networks
14	Risk-Mgmt Network Refinements
15	**Risk Management Plan**
16	Draft Risk Management
17	Merge Input from PI's and NSF
18	Milestone: Risk Management Plan
19	**Configuration Mgmt Plan**
20	Determine Relevant Components
21	Formalize Configuration Process
22	Populate Configuration Board
23	Milestone: Configuration Plan
24	**Change Mgmt Plan**
25	Determine Change Protocol
26	Identify Initial Candidates for Change Procedure
27	Identify Change Exceptions
28	Determine Change Handling Criteria