



## **THE CONSORTIUM FOR THE GEORGE E. BROWN JR. NETWORK FOR EARTHQUAKE ENGINEERING SIMULATION**

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### **SUMMARY**

In October 1999 the National Science Foundation launched a major initiative to reduce the vulnerability of the U.S. to earthquake disasters by establishing the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES). Now almost complete, NEES includes fifteen university-based Equipment Sites that offer unparalleled experimental facilities and a grid-based IT infrastructure that enables not only access to these facilities from remote locations, but also a vehicle for fostering collaboration, sharing data, and disseminating research. This paper summarizes the objectives of NEES and outlines the structure of the Consortium that has been established to manage and lead the NEES Collaboratory.

### **INTRODUCTION**

In October 1999 the National Science Foundation launched a major initiative to reduce the vulnerability of the U.S. to earthquake disasters by establishing the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES). Now almost complete, NEES includes fifteen university-based Equipment Sites that offer unparalleled experimental facilities and a grid-based IT infrastructure that enables not only access to these facilities from remote locations, but also a vehicle for fostering collaboration, sharing data, and disseminating research.

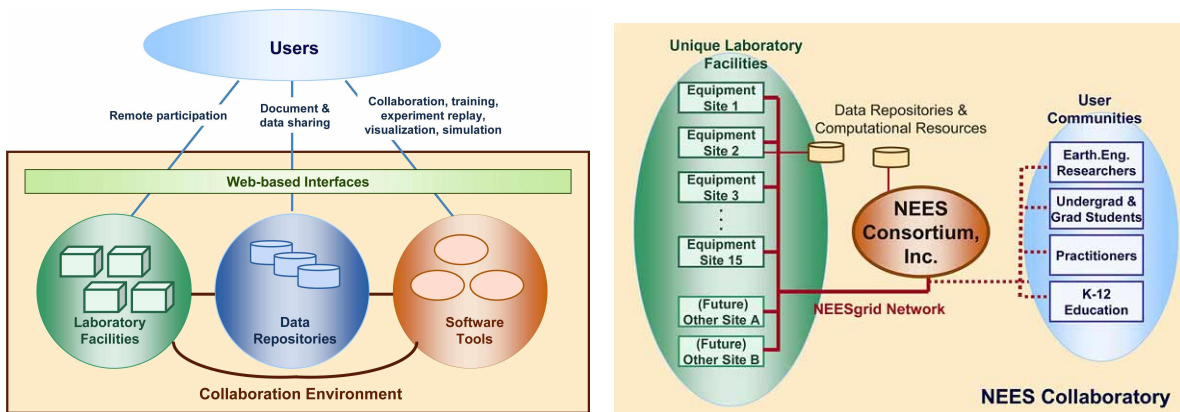
It is intended that NEES will facilitate the establishment of a *collaboratory* of researchers and practitioners from relevant disciplines, including the public-at-large, for the common purpose of reducing seismic risk in the U.S. and elsewhere in the world. In general, a collaboratory is an organizational entity that spans distance, supports rich and recurring human interactions in a common research area, and provides access to the data sources, artifacts and tools required to accomplish key tasks (SOC [3]). Most collaboratories have four basic characteristics which include distributed research facilities, shared

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instruments, a community data system, and an open, community-based, contribution system (SOC [3]). Today, web-based interfaces are used to facilitate these collaborative environments (Figure 1a), and in the case of the NEES Collaboratory, a grid-based network has been developed expressly for this purpose called NEESgrid (Figure 1b).



**Figure 1. Research collaboratories**  
**(a) left: Elements of a collaborative environment, (b) right: NEES collaboratory.**

In addition to the Equipment Sites and NEESgrid, a Consortium has also been established to manage and lead the NEES Collaboratory. Accordingly NEES Consortium Inc (NCI) is expected to:

1. provide access to an unprecedented collection of experimental facilities that can be shared by national and international researchers regardless of their physical location
2. empower researchers to address issues of critical importance to the global earthquake engineering community by providing an IT infrastructure capable of integrating physical and numerical simulation
3. foster the open exchange of data and information using data repositories that employ state-of-the-art methods for data preservation and dissemination
4. motivate the research community to embrace more collaborative modes of conducting research through a web-based environment that facilitates collaboration, and
5. develop a more diverse, capable workforce committed to improving seismic safety through an active program of education and outreach that exploits the collaborative infrastructure.

NCI was established to represent and serve the U.S. earthquake engineering community. Its goals are to substantially broaden participation in earthquake engineering research, education, and community-building activities, and to accelerate the rate at which research discoveries are integrated into education and engineering practice. The structure of the Consortium reflects this diversity of constituencies, needs and opportunities.

The infrastructure managed by the Consortium is expected to revolutionize research in earthquake engineering by promoting multidisciplinary, multi-institutional collaborations involving the real-time integration of different types of physical and numerical experiments. This will transform what are now largely topic-oriented individual research efforts into the kind of collaborative and interactive process needed to address the complex nature of seismic events and their physical and social impacts. The new discoveries enabled by NEES will also yield new methods for evaluating and reducing vulnerability.

These in turn will provide a scientific foundation for designing buildings and lifelines to reduce losses from ground shaking, ground failures, and tsunamis, and for establishing performance-based codes and standards and related mitigation strategies.

NEES will be managed by dedicated, full-time staff at NCI headquarters, with strategic vision and direction determined by an elected Board of Directors and Committees drawn from the earthquake engineering community including computer science educators, researchers, and practicing professionals. The Consortium's Business Plan includes the establishment of an IT Services Center (NITSC), a physical home for NEES (i.e. headquarters), a Board of Directors and several Standing Committees. Many of these key groups are already engaged. The NEES Equipment Sites and the NEES IT Infrastructure will be operational on, or before, October 1, 2004, and start-up operations have begun for establishing the headquarters of NEES. Annual assessment procedures are in place to evaluate the performance of each service component and to ensure the overall system is responsive to evolving community needs. A proposal is currently under review by the National Science Foundation for the management, operation and maintenance of the Consortium for the ten-year period: FY 2005-2014 (NEES [1]). The major elements of NEES are described in subsequent sections of this paper.

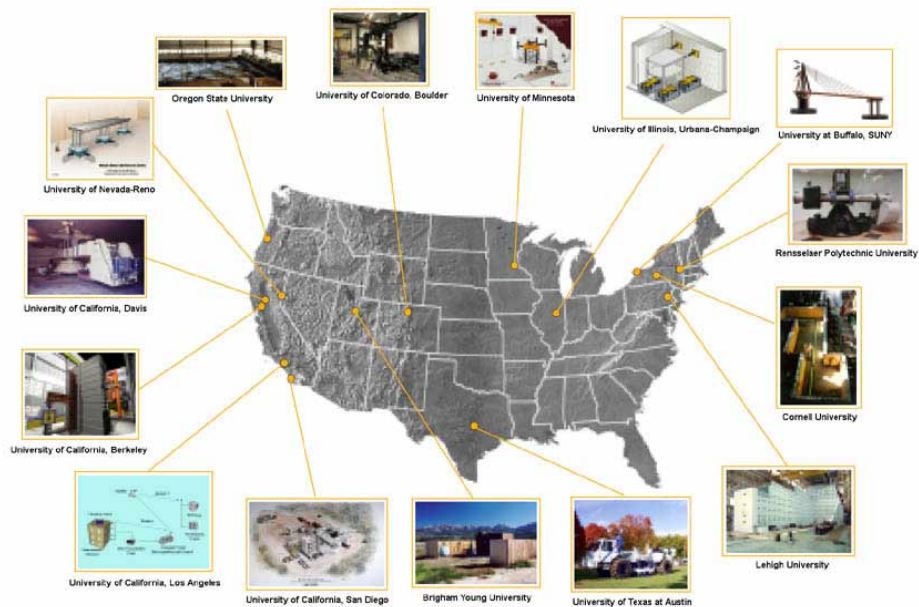
### NEES EQUIPMENT SITES AND SHARED-USE

Figure 2 shows the fifteen NEES Equipment Sites that are either completed or under construction as of February 2004. Appendix A lists these same sites by category where it is seen that there are three field sites, three geotechnical sites, eight structural sites, and one tsunami site. Each of these sites has made a commitment to provide shared-use access to its facilities for the ten-year period Oct 2004 to Sept 2014, and in return receive operation and maintenance funds that are expected to meet about 50% of their annual operating and maintenance (O&M) budget. Under this plan, these facilities will be available at no additional cost to those researchers who have NSF research grants through the NEES Research Program (NEESR [2]). Other researchers are also encouraged to use these facilities, including international researchers, but maintenance and operation charges may apply. It is noted that the NEESR research program is managed and operated by NSF independently of the Consortium, and thus the Consortium does not conduct research, evaluate proposals, or make research awards. The fifteen sites provide the following:

**Facilities:** Host institutions are responsible for maintaining the building and infrastructure needed for operation of that facility. In addition, each site will provide researchers with access to ancillary facilities (such as cranes, forklifts, and machine shops), provide safety and risk management for staff and visitors, and address the on-site needs of NEES researchers and students.

**Equipment:** Technical staff at each site are responsible for operating and maintaining the equipment at that site in support of NEES research. This includes reconfiguring equipment to conduct specific experiments as needed, repairing or replacing equipment that has malfunctioned or suffered damage, and replacing obsolete equipment to the extent possible with available funding.

**Instrumentation:** Technical staff at each site maintain the instrumentation to be used in support of NEES research. This includes calibrating sensors, assisting researchers with sensor installation, repairing or replacing sensors that have malfunctioned or suffered damage, and replacing obsolete sensors to the extent possible with available funding. It is expected that some experiments will require sensors and installation labor beyond the baseline currently funded by the NEES O&M budget, and these costs will be the responsibility of the researcher.



**Figure 2. The fifteen NEES Equipment Sites.**

**Training:** Staff at each site are also responsible for developing appropriate safety and training materials for their facility. These include web-based training materials, on-site training sessions for new researchers and materials, and personal instruction that emphasizes safety within the laboratory on a continual basis.

## **INFORMATION TECHNOLOGY SERVICES**

As noted earlier, advanced IT is central to the vision for the NEES Collaboratory. Core elements of the required IT services are under development by the NEES System Integrator at the National Center for Supercomputing Applications (NCSA) at the University of Illinois, Urbana-Champaign. When complete in late summer 2004, these elements will be taken over by the NEES IT Services Center (NITSC), currently being established at the San Diego Supercomputing Center on the campus of the University of California, San Diego. Nine core service components are to be provided as described below.

**Network and Grid Services:** Activities include monitoring network performance, providing certificate authority for NEESgrid security systems, ensuring reliable and secure transfer of data, providing IT support to the Equipment Sites, serving as point of negotiations with Internet2, and maintaining and/or upgrading the system software in response to changes in operating systems. Provided by technologies and round the clock staffing, these services will be invisible to users, but essential to the day-to-day operation of the Collaboratory.

**Data Ingestion Services:** Activities include providing a vehicle for preserving, curating, analyzing, and retrieving data from physical and numerical experiments. Services include support and enhancement of data and metadata standards; evolution of the NEES tool suite to support a strong, reliable, curated data repository; maintenance and enhancement of usable and well-integrated interfaces at each equipment site to ensure relevant data and metadata are captured; evolution and enhancement of a web-based query interface as the data repositories and experience database grow; and performance enhancements to the

data transfer systems to handle increasing data rates, resolution requirements, and the like. Data mining techniques will also be provided as the volume of data increases.

**Data Storage and Retrieval Services:** The NEES data repositories provide an essential mechanism for users to collaborate and share research results. Activities within this component are intended to maintain and support a reliable, comprehensive data storage infrastructure. NITSC Staff are responsible for hardware and software systems to support high-volume data and reliable long-term storage of all data from NEES researchers; a data server with high-speed I/O capabilities and 10 Gbs access to the wide-area-network; offline and offsite backup systems for maintaining the integrity of the data; and database and data storage administration of the NEES repository, including support of relational database software, software installations and upgrades, performance tuning, backups and recoveries. Standard search and retrieval tools are provided and the ability to generate reports and visualize data is offered (see Visualization Services).

**Web Services:** The NEES website ([www.nees.org](http://www.nees.org)) is the principal mechanism for keeping members of the Consortium apprised of activities, disseminating training materials, announcing short courses, research opportunities, upcoming experiments, and surveying users about NEES resources and services. Documentation about NITSC services are also available from the nees.org website. Each equipment site also maintains a web site that provides detailed specifications and capacities of the equipment at that site, safety procedures, testing schedule, a list of site personnel, contact information and the like.

**Collaboration Services:** Collaboration services include project-oriented discussion groups, document sharing and an expertise clearinghouse. These services are based on the CompreHensive collaborative Framework (CHEF), a group-oriented portal environment developed at the University of Michigan. CHEF provides a single sign-on user interface for generic collaborative tools such as a calendar, chat applications, data viewers and the like. An upgrade to CHEF 2.0 is expected in Fall 2004 which will allow, for example, instructors to build web pages that allow students to move from course content to research content using data from live or recorded experiments.

**Telepresence Services:** These services include support of remote participation in experiments using real-time video and data viewing, and videoconferencing. NITSC supports the telepresence capabilities developed by the NEES System Integrator, which consist of a set of platform-independent hardware and software services that allow access to the Equipment Sites via standard browser software.

**Simulation Services:** Simulation services provide and maintain access to numerical simulation tools using web portals developed by the System Integrator. Currently these tools include OpenSEES and FedeeasLab, a finite element toolbox for MATLAB, both developed by the University of California, Berkeley. Additional simulation tools will be added based on demand. Such services are considered essential for hybrid experiments where only a portion of structural or geotechnical system is tested physically and the remainder is simulated using a computational (numerical) model.

**Visualization Services:** These services are offered to enable researchers to quickly and efficiently comprehend, interpret, and gain insight from large volumes of both experimental and numerical data. Visualization tools are invaluable for the curation of data, locating and extracting critical elements of data. At the present time these tools are still very basic and are accessed through CHEF (see Collaboration Services). They include simple animations, x-y plotting, and multiple time histories with or without synchronized video. Additional services will be provided as resources permit.

**User Support Services:** User support services are provided for all components of NITSC operations such as answering telephone and email questions, maintaining and supporting NEES electronic discussion groups, providing and supporting software bug-reporting systems, and supporting IT-related needs for NEES demonstrations at conferences, meetings, training courses and the like.

## **EDUCATIONAL AND OUTREACH SERVICES**

The objective for the Education, Outreach and Training program within the NEES Consortium, is to educate a diverse and capable workforce (both researchers and practitioners) who are committed to improving seismic safety. In this regard the Consortium's strategy is to focus on what is unique about NEES rather than duplicate the efforts of existing programs, such as those offered by the three NSF-funded earthquake engineering research centers in the U.S. For example, remote participation in experimental research offers educational opportunities that were unimaginable a few years ago. In this regard, seven target user communities are identified as below.

**Researchers:** In order to propose research projects, researchers need information about the equipment at each site, available instrumentation, telepresence capabilities, and data and metadata standards. This information is provided using web-based modules, short courses and visiting scholar programs.

**Graduate Education:** Graduate students engaged in NSF-supported NEES research will likely spend extended periods of time at a NEES Equipment Site during construction and testing phases of their projects. Host institutions are encouraged to allow these students to take classes while at the Site and the home institution to accept such credits. Office accommodation for visiting students and scholars and related support services are provided by the host institution.

**Undergraduate Education:** Assistance is provided with integrating research projects into classroom activities using appropriate modules based on live or recorded data from NEES experiments. Furthermore, summer positions at NEES Equipment Sites expected to be available through the NSF Research Experiences for Undergraduates (REU) program.

**K-12 Education:** K-12 teachers and their students have access to real-world applications of science, technology, engineering, and mathematics. Classroom demonstration kits with curriculum-enhancing models, posters and internet-based simulations not only educate students about earthquake risks but also provide information about career opportunities. Mentoring and internship opportunities are also available. The NSF Research Experiences for Teachers (RET) program provides teachers with the opportunity to learn first hand about earthquakes and their effects on manmade structures at any NEES site.

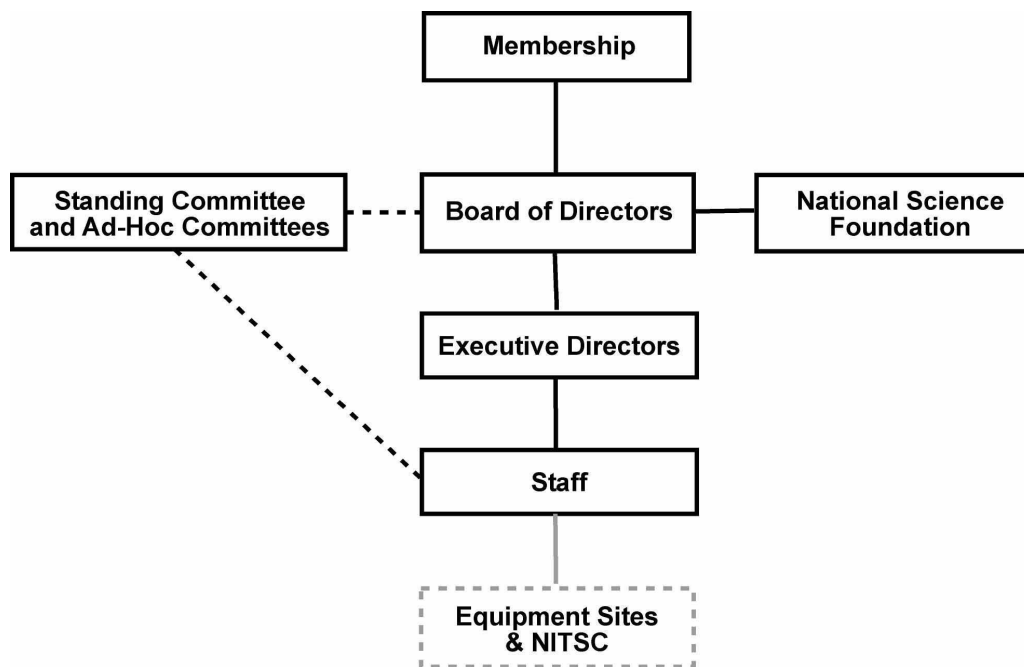
**Practicing Engineers:** Vehicles for disseminating research results into practice will be assessed and enhanced as necessary. These include not only the traditional mechanisms such as written publications, continuing education short courses, and presentations at professional meetings, but also web-based outreach and the active involvement of the practicing community in experiment design, test protocols and interpretation of the data using telepresence. The opportunity to have payload projects proposed by practitioners and funded by NSF, is a particularly attractive option in this regard.

**Informal Education:** Public outreach, including presentations at non-engineering meetings, using all branches of the media, are supported by this program. Assistance will be given to museums and other entities with interactive displays that may wish to take advantage of the telepresence capabilities of the Equipment Sites.

**Support Staff:** Training programs for support staff at each Equipment Site are offered to ensure consistency and timeliness of on-site services related to IT and other Collaboratory-wide elements, such as training on a NEESpop, LAN / NEESgrid system administration, application interfaces, and data services. Safety courses are also offered at each site.

## CONSORTIUM GOVERNANCE AND STRUCTURE

Members of the NEES Consortium are represented in the governance of the Consortium through an elected 15-person Board of Directors (Figure 3). The Officers of the Board are the President, Vice President, Secretary and Treasurer. A five-person subset of the Board, consisting of its officers and one other Director serves as the Executive Committee.



**Figure 3. Governance structure of NEES Consortium Inc.**

Six standing committees advise the Board on operational issues and policies (Figure 4). These committees have community-based membership consistent with the fact that the NEES Consortium is a community-based entity and exists to advance earthquake engineering for the benefit of society as a whole. Democratic governance from below (rather than control from above) with open interaction between all parties is expected to assure this goal is reached, and that the Consortium will flourish and reach its full potential.

The responsibilities of these six committees are summarized below.

**Site Operations Committee:** This Committee oversees the shared use of the NEES Equipment Sites. Specific tasks include developing the NEES Facilities User Guide, reviewing annual operations and maintenance budgets at the Equipment Sites, and developing guidelines on how shared use should be defined and implemented for the sites. The User's Guide, now under development, contains provisions on

such topics as PI and Site responsibilities during proposal preparation; resolution of scheduling conflicts after NSF research awards are made; definition and metrics of shared-use components; safety and insurance; and hosting of students.

**IT Committee:** This Committee oversees IT activities at NITSC (NEES IT Service Center), the Equipment Sites, and at NEES Headquarters. Specific tasks include developing strategic plans for upgrading IT resources and capabilities, reviewing annual IT Budgets at the Sites and NITSC, and advising the board on operation and budgeting of IT services.

**Data Sharing and Archiving Committee:** This Committee develops and oversees policies for the sharing and storage of data, from both experimental and numerical simulations. It also develops quality assurance standards for data, maintains and enhances data schema and metadata standards. It works closely with NITSC and the IT Committee regarding the maintenance and operation of the NEES data repository.

**Education Outreach and Training Committee:** This Committee oversees all education, outreach and training activities within the Consortium including public relations activities.

**Finance Committee:** This Committee oversees all financial policies and procedures within the NEES Consortium. The Committee reviews and integrates recommendations from other committees into a single annual budget for review and approval by the Board.

**Nominations Committee:** This Committee nominates candidates for election by members of the Consortium to fill positions on the Board of Directors and three of the standing committees. Nominations from the ‘floor’ are also permitted by petition under the Consortium’s Bylaws.

Figure 5 is the NEES timeline from the beginning of construction of the Equipment Sites and NEESgrid in 2000, through the startup of the Consortium in 2004, to its operation for the ten-year period 2004-2014. The first set of research projects to use these facilities under the NEESR Solicitation [2] is expected to be announced late summer 2004 and commence October 1, 2004.

NEES Phase	Federal Fiscal Year (Oct. - Sep.)														
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Facilities Development (MREFC)															
Consortium Development (MREFC)															
NEES Operations Start-Up															
NEES Research															
NEES Management, Operation, Maintenance															
Annual Reporting (NSF/GPRA)															
Renewal Proposals															

**Figure 5. NEES timeline.**

## CONCLUSIONS

It is intended that the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) will enable the establishment of a collaboratory of researchers and practitioners from many disciplines, including the public-at-large, for the purpose of reducing seismic risk in the U.S. and elsewhere in the world. Now almost complete, NEES includes fifteen university-based Equipment Sites that offer unparalleled experimental facilities and a grid-based IT infrastructure that enables not only access to these

facilities from remote locations, but also a vehicle for fostering collaboration, sharing data, and disseminating research. This paper has summarized the objectives of NEES and the structure of the NEES Consortium, which has been established by the National Science Foundation, to manage and lead the NEES Collaboratory.

## ACKNOWLEDGEMENTS

This paper is based on the Proposal submitted to the National Science Foundation by NEES Consortium Inc for the ten-year operation of the NEES Consortium from FY 2005 - FY 2014 [1]. Grateful acknowledgement is therefore made of the authors of this proposal for their contributions to this paper. These contributors include: Thalia Anagnos, Harvey Bernstein, Dante Fratta, Catherine French, William Holmes, Jeremy Isenberg, Anke Kamrath, Philip Liu, Stephen Mahin, Robert Nigbor, Cherri Pancake, Kim Roddis, Susan Tubbesing and Sharon Wood. Significant contributions to the content of this paper have also been made by Roberto Leon and Andrei Reinhorn.

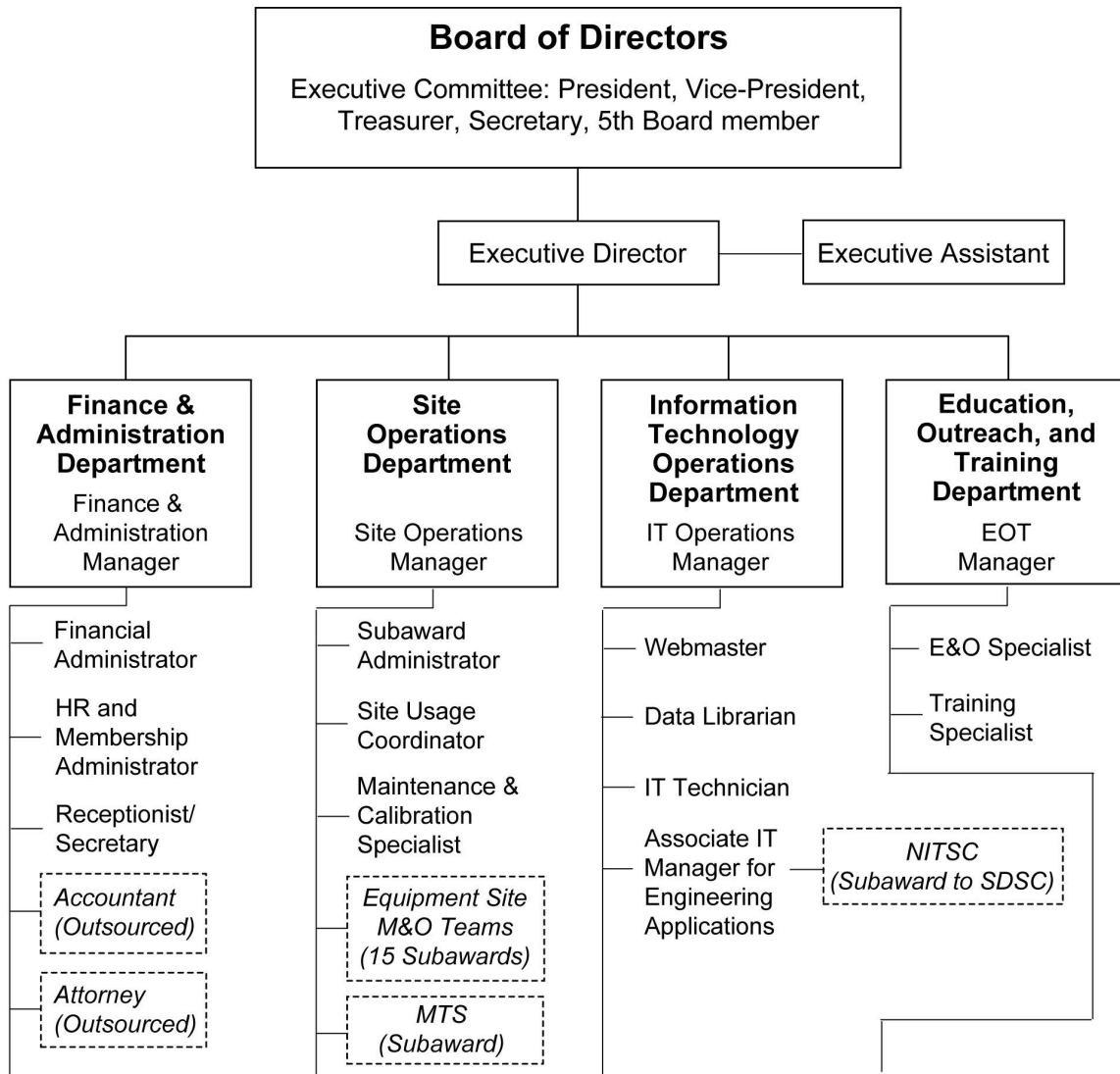
## APPENDIX A. NEES EQUIPMENT SITES

The fifteen University-based NEES equipment sites are as follows:

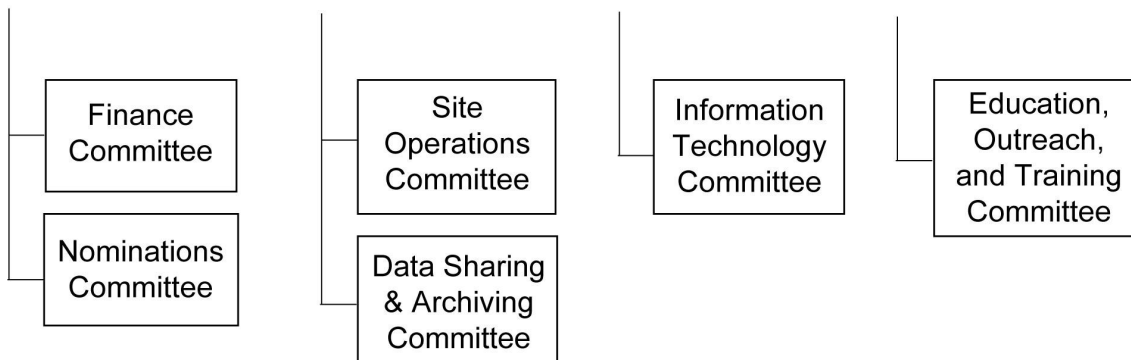
<b>Field Sites</b>	University of California, Los Angeles	Structural field testing (mobile)
	University of California, Santa Barbara	Seismological / geotechnical field site
	University of Texas, Austin	Geotechnical field testing (mobile)
<b>Geotechnical Sites</b>	Cornell University	Soil-structure interaction box
	Rensselaer Polytechnic Institute	Geotechnical centrifuge facility
	University of California, Davis	Geotechnical centrifuge facility
<b>Structural Sites</b>	University at Buffalo	Shake tables (2) and structural test facility
	University of California, San Diego	Shake table (1) facility
	University of Nevada Reno	Shake tables (3) facility
	Lehigh University	Structural test facility
	University of California, Berkeley	Structural test facility
	University of Colorado, Boulder	Structural test facility
	University of Illinois, Urbana-Champaign	Structural test facility
	University of Minnesota, Twin Cities	Structural test facility
<b>Tsunami Site</b>	Oregon State University	Wave basin facility

## REFERENCES

1. NEES. "NEES Consortium Operations: FY 2005-2014: A proposal submitted to the National Science Foundation", NEES Consortium, Richmond CA, 2003.
2. NSF. "George E. Brown Jr. Network for Earthquake Engineering Simulation Research (NEESR)", National Science Foundation Solicitation 03-589, Arlington VA, 2003.
3. SOC. " Overview of Science of Collaboratories Project", Science of Collaboratories Project, <http://www.scienceofcollaboratories.org/>, 2003.



Committees are composed of Board-appointed and membership-elected members. They report to the Board; each has a Board member contact. They are supported by staff in their respective departments.



**Figure 4. Committee structure of NEES Consortium Inc.**