Unrealized Potential: The Socio-Technical Challenges of a Large Scale Cyberinfrastructure Initiative

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EXECUTIVE SUMMARY

In 2007 the National Science Foundation awarded a grant to the University of Michigan, School of Information to evaluate the George E. Brown Jr. Network for Earthquake Engineering and Simulation (NEES). The objective of the evaluation is to understand how NEES is working in its first years of operation. Although NEES is a huge technological undertaking, this evaluation uses qualitative and quantitative data collection methods to consider the social and organizational aspects of NEES as well. It is a formative evaluation intended to provide guidance for the second phase of the NEES operation and to inform current cyberinfrastructure (CI) initiatives that are underway. As a precursor to the current CI initiatives, NEES is not merely an innovation in how to do EE research, but an innovation in how to do research generally. NEES has shown that useful CI can be developed on a large scale to serve a scientific and engineering research community. Its capabilities have encouraged researchers to propose and conduct more innovative experimental research that spans disciplines and research methods. As an early initiative with few examples to draw upon, NEES has also shown that developing CI on such a scale can be a difficult process that does not always go as planned. This study reports the successes and challenges NEES has experienced in the context of five major findings.

- Earthquake engineering (EE) researchers are impressed by the capabilities and service equipment sites provide, but they are less enthusiastic about the new administrative work that comes with managing a shared use environment.
- More collaborative NEES research (NEESR) projects are being funded, but reactions to them are mixed with EE researchers questioning whether some NEESR projects are yielding anything fundamentally new.
- EE researchers are willing and excited to share and reuse each other's data, but the time and labor intensive data management process is slowing progress.
- EE researchers see the value many NEES technical capabilities have for research work, but are less inclined to use the software and services the NEES IT Services Center (NEESit) has developed to support them.
- There have been several successful, innovative education, outreach, and training (EOT) activities, but not a consistent set of well coordinated, high impact EOT activities across a broad range of participants.

The first years of the NEES operation have been successful. Drawing from Jackson et al. (2007), findings from this evaluation indicate that NEES participants have been growing the NEES CI in its early years of operation. As new participants have become involved with NEES, new technical, social, and organizational challenges have cropped up that needed to be resolved before NEES could be adopted. Findings indicate that NEES success is partly due to its participants' willingness to work through the challenges. Findings also indicate that more needs to be done in the second phase of the NEES operation to realize its full potential. As new participants continue to become involved, new challenges will continue to arise. NEES participants have to get better at recognizing and reconciling the challenges they encounter more quickly and completely. This report describes three approaches to do so that include: 1) negotiating changes that address the multifaceted nature of the challenges NEES participants face, 2) making the recognition and reconciliation process more inclusive of the NEES participants that the challenges affect, 3) sensing and responding to the challenges that are ahead.

1.0 INTRODUCTION

Over the years the National Science Foundation (NSF) has funded a number of large multidisciplinary collaborations to develop what has recently been described as cyberinfrastructure (CI). CI is described as a combination of hardware, software, algorithms, communications, institutions, and personnel (Atkins, et al., 2003). A goal of CI initiatives is to enable the creation of effective virtual environments, where scientists and engineers can access distributed resources (e.g. computational tools and services, instruments, experiments, data) (Cummings, Finley, Foster, Kesselman, & Lawrence, 2008). Rather than restrict service to small or even large groups of scientific and engineering researchers, the virtual environments are developed to serve entire communities. They are expected to enable scientific and engineering research communities "to innovate and eventually revolutionize what they do, how they do it, and who participates" (Atkins, et al., 2003, p. 5). As such scientific and engineering research is expected to impact society more broadly, including students, educators, and funding agencies as well as practitioners, policy makers, and the public. There is a great deal of enthusiasm around the promise of CI, but little systematic study of CI initiatives in operation. This report provides results from an evaluation of the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES). NEES has been in operation since October 2004.

In the process of providing the earthquake engineering (EE) community with advanced equipment and information and communication technologies to perform paradigm shifting science, NEES has also tried to change the way research work is conducted. As a precursor to the current CI initiatives that are underway, NEES is not merely an innovation in how to do EE research, but an innovation in how to do research generally. With state of the art equipment installed at 15 universities across the United States, NEES has motivated EE researchers to propose innovative experimental research projects that have not been done before in terms of scale, complexity, completeness, and realness. As a shared use environment, NEES allows EE researchers to conduct this kind of research regardless of their university affiliation. Large collaborative teams that span disciplines and research methods can now form to propose projects that push the boundaries of EE research. These teams can take a more holistic approach to studying earthquake hazards and mitigating the associated risk and loss. This is a huge shift from the individual investigator and small team research done at one's own university with colleagues who have the same background, skills, and experiences. NEES has also extended the collaboration beyond EE researchers to include other NEES participants with different skills and interests. To share equipment and laboratory time and plan and complete research, the EE researchers are likely to work more closely with NEES equipment site personnel. EE researchers are also likely to work with NEES personnel at headquarters (NEESinc) and the NEES IT Services Center (NEESit) for administrative and technology support and services. Working more closely with major stakeholders such as students, educators, funding agencies, practitioners, policy makers, and the public is also expected. As NEES has tried to transform what research gets done and how that research gets done, EE researchers have had to accommodate new relationships with people and technology that are beyond their usual working environments.

As an early CI initiative, NEES has few points of reference on which it can rely. What NEES is attempting is not something that is done every day. There are no CI frames of reference or baselines to put the findings from this evaluation into context. Much of the prior research on CI initiatives has focused on the development phase (e.g. Finholt & Birnholtz, 2006; Lawrence,

2006; Lee, Dourish, & Mark, 2006; Olson, et al., 2008). What the findings from these prior studies do show is the benefit of taking a socio-technical approach to studying CI. A socio-technical approach can be thought of as a broad view of CI that goes beyond concern for the development of the technologies to include the social and organizational contexts within which the technologies are embedded (Scacchi, 2004). The approach does not merely consider the relationships between the social and organizational contexts and the CI, it considers the social and organizational contexts as part of the CI (Lee, et al., 2006). Taking such an approach has the distinct advantage of providing a window into the web of the technical, social, and organizational aspects of a working environment that have to be aligned to meet the diverse and evolving needs of all participants (Scacchi, 2004).

The consequences of not paying attention to all three aspects of CI during the development phase are well documented in a study of the Worm Community System (WCS) (Star & Ruhleder, 1996). When it came time to use the WCS, the authors found that the seemingly straightforward task of "signing on and hooking up" to the WCS was impeded by various social and organizational issues, such as the technical support at potential WCS users' departments and universities. Moreover, they found that these kinds of issues never surfaced during the development phase, despite user involvement and feedback. In more recent research, Kling and colleagues have shown how examining the relationships between the technical, social, and organizational aspects of CI environments can yield a richer understanding of human behavior and a more complete understanding of the conditions and activities that support the sustainability of CI environments (e.g. Kling, McKim, & King, 2003; Kling, Spector, & Fortuna, 2004).

Based on what was known about NEES at the start of this evaluation and the prior research on CI environments, there are three objectives to this evaluation. The first is to examine how NEES is transforming what research is done and how research is done. The second is to take a socio-technical approach to examine NEES as a means to enrich the story of how NEES is doing. The third is to use findings from the evaluation to determine what can be learned and used to help NEES and other CI initiatives continue to move forward. To accomplish these objectives, this evaluation examines how NEES is facilitating EE researchers' access to distributed resources and the impact such access is having on the EE community. More specifically, this study provides a snapshot of the NEES operation based on four topics of inquiry.

- The challenges and successes NEES has had in serving the EE community
- The impact NEES has had on EE research to date
- EE researchers' past and present data management, sharing, and reuse practices
- EE researchers' current information technology use

Since beginning operation in 2004, findings indicate that NEES has made significant progress, but events are not unfolding exactly as planned. NEES has experienced successes and challenges with the new technical, social, and organizational aspects of NEES. In this report, the successes and challenges are described as they relate to: 1) equipment sites, 2) NEES research (NEESR) projects, 3) data management, sharing, and reuse, 4) NEESit software and services, and 5) education, outreach and training (EOT). The five major findings are as follows.

- EE researchers are impressed by the capabilities and service equipment sites provide, but they are less enthusiastic about the new administrative work that comes with managing a shared use environment.

- More collaborative NEES research (NEESR) projects are being funded, but reactions to them are mixed with EE researchers questioning whether some NEESR projects are yielding anything fundamentally new.
- EE researchers are willing and excited to share and reuse each other's data, but the time and labor intensive data management process is slowing progress.
- EE researchers see the value many NEES technical capabilities have for research work, but are less inclined to use the software and services the NEESit has developed to support them.
- There have been several successful, innovative education, outreach, and training (EOT) activities, but not a consistent set of well coordinated, high impact EOT activities across a broad range of participants.

The remainder of this report is organized as follows. A brief description of NEES including its history and current operations is provided next. This is followed by a discussion of the study methodology, including data collection and analysis procedures. Next, the results are reviewed. This is followed by a discussion of study findings and next steps.

2.0 NEES HISTORY

Plans to develop NEES began in the mid 1990s. The goal was to use information technology to create a network of shared use research facilities throughout the U.S. despite geographical dispersion of universities and university researchers. The NEES initiative was divided into two phases, the construction phase and the operations phase. Much of the information about these phases was gathered from the NEES website (http://www.nees.org/About_NEES/History/). The sections below describe each phase in terms of the participants and their roles.

2.1 The Construction Phase

The construction phase of NEES occurred from October 1, 2000 to September 30, 2004. During these 4 years, NSF funded 15 equipment site projects, a systems integration project, and a consortium development project. The 15 universities were funded under the Major Research Equipment Facilities Construction (MREFC) to construct or upgrade their existing research facilities (i.e. equipment sites). Each equipment site specialized in specific kinds of experimental work including, geotechnical centrifuge research, shake table tests, large-scale structural testing, tsunami wave basin experiments, and field site research.

The National Center of Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign led the effort to develop the NEES information technology infrastructure (NEESgrid). It included the development of software and services to support distributed collaboration among equipment sites and EE researchers, data management, sharing, and reuse, and remote participation in laboratory experiments. The work was done in collaboration with information technology researchers at the University of Southern California, Information Sciences Institute, the University of Michigan, School of Information, and the Argonne National Laboratory.

The Consortium of Universities for Research in Earthquake Engineering (CUREE) was funded to set up the NEES Consortium Inc (NEESinc). NEESinc, a nonprofit organization, was created to manage NEES as a national shared use research facility for EE researchers. The desire was to

create a community-based and community-led shared use environment. Therefore, NEESinc was expected to get input and broad consensus from EE researchers about the NEES operation, including its organizational structure and governance.

2.2 The Operation Phase

NEES has been in the operation phase since October 1, 2004. The four key components of the NEES operation phase include the: 1) NEESR awards 2) NEESit, 3) the equipment sites, and 4) NEESinc. The funding structure across the four components of the NEES operation varies. In the third year of operations, funding for each of these components was approximately $9M, $4.6M, $14.3M, and $2.2M respectively. In the following paragraphs, the four components of the NEES operation are described in more detail.

2.2.1 NEESR Awards

A separation between providing facilities and services to conduct research projects and awarding research grants is stipulated in NEESinc Bylaws. Therefore, NEESR proposals are vetted and award decisions are made through NSF's existing peer review process. NEESR awards have been made to EE researchers every year since 2004. Given the amount of money available to conduct NEESR research vs. the number of EE researchers vying for awards, the competition for funding is intense. As of June 2007, the 5th annual NEES meeting, there were 35 NEESR awards.[1] Of the 35 NEESR awards, 10 were individual investigator awards, 17 were small group awards, and 2 were grand challenge awards, and 6 were payload awards. At the time of the 5th annual NEES meeting, several of the NEESR projects were at or near completion and early research results were being disseminated. The experimental data from the projects were being curated and documented so that the EE community could reuse them.

2.2.2 NEESit

For the operation phase, the responsibility for information technology development and maintenance moved from NCSA to the San Diego Supercomputer Center (SDSC) at the University of California at San Diego. There were initial roles for the Argonne National Laboratory, the University of Michigan, and University of Oregon, but they had ended by the time this study began. NSF provides funds to SDSC directly for ongoing NEESit development and maintenance activities. NEESit has three primary responsibilities. One is to maintain the technical infrastructure, which includes providing a secure, reliable environment. The second is to provide field support to NEES users and equipment sites by responding to ongoing issues (e.g. bugs). The third is to support several software and service development areas, such as the data management, sharing, and reuse, data viewing, teleobservation and teleoperation, and hybrid simulation[2].

2.2.3 The Equipment Sites

Funding for the 15 equipment sites is used to maintain systems, repair and replace equipment, and employ personnel, such as site operations managers, technicians, engineers, IT specialists,

[1] There were 9 pre-NEESR awards made in 2003-2004.

[2] Hybrid simulation is a test method used to evaluate the seismic performance of structures by integrating physical and numerical simulation of substructures into a single model (Mosqueda, Stojadinovic, & Mahin, 2005).

and EOT coordinators. Site directors are expected to utilize half their equipment site capacity for NEESR projects and the remaining half for non-NEESR projects (e.g. government and private industry projects). Although most sites have NEESR projects, their NEESR capacity is not yet fully utilized. Their non-NEESR capacity is also not yet fully utilized. Unlike the development phase, NSF decided not to provide separate funding to each equipment site during the operations phase. Instead, NEESinc oversees the operations and maintenance subawards (i.e. subcontracts) for the equipment sites. Equipment site funding is based on equipment site performance (e.g. proportion of shared use research projects).

2.2.4 NEESinc

NEESinc, a nonprofit organization, has served as headquarters during the NEES operation phase. NEESinc responsibilities as quoted from the NEESinc mission statement (http://www.nees.org/About_NEES/Mission/) include:

- Promoting the goals of NEES
- Providing leadership and planning to ensure that NEES remains a state-of-the-art distributed facility accessible to the earthquake engineering community
- Managing the shared-use maintenance and operations budget for equipment sites
- Facilitating the scheduling of NEES research activities at equipment sites
- Managing the system-wide information technology infrastructure of the NEES Collaboratory, providing access to a broad range of users
- Maintaining repositories for NEES data and simulation tools
- Managing an education, outreach, and training program
- Advancing NEES infrastructure capabilities through the pursuit of opportunities for technology development
- Fostering linkages and partnerships with federal, state, and local government entities, national laboratories, the private sector, and international collaborators
- Facilitating advanced research usage of NEES, while not competing with the NEES Consortium members in the conduct of research

In the operation phase, NSF provides funding to cover the organizational costs associated with running NEESinc (e.g. staff, facilities, etc.). The Board of Directors is responsible for establishing policy and procedures, governing NEES, and deciding how NEESinc should be managed. The Executive Director at NEESinc manages and coordinates program activities in three major areas: site operations, IT, and EOT. At the time of this study, three Directors were employed to oversee each area.[3] In the early years of operation, NEESinc was primarily focused on creating administrative structures, policies, and procedures necessary for operating a shared use environment. For example, reporting requirements that include annual work plans and quarterly progress reports have been established for the equipment sites. Standing committees are comprised of EE researchers, practitioners, and equipment site personnel and help set

[3] The IT and EOT Directors are no longer with NEESinc and have not been replaced.

policies and procedures as they related to site operations, IT, and EOT. The site operations committee reviews equipment sites plans and performance annually. The EOT committee reviews EOT activity at NEESinc, the equipment sites, and NEESit annually as well. The finance committee then reviews the annual budget and uses recommendations from the site operations and EOT committees to advise the Board of Directors about the subaward decisions for each equipment site. NEESinc also has formed temporary task groups to address particular policy and planning issues as necessary. Former task groups have focused on governance, the development of a NEES IT vision, and a shared-use partnering policy.

In sum, NEES was in its third year of operations at the start of this study. The move from the construction to the operation phase brought three major changes. First, a governing body was created for and by the EE community. It was comprised of EE researchers, practitioners, and NEES personnel, some of whom were also EE researchers. Second, there was a shift in equipment site funding and review responsibilities. Although NSF still provided the funding, the NEES Board of Directors decided how much funding to provide each equipment site based on performance review data. Third, the development and maintenance of NEESit software and services changed from NCSA to SDSC. Unlike the equipment sites, NSF provided funding directly to SDSC.

3 STUDY METHODOLOGY

Data collection for this study took place from June 2007 to February 2008. Both qualitative and quantitative methods were employed to address the four major topics of inquiry. Interviews and observation took place from June 2007 to November 2007. The objective was to gain a more detailed understanding of NEES from the perspective of current and potential NEES participants, including EE researchers and NEES personnel. A survey was administered from January 2008 to February 2008. The survey was administered to EE researchers who were current members of the NEES Consortium. The objective was to surface perceptions about various aspects of NEES operation. To protect the anonymity of the study respondents, only general information about them is provided in this report.

3.1 Interviewing and Observation Methods

Individual interviews were conducted with 53 people. Of the 53 interviewed, 36 were NEES personnel. NEES personnel included people who were working at an equipment site, NEESit, or NEESinc or were serving or had served on the Board of Directors, a standing committee, or task group. The remaining 17 people interviewed were EE researchers who represented current or potential NEES users. Since NEES was run for and by the EE community, several NEES personnel were also EE researchers. The interview questions they were asked related to the primary reason they were selected to be interviewed. At times, they also provided additional comments based on their roles and experiences as EE researchers. The additional comments were also included in the analyses.

Interview sessions totaled approximately 49 hours. On average, interviews lasted 45 minutes to 1 hour. Most interview participants agreed to be audio taped. These interviews were then transcribed. For interview participants who did not want to be audio taped, notes were taken instead. Observation took place during visits to two equipment sites and headquarters and while

attending the NEES annual meetings in June 2007 and June 2008. Additional documents such as presentation slides, reports, web content was also collected during these observation activities.

3.1.1 Interviews with NEES Personnel

The 36 NEES personnel interviewed for this study represent 10 of the 15 equipment sites, NEESit, NEESinc, the Board of Directors, standing committees, and task groups. The equipment site personnel interviewed included PIs, directors, operations managers, technicians, EOT coordinators, engineers, and IT specialists. The objective of interviewing NEES personnel was to gain multiple perspectives about the NEES operation. NEES personnel were asked about their current roles and responsibilities, how they became involved with NEES, their perspective on the challenges and successes related to operating NEES, the impact NEES resources and capabilities were currently having on the EE community, and what needed to happen to make the next leap forward in EE research.

3.1.2 Interviews with EE Researchers

Of the 17 EE researchers interviewed for this survey, 15 were Principle Investigators (PIs), Co-Principle Investigators (Co-PIs), graduate students, or post docs working on NEESR projects. The remaining 2 had not received a NEESR award. Of the 17 interviewees, 10 were identified as structural engineers, 5 as geotechnical engineers, and 2 as tsunami researchers. The EE researchers were primarily experimentalists, numerical computation modelers, or did some combination of both. The objective of interviewing EE researchers with different research disciplines and methods was to learn about their current research as it related to the resources and capabilities NEES offered. Interviewees were asked about their current research, including NEESR projects if appropriate. They were also asked about their data management, sharing, and reuse practices, technology use, challenges and successes related to using NEES resources and capabilities, impact NEES resources and capabilities were having on their research, and what needed to happen to make the next leap forward in EE research.

3.2 Survey Method

The survey was developed to capture a broader perspective about how NEES resources and capabilities were meeting EE researcher needs. Respondents were asked about their current research activities, data reuse practices and needs, current involvement with NEES, attitudes toward NEES equipment facilities, NEES technical capabilities, as well as the impact of NEES on their research. Survey questions (Appendix A) were based in part on the understanding of NEES gained from the interview data. A panel of experts in EE research and NEES reviewed the survey questions to ensure clarity and understanding. The survey was then piloted with three EE researchers.

3.2.1 Survey Administration

The web-based survey was administered through SurveyMonkey.com to current NEES Consortium members. The Executive Director of NEESinc sent an email to current NEES Consortium members informing them that a survey was going to be administered and their names and contact information would be shared unless they opted out. Of the 312 members, 11 opted out of the survey. A list of the 301 remaining NEES Consortium members, including their contact information was provided to the UM research team. The list of contacts was reviewed

and NEES Consortium members were removed from the list if they 1) were not active EE researchers, 2) were employed at NEESinc, or 3) had incorrect contact information. After the review, 276 contacts remained.

To initiate contact with the 276 NEES Consortium members, the UM research team sent a letter to inform them they were selected to participate in a web-based survey. In the letter, the purpose of the survey and how aggregate responses would be used was described. The letter also provided a link to the survey. To encourage participation, a $2 cash gift was enclosed along with a letter of endorsement from the Executive Director of NEESinc. A week later, an email was sent to all NEES Consortium members to reiterate the purpose of the survey and provide the survey link. Three reminders with the same information were sent a week apart to non-respondents. The first two reminders were sent via email. The third reminder was sent via a postcard. Of the 276 NEES Consortium members, 135 responded for a response rate of 48.9%. Eighteen surveys were incomplete. Once removed, 117 surveys remained for a response rate of 42.4%.

3.2.2 Descriptive Statistics

The majority of the 117 respondents are male (approximately 79.5%[4]), have a Ph.D. (87.2%), are affiliated with a research university (approximately 86.3%[5]), and are full professors (34.2%), associate professors (19.7%), or assistant professors (17.1%). Of the 117 respondents, 66.7% are registered users of NEESCentral, 59% have been named as a PI or Co-PI on a proposal submitted to the NSF or other sponsor to use NEES equipment facilities. Of the 59% who submitted proposals, 69.6% have been awarded a grant to use NEES equipment at one of the equipment sites. The primary area of research for 76.1% of the respondents is earthquake engineering. The remaining 23.9% describe their primary research in a number of different ways, including water waves, dynamics, seismology practice, coastal engineering, earthquake instrumentation technology, structural stability, information technology for earthquake engineering research, loss modeling.[6]

In Figure 1 see that EE researchers describe their primary area as structural engineering (65%), geotechnical engineering (23.1%), or tsunami research (5.1%). The remaining 6.9% describe their primary area of EE research as soil structure interaction, seismic hazard assessment practice, nonstructural, buried pipelines, seismic wave propagation, loss modeling for buildings, and information technology. Figure 2 shows that respondents have several research approaches at their disposal and often use more than one, including laboratory experiments (85.5%), field experiments (45.3%), numerical modeling (86.3%), and hybrid simulation (20.5%). The remaining 12.8% of respondents report using other approaches, including theory, seismic hazard assessment practice, in factor testing of new technologies, FEM, case histories, literature review, analytical modeling without the use of computers, instrumentation development, concept development, field investigations.

[4] Seven respondents did not answer the question about gender.
[5] One respondent did not answer the question about institutional affiliation.
[6] A complete list is available upon request.

Figure 1. Primary EE Research Area as Reported by the Respondents

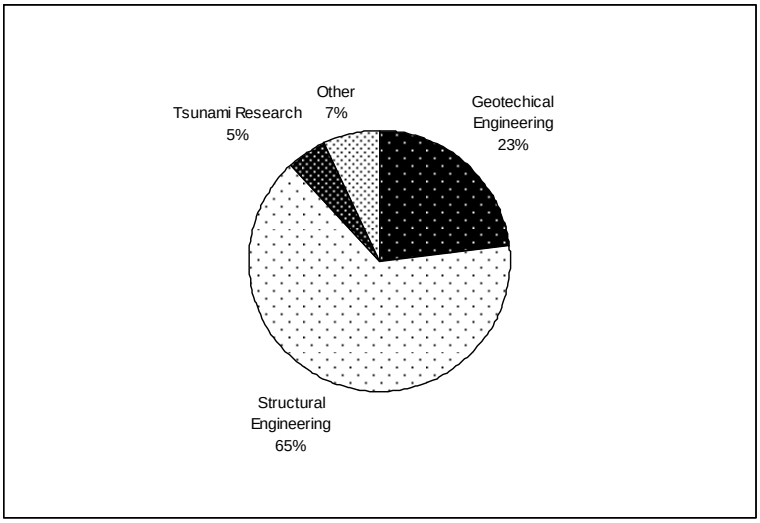
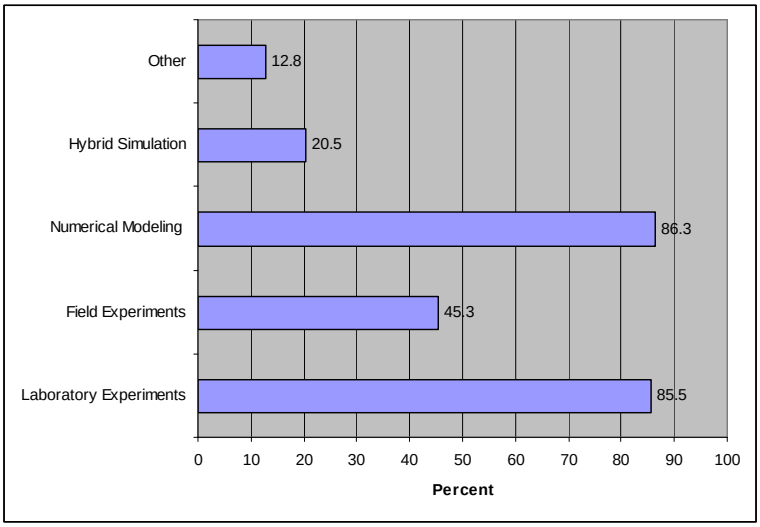


Figure 2. Research Approaches Respondents Report Using



The survey asked respondents to choose up to three activities that would be the most valuable in advancing their research in the next 1-3 years (Table 1). The top five activities are collaborating with researchers who use different research approaches (48.7%), collaborating with practicing engineers (47%), reusing data from other researchers (41.9%), collaborating with researchers outside of their area of expertise (40.2%), and collaborating with researchers within their area of expertise (40.2%). Sharing their data with other researchers and gaining access to state of the art equipment at other research institutions are reported to be less valuable at 24.8% and 23.9% respectively. It is not a surprise that EE researchers value reusing data from their colleagues much more than taking the effort to share their own. The low percentage of respondents who value accessing the shared equipment however, is surprising, especially given the resources (i.e. time, money, effort) expended on the equipment sites to date.

In sum, the majority of survey respondents conduct earthquake engineering research, particularly structural engineering research. The majority of the respondents use laboratory experiments

and/or numerical computation modeling to conduct their research. Respondents view collaboration and reuse of each other's data as the most valuable activities for advancing their research in the next 1-3 years.

Table 1. Activities Most Valuable in Advancing Research in the Next 1-3 Years

Question Stem: Which of the following do you think will be the most valuable in advancing your research in the next 1-3 years? *(choose up to three)*	
Sharing your data with other researchers	24.8%
Reusing data from other researchers	41.9%
Collaborating with researchers *outside of your area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research)	40.2%
Collaborating with researchers *in your area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research)	40.2%
Collaborating with researchers who use different research approaches (e.g. laboratory experiments, field experiments, numerical computation, hybrid simulation)	48.7%
Collaborating with practicing engineers	47.0%
Gaining access to state of the art equipment at other research institutions	23.9%

3.3 Data Analysis

An initial coding scheme to analyze the qualitative data was based on the research questions and specific aspects of NEES respondents discussed. They included equipment sites, NEESR projects, data management, sharing, and reuse, NEESit software and services, and EOT activities. The codes were further refined to include specific aspects of the technical, social, and organizational aspects of NEES and EE research. The survey data was analyzed using SPSS.

4 RESULTS

The findings from this study are organized into five major sections based on the five major themes that emerged during data analysis. Both qualitative and quantitative findings are presented in each section.

- Equipment Sites
- NEESR Projects
- Data Management Sharing and Reuse
- Development and Use of NEESit Software and Services
- Education, Outreach, and Training

For each section, the successes and challenges of NEES are discussed. When findings warrant it, the reasons behind some of the challenges are provided. Each section ends with a brief discussion of potential implications of the results. The implications should be viewed as a preliminary discussion of results, since this study is intended as a formative evaluation that provides guidance for the second phase of the NEES operation.

4.1 Equipment Sites

Together 15 universities provide EE researchers shared access to state of the art equipment and information and communication technology regardless of the EE researchers' university affiliation. Findings indicate that equipment site capabilities and site staff service are well

regarded, but the administrative overhead that comes along with managing a shared access environment is not.

4.1.1 Capabilities and Service

There is widespread agreement among NEESR researchers, NEES management, and equipment site personnel that equipment site capabilities and service are impressive. According to interview respondents, NEES equipment sites accommodate large scale experiments that are more complex, complete, and real than other university equipment sites. One respondent discusses the ability to approach real time speeds, put on more realistic loadings, and move specimens (i.e. bridge piers) independent of each other as unique steps forward in earthquake engineering experiments. The following quote is representative of how several NEESR researchers describe the benefits of the shared use environment.

> …the NEES resources allowed me to conduct these tests that I would not have been able to conduct otherwise. I don't have the experimental facilities to test these large scale dampers at the speeds that they needed to be tested at and so they literally allowed me to even conduct these tests.

Of the survey respondents who are NEESR researchers and have used the equipment sites (Table 2),

- 54.8% agree or strongly agree that the focus of their research conducted at NEES equipment sites is different than if they had been working at a non-NEES facility
- 59.7% agree or strongly agree that the quality of their research conducted at NEES equipment facilities is higher than if they had been working at a non-NEES facility
- 62.9% agree or strongly agree that their experience at NEES equipment facilities has had a significant positive influence on their research productivity

Table 2. Equipment Site Capabilities

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Overall I would say the *focus* of my research conducted at NEES equipment facilities is different than if I had been working in a non-NEES facility.	30.6%	24.2%	24.2%	17.7%	3.2%
Overall I would say the *quality* of my research conducted at NEES equipment facilities is higher than if I had been working in a non-NEES facility.	27.4%	32.3%	25.8%	11.3%	3.2%
Overall, I would say that my experience at NEES equipment facilities has had a significant positive influence on my *research productivity*.	37.1%	25.8%	29%	4.8%	3.2%

Interview and survey findings (Table 3) indicate that equipment site service is also viewed positively. Service starts during the proposal preparation and grant award stages. Of the survey respondents who have submitted proposals to use NEES equipment facilities, 81.1% agree or strongly agree that NEES personnel have been available to answer questions. Of the survey respondents who have been awarded a grant to use NEES equipment facilities, 70.8% agree or

strongly agree that NEES personnel have helped them get their research participation agreement signed.

Table 3. NEESinc and Equipment Site Service Levels

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
NEES personnel (i.e. NEESinc, NEES equipment facilities) made themselves available to answer any questions I had as I wrote my proposal to use NEES equipment facilities.	27.5%	53.6%	17.4%	1.4%	0.0%
NEES personnel (i.e. NEESinc, NEES equipment facilities) helped me get my research participation agreement (RPA) signed in a timely manner.	25.0%	45.8%	22.9%	4.2%	2.1%

NEESR researchers and NEES management also acknowledge onsite service equipment site staff provide. NEESR researchers comment on the helpfulness of equipment site staff when it comes to sharing equipment site resources.

> Everybody has a good attitude about sharing resources and doing a good experiment. There is no provincialist that I have detected – this is my facility; my data; don't bother me, stuff like that. It's still been very difficult because the scientific aspect is very difficult. But from the viewpoint of attitude and relationship it has been excellent.

NEESR researchers also appreciate the staff's effort to make sure the tests are successful. One respondent describes his overall experience during an interview.

> I think they put in a lot of effort and they clearly wanted my project and NEES to succeed in the testing and they did all that they could towards that end and I'm very happy with everything.

Others describe the equipment site staff's readiness to handle the data capture and archiving processes and their collaborative approach to service delivery.

> Once the specimen is in place, then they [the people at the equipment site] know how to operate. Once the construction was done they were really prepared to capture the data. The amount of data they are able to capture with the video cameras […]. What they promised they delivered.

> Well I think the collaborative approach that the NEES facility [the equipment site] is taking is very much appreciated by all the PIs in the project.

Another describes the staff as being experienced and able to go well beyond their job descriptions to address unexpected difficulties that come up during the experiment.

> At the [field] site we were at a very isolated location, limited access, there were no utilities, there was no water but what happened was we had a lot of…just building the specimens was much more difficult then I was used to because I'm used to building things in the laboratory and so the staff came up with

> incredibly ingenious ways to get stuff done. It turned out that their operator can run any type of equipment so we could rent…all terrain forklifts and we were able to do things whereas if I had to run them we would still be out there. The staff had skills that went well beyond what their job description is and that helped us tremendously.

In sum, interview and survey respondents hold equipment site capabilities and staff service in high regard. The shared use environment allows EE researchers to do research that they would not be able to do otherwise and the equipment site staff provides end to end service and support to ensure EE researcher success.

4.1.2 Managing a Shared Use Environment

Hosting NEESR projects at equipment sites requires advanced planning and ongoing management to deal with the unexpected. Both NEESR researchers and site managers have to engage in advanced planning in order for the equipment site to be successful. Both have problems accepting the changes that come with the new way of doing things.

NEESR Researchers Resist Advanced Planning

In interviews the site personnel mention a preference to be involved in the planning stages of NEESR projects early and often. Although site personnel note several benefits of advanced planning, they have had a hard time convincing NEESR researchers to do it. According to one respondent, equipment sites meet NEESR researcher needs more effectively when site personnel understand the scope and scale of NEESR projects in advance.

> Now I would say information is power like NEES is all about information. I never complained about too much information. I always complain of too little of it, of information. I would like to be in the loop all the time, understand the problem. I would like to be part of the researchers' meeting. When we understand the scale of the project and the problem, we understand that well you won't be able to do it that way, and then shall we postpone it a little bit. Or you know what you may not need two tables. You may need a table and an actuator and we can do it better than that so we have to provide this input to the researchers so the more we know about the operations, the more we know, the more effective the sites can be.

By getting details in advance, site personnel are able to spot potential problems in experimental designs and identify better ways to get the work done. Involvement in the planning stages of NEESR research also allows site staff to set expectations about staff roles and responsibilities. This is important because they often vary from site to site. They are also different than what EE researchers have experienced at their home institutions. One respondent describes how a graduate student shows up expecting more staff help than the equipment site provides. The respondent explains that the student's expectations are due in part to how he works at his own university.

> I think the student showed up and assumed that everything would get done for him and that he would basically just be sitting at a desk and the way our lab works is the project provides the majority of the labor to build the specimens and test them. And so he was kind of shocked that he was going to be asked to put up floor mark and tie rebar and all these other things that are what we expect the projects to provide. And I think at the lab that he came from […], they had technicians to do a lot of that and we don't have the funding for that here so we don't have that and I think nobody explained to him what was going to be expected of him when he showed up.

According to site staff, other NEESR researchers expect the site staff to purchase materials and construct specimens on the spot rather than figure these activities into the time and effort of conducting the research at the equipment site. One respondent reasons that this is because NEESR researchers underestimate the time and complexity associated with doing large scale experiments.

> we have [had] people show up a month before their test date and they're still trying to draw their structures and they have to go to a machine shop and be fabricated and sometimes it can take a few weeks for a purchase order to be…if it's expensive enough it can take weeks to go through university purchasing and then you have to have the machine shop lead time on top of that, it's like…you've got to get that stuff done before you even show up.

Findings indicate that responding to just-in-time EE researcher planning is more likely to occur at an EE researcher's own university where scheduling and throughput are less important. As one respondent says, figuring out experimental designs before entering a NEES equipment site is not something EE researchers are used to doing.

> We've been trying to require projects to develop a written work plan that addresses everything that they're going to need to do from the moment they set foot in the lab until the moment they leave. And it's a different way of doing experimentation than what people are used to because we're all just in time and now we're telling people no you can't be just in time you have to have it all figured out before you show up.

Not only are NEESR researchers expected to design their experiments in advance, they are also expected to share them with equipment site personnel. According to one respondent, this is something EE researchers rarely did with others, except close colleagues.

> Well NEES is a new way of thinking. Researchers need to adapt to that kind of, doing that kind of research. The researchers used to keep things well, not in secret, but to keep it to themselves until they publish the paper, until they're ready to show it off. They're not willing to share much at the beginning, at early stages of the project. Now I can tell you that it's getting better now but it's still we're not up to that level yet.

Findings also indicate that NEESR researchers may resist doing advanced planning, given their level of expertise. For example, one of the more experienced NEESR researchers thinks the work plans are too detailed. He has never created such a detailed work plan for experimental research.

> The biggest challenge has been dealing with an overly detailed work plan that had to include all tasks in extreme detail. The work plan is something submitted to the site, but the site wouldn't sign the contract until the work plan was approved, and it took forever.

In sum, advance planning offers NEESR researchers several benefits, including fewer unforeseen problems in the lab with respect to roles and responsibilities as well as experimental designs and tests. Yet, NEESR researchers resist planning, in part because it is different than how they have gone about their research work in the past. They are used to just-in-time planning in the lab not advanced planning outside of it. In addition, they are not used to sharing their plans with outsiders so far in advance of publications. Lastly, for more senior EE researchers the planning may seem overly detailed given their expertise.

Site Staff Accept Planning But Want More Autonomy

Equipment site staff does advanced planning as well as progress reports. Annual work plans and quarterly progress reports are submitted to NEESinc for Site Operations Committee review. Although site personnel understand the need to plan, manage, and report progress, several express dissatisfaction with the reporting requirements. Findings indicate that the site staff's dissatisfaction may not be due to the reporting requirements per se, but rather the loss of autonomy given their experience running equipment sites in the past. According to one respondent, there were few opportunities for site staff to provide feedback about the initial reporting requirements. Since then, reporting requirements have been in flux and according to one respondent they have yet to stabilize, in the fourth year of operation.

> there was never a feeling that there was a channel back that we could get some input and say you know it really doesn't make any sense to construct the reporting in this way because it's unrealistically burdensome and maybe information that's not ultimately really needed and then have any response to that. There was never any response to that that was anything other than sorry. It's just the way it is.

In the process of getting new or upgraded equipment site capabilities, some site personnel have felt frustrated by the strict adherence to their annual work plans. According to one respondent there is a level of uncertainty about running a research facility that cannot be accounted for when scheduling NEESR projects 12-18 months in advance.

> In many cases these annual work plans have so many holes in them because there's so much uncertainty about running a research facility. There's so much you don't know with respect to any research project and researchers have their own limitations about telling us you know their time lines, their plans, what they expect to do, what kind of resources they expect to need. They can't do it in absolute terms. It's not how academic research historically has

> ever worked. So researchers are only capable of providing it for certain level of information so for us to be able to say that beginning in August of next year this is what we're going to be doing, this is what we're going to need and this is the type of work we're going to be doing, we can't say that.

Some site personnel want more autonomy in planning, managing, and scheduling NEESR projects as a result. Several site personnel also express the desire for more authority to flexibly reschedule NEESR projects as issues arise.

> I think the biggest thing that NEES needs to help us with is to remember that we need some flexibility in our schedules to try and accommodate things like this. Things like people need to be rescheduled, experiments fail, sometimes they come back and the structure that NEESinc sort of put in place for some of the adherence to a certain level of detail to their work plan and spending. Sometimes they [equipment site staff] could feel like that flexibility at the site is being not really supported or provided.

Site personnel understand the importance of reporting plans and progress. Many have had experience running their own sites prior to becoming one of the 15 universities associated with NEES. A key issue seems to be that site personnel feel that more reporting requirements come with less decision making authority and less autonomy, both of which they believe are important in successfully running their equipment sites.

4.1.3 Implications for Equipment Sites

A shared use environment needs to have not only superior capabilities and service, but also scheduling and coordination across several NEESR projects to get the greatest throughput. The new and upgraded equipment sites have been well received, but the organizational changes needed to manage a shared use environment have not. For example, NEESR researchers have been reluctant to plan and share their plans with equipment site staff in advance. Although the time and effort advanced planning requires may be one explanation for NEESR researchers' resistance, a lack of trust and changes to existing ways of working may be more telling. Advanced planning is a change from EE researchers existing ways of working. It requires that they share early research ideas beyond trusted colleagues and reject their just in time approach to experimental work in the laboratory, an approach that has worked for them in the past. Even though making the advanced planning process easier to do and providing training to fill out the paperwork may help reduce time and effort, it may not be enough. Findings indicate that there may also be a need to educate EE researchers about the importance of advanced planning in a shared use environment and assure them that their research ideas will be kept confidential. Another objective may be to convince EE researchers that advanced planning is worth their time and effort. Keeping them engaged by providing benefits along the way from initial planning to final execution of their research project is one approach. Engaging EE researchers with benefits from their advanced planning efforts may be especially important for EE researchers who have successfully completed experiments at their own institutions in the past, without much advanced planning.

Issues related to culture and trust also surface in interview findings with site personnel about their advanced planning with NEESinc. Most site personnel understand the importance of monitoring planning and performance, because they have done it when running equipment sites in years prior to NEES. Yet, they are dissatisfied with the new ways of working. Unlike NEESR researchers their dissatisfaction seems to be due in part to a loss of autonomy. They were not consulted during the initial development of the reporting requirements and do not find the requirements helpful in planning and managing site activity as a result. After gaining years of experience managing equipment sites, some site personnel feel their expertise is not recognized or valued because they are given little decision making authority to flexibly schedule NEESR projects as events arise.

Administrative coordination mechanisms like advanced planning seem like easy fixes to improve efficiency and in most cases have a role in running an entity like NEES. Designing easy processes, providing templates, and providing training about how to complete paperwork is one approach. In the context of NEES, however, findings indicate that more thought needs to be given to how these kinds of administrative coordination mechanisms should be designed, developed, and introduced. Findings indicate that the expertise and existing work practice of all people who are affected should be considered when designing, developing, and introducing such mechanisms. In addition, trusting relationships need to be built among all parties with respect to what administrative information is required and how the required administrative information will be collected and used.

4.2 NEESR Projects

NEES aims to provide access to shared use equipment sites so that EE researchers can conduct research that is more collaborative and transformative. As indicated in the prior section, NEESR researchers are excited to conduct research at equipment sites that allow for large scale experiments that are more complex, complete, and real. Yet, findings indicate mixed reviews about the collaborative and transformative nature of NEESR projects to date.

4.2.1 NEESR Project Collaborations

In terms of NEESR project collaborations to date, the grand challenge projects are viewed as the exemplars. During interviews and at NEES annual meetings, the grand challenge projects are showcased as the future of EE research. Grand challenge projects are not only large scale, complex experiments. They are interdisciplinary research collaborations that take a holistic view of an earthquake engineering issue. In addition, grand challenge projects consider the full range of EOT stakeholders, particularly those in private industry. One respondent explains the importance of one of the grand challenge projects in the quote that follows.

> And the reason I think [the grand challenge project is] important […] is you notice that it wasn't just the cranes…you know as engineers I was expecting them to show all kinds of analyses of the cranes, sort of getting into the nuts and bolts and the numbers and the details and that but I think for engineers [we] have more to offer and I think looking at the port as a system okay I think that really helps us because again we're in a market place and we have capabilities and products that we can offer that we couldn't offer before. For example, the ability to go in and analyze or help a port

> operator look at their system from a resiliency standpoint, that's never really been done before. And so Glen's project does that and develops techniques and it provides the practicing community with a new product and it has credibility.

Respondents view the increase in NEESR project collaborations as a positive step forward for NEES, but concerns are expressed about certain kinds of NEESR collaborations. First there are NEESR collaborations that involve site personnel as PIs or Co-PIs. Even though respondents value the expert knowledge site personnel provide, they worry about using site personnel as PIs or Co-PIs. They believe some EE researchers do it simply as a means to increase their chances for funding and research project success rather than intellectual stimulation.

> I think it would be helpful if there were somebody that was an expert at this type of testing and somebody who had inherent knowledge of … detailed knowledge of the site. But at the same time I'm also opposed to that model of let's put… yeah….let's take all the earthquake engineering research money and fund it knowing that it all has to go through or involve these 15 equipment sites. The general idea was the community at large could use, could do research and you wouldn't have to involve these 15 equipment sites as PIs or Co-PIs.

Another respondent wants to see more interdisciplinary collaborations for small group research projects. The respondent thinks current small group NEESR projects rely too heavily on people within the same discipline and/or university.

> […] I would like to see a much more sophisticated integration of disciplines within civil engineering so the geotech guys, the structure guys, all those guys, people working together. […] Most of the projects have groups of people who are of their own kind, two structural engineers […] Many NEES projects are three of us in this university and nominal partner here. If you look at the…just print the names of the PIs, look pretty hard, and you'll see that.

Survey findings support the respondents view about existing research collaborations (Table 4). Although 54.7% of respondents agree or strongly agree that their research opportunities have expanded since being affiliated with NEES, most of the opportunities seem to be within rather than outside of their area of expertise. Fifty-nine percent of survey respondents agree or strongly agree that their research has benefited from collaboration with researchers within their area of expertise (e.g. structural engineering, geotechnical engineering, tsunami research, etc.). In contrast, only 39.3% agree or strongly agree that their research has benefited from collaboration with researchers outside of their area of expertise (e.g. structural engineering, geotechnical engineering, tsunami research, etc.). Survey findings also indicate that 82.9% of respondents plan to participate in NEES related activities over the next 1-3 years, so shifting the kinds of collaborations they engage in over time may be helpful.

In sum, findings indicate that EE researchers' affiliation with NEES and NEESR funding has spurred collaborations, but there is some concern about the type of collaborations being formed. With the exception of the grand challenge projects, respondents feel research collaborations tend

to occur among researchers within the same discipline. Some interview respondents question the validity of NEESR collaborations that involve site personnel, thinking that they may be used to increase funding success rather than intellectual stimulation.

Table 4. NEES Impact

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Since I have been affiliated with NEES, the nature of my research has improved through interaction with practicing engineers and other professionals interested in mitigating seismic risks.	6.8%	35.9%	35.0%	17.1%	5.1%
Since I have been affiliated with NEES, my research has benefited from collaboration with researchers *within my area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research, etc.).	12.0%	47.0%	30.8%	6.8%	3.4%
Since I have been affiliated with NEES, my research has benefited from collaboration with researchers *outside of my area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research, etc.).	8.5%	30.8%	32.5%	23.9%	4.3%
My research opportunities have expanded since I have been affiliated with NEES.	13.7%	41.0%	28.2%	13.7%	3.4%
I plan to participate in NEES related activities over the next 1-3 years.	41.0%	41.9%	14.5%	1.7%	0.9%

4.2.2 NEESR Research Impact

Equipment site capabilities have improved and NEESR project collaborations have increased. Yet, interview respondents say that the number of transformative research projects is limited. From their perspective several of the individual investigator and small group NEESR projects to date are not challenging the capabilities of the equipment sites.

> […] the projects that are being funded are very traditional and it seems like the full capabilities of the sites are not being challenged by those projects.

Several EE researchers do not see these NEESR projects offering anything fundamentally new.

> No one can do nicer tests [than the NEES labs], they are fairly sophisticated, but I'm not learning anything beyond what I already know from here [my home institution and its equipment site].

According to one respondent who works at a site, the individual investigator and small group NEESR projects that are being funded are "small increments in the right direction", but "they're going to have an impact that a regular NSF project would have" prior to the existence of NEES. Survey findings indicate that less than half of the respondents (43.6%) agree or strongly agree that the current portfolio of NEESR projects represents the cutting edge research NEES equipment sites are meant to encourage (Table 5).

Table 5. Perception of Current Portfolio of NEESR Projects

Question Stem: Please indicate your level of agreement with the following statements	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Don't Know**
The current portfolio of NEES research projects represents the cutting edge research NEES equipment facilities were built to encourage.	3.4%	40.2%	33.3%	10.3%	7.7%	5.1%

Two major reasons emerge to explain why some NEESR projects are not viewed as transformative. First, interview respondents think it is too early for NEESR projects to have a transformative impact. At the time of these interviews, NEES was only in its third year of operation and the smallest individual investigator projects take 3 years to complete. Second, several respondents say that there is no research vision to guide proposal writing and review. Without a research vision they see little opportunity to write and award a set of proposals that innovatively and integratively address pressing problems in the EE community.

It is too early for NEESR impact

Some EE researchers and members of NEES management think it is too early to talk about impact. Respondents point to several proof of concept tests that have been done to demonstrate NEES capabilities in its early years of operation. For example, some NEESR projects have tested the collaborative aspects of the NEES infrastructure.

> It's too early to say anything about impact of NEES. I think not directed to my project … my project is more or less … it was just an implementation and collaboration for the sake of trying to see if this is working. So it wasn't for making an impact on that part. But I am aware again from the projects that have been done here and the few projects that have been done other places they were unique experiments and unique type of outcomes that were never developed in anyplace else. Absolutely [there will be future impacts] but it's not yet something that NEES can say today that they have already made an impact.

One respondent warns that some EE researchers view these kinds of proof of concept tests as technological novelties rather than real research discoveries that result in better science. The respondent takes multi-site hybrid testing as an example. He is impressed by the demonstration, but wonders whether the test results contribute to research, especially in cases when the same test could have been conducted using one site rather than multiple ones.

> The multi-site hybrid [simulation] is the classic example that they couldn't do that beforehand and they can now – that's big. Now are they learning anything new because of it is something else and that question has been posed by more than one person.

Another reason why respondents think it is too early to ask about the impact of NEESR projects is that they are just nearing completion. Findings from the grand challenge projects are the most anticipated, but those projects are not finished yet.

> I think the successes for the field are still in [development] and I'm going to say that because I want to remind you that the first NEESR projects aren't done yet. The simplest [single investigator project is] a three year project […] And normally people are a year over. The bigger [grand challenge] projects, the ones that are more likely to have bigger impact are five year projects and they were not awarded in the first year so it was awarded in the second year so it will be, two or three years down the road before the findings for the community are coming out the other end of the research pipeline.

Another respondent believes that the impact will come from the NEESR data rather than the findings. The data management, sharing, and reuse initiative is seen as the primary means to transform EE research and practice, but the data are not yet available.

> I think the way to transform research is through the data repository, is through the knowledge sharing and specifically we haven't had time to focus on this but the ultimate goal is to get research into practice much faster than it currently is. By making the data available […] by giving them [the practicing engineers] data and having them easily see information that's interesting to them relevant to the type of structure they're building or whatever […] so I think that's where the big win could be. It's just we're still…if you think about it yes we're three years into operations but we're still in our infancy mode of actually getting data published and getting it out there.

In sum, findings indicate that it may be too early to expect to see the impact of NEESR projects. In the early years of operation, proof of concept tests have demonstrated the technical capabilities of NEES, which is important. The grand challenge projects represent forward thinking research that has created excitement among EE researchers, but they are not finished yet. The data repository is seen as a way to transform EE research into practice, but the data has not been made available yet.

<u>There is no research vision guiding NEESR research investments</u>

The absence of a clear research vision to guide NEESR proposal preparation and funding is the second issue. Some believe that the lack of vision has led to proposal submissions and awards for individual investigator and small group research that is not offering anything fundamentally new. For example, several respondents blame the review panels for the limited number of forward thinking projects and think NSF needs to do a better job instructing panel members.

> NSF's mission is to fund fundamental research, but when someone proposes innovating ideas, the panel is very critical [about the likelihood of success]. There's a saying, NSF funds research that has already been done. Those make very well written proposals. The solution is that NSF needs to take the lead and clearly say that they want to fund really innovative research—tell the panel. Push them to think more carefully about what they're funding.

Even if NSF review panels are instructed to fund more innovative, forward thinking projects that would only solve part of the problem. Several respondents working on NEES management issues say that the lack of strategic, integrative thinking that results in a well articulated research vision is the real hindrance.

> If you say that you're going to build 15 large equipment sites to do large scale experiments people come up with great large scale experiments to do but if they're supposed to be integrated in some way and achieving this vision that people set forth almost 10 years…or maybe more than 10 years ago for NEES there has to be something strategic in terms of making that a priority or making that happen.

NEESR project investments produce large scale experiments that are more complex, complete, and real. This is a step forward, but findings indicate that the sum of all the NEESR projects may not necessarily be greater than the whole portfolio, because there is a lack of synergy between projects. According to one respondent the lack of a research vision leads EE researchers to think about their personal short term gains rather than the EE community's long term gains when it comes to research and funding.

> I think many researchers view this [NEES and NEESR funding] as just another pot of money that they can tap into for the duration that it's available, but they're not getting the big picture.

The limited amount of research funding is an issue that has been raised in the interview and survey findings. Some respondents see the limited "pot of money" as more reason to have a research vision that guides proposal preparation and review. From one respondent's perspective, the limited money should be targeted to address a specific research agenda that is important to the EE researchers.

> I think they've [the EE researchers have] got to have a vision though so that when, assuming that the funds are sparse, the funds are limited in terms of what kinds of research projects can be done there's a lot of concern about solving the right problems. If you've got 10 million dollars and you're going to spend, you've got to spend it on the right stuff. And the approach now is that everything gets reviewed so you could have 25 projects in reinforced concrete that might come in and they might all be great and the steel guys could come out with 25 projects and write them poorly which would mean there would be a predominance of concrete getting funded and yet the steel problems maybe the more important so there's a real systematic problem there that ideally the community could offer some guidance that those doing proposals to say hey here are the research needs guys, don't be looking at some of these other things that really aren't important.

Others respondents note that the agenda needs to speak to the needs of researchers as well as practitioners, policy makers, and society at large. According to one respondent it is not only about convening panels to set national policies every 5 years. It is also important for EE researchers to describe the impact their research has on society in ways that speak to the needs of

their stakeholders. Short of another big earthquake, the respondent says that EE researchers need a better way of bringing the risks into focus. He suggests a more proactive approach focused on what could happen as a result of an earthquake and what needs to be done to prevent it rather than what happens as a result.

> identifying what is risky, developing a proposed plan, approaching the politicians, money givers, the people who vote for bonds in a sensible way, if say a bond proposition was supported not only by a few pieces of paper but also by a computer model of what could happen or an experimental computer model or an experimentally done model with the equipment that we have, I think it would make a stronger impact. In some sense it needs a Discovery Channel type of commercial […].

Survey findings also indicate room for improvement. When asked about the benefits of their affiliation with NEES, only 42.7% of survey respondents agree or strongly agree that the nature of their research had improved through interaction with practicing engineers and other professionals interested in mitigating seismic risks; 35% are neutral (Table 4).

In sum, findings indicate that many of the NEESR projects may not have a transformative impact. Some respondents believe this is due to conservative NSF review panels, whereas others think that the absence of a research vision is the real problem. Without such a vision, NEESR submissions and awards are not addressing a specific set of problems important to the EE community. Given the limited amount of funding available for research, some respondents feel that a guiding vision is critical.

4.2.3 Implications for NEESR Research

The installation of new and upgraded technology at equipment sites is not enough to transform EE research. In order to have a transformative effect, findings indicate that NEES needs not only more time, but also a research vision. NEES was created to transform EE research. A vision has been articulated with respect to how EE researchers should work. For example, EE researchers are expected to aspire to more interdisciplinary research collaboration and increased data sharing and reuse. However, the vision does not describe what research questions EE researchers should aspire to answer given these new ways of working. In other words, what are the pressing problems that the EE community must confront in the next 3-5 years and how can NEES help the EE community achieve them. In the absence of clear and compelling reasons why NEES exists and what it can do to help its major stakeholders, it runs the risk of missing the opportunity to challenge, innovate, and excite research, teaching, and practice.

A well crafted research vision can become part of the fabric of NEES that gets woven into everything NEES participants say and do. For EE researchers, it may be a powerful rallying point that helps them coordinate their work. It may allow them to convene around a core set of EE issues regardless of whether they are individual investigator, small group, or grand challenge projects. The vision may also serve to calibrate review panels by signaling the kinds of research that is valued. For NEES, the vision may serve to outline future research possibilities given the capabilities of the state of the art equipment and information and communication technology that is now available for use. What may have seemed like an innovative project 5-10 years ago may be less so now given capabilities and skills of the site equipment and staff respectively. The

research vision may also be used to take account of the needs of major stakeholders who are less interested in the technology than what the technology can do for them. In other words, the research vision can serve to describe what the technology can do for them in practical, concrete terms that speak to their needs (e.g. dollars, death, and destruction). Appealing to the needs of stakeholders in this way may also serve to open the door to future funding opportunities. In short, implementing technology advances that support new ways of working is not enough. There is a need to articulate a vision that describes the kinds of problems that can be posed and solved in research, teaching, and practice in light of the technological advances.

4.3 Data Management, Sharing, and Reuse

Interview and survey findings indicate that the initiative to mange, share, and reuse experimental data produced during NEESR projects is one of the most anticipated undertakings.

> I think that if the true vision of the repository comes where it's searchable and easily accessible I think it will be the best part of NEES.

Approximately 68% of survey respondents say their recent research has used data collected by people working independently of them (Table 6). Approximately 93% of the survey respondents report that they would be most likely to reuse someone else's experimental data. If data were currently available in a shared repository for reuse, 63.6% of respondents say that they would be more than 50% likely to reuse the data in the next 12 months (Figure 3).

Lastly, survey respondents see several benefits to reusing someone else's data (Table 7).

- 92.3% agree or strongly agree that reusing someone else's data provides opportunities to conduct a broader range of research
- 85.5% agree or strongly agree that reusing someone else's data costs less than collecting new data
- 72.6% agree or strongly agree that reusing someone else's data takes less time than collecting new data
- 66.7% agree or strongly agree that reusing someone else's data takes less effort than collecting new data
- 55.5% agree or strongly agree that reusing someone else's data provides opportunities for novel research

Table 6. Percent of Respondents Whose Recent Research Uses Data from the Following Sources

Data collected by you alone	88.0%
Data collected by you and one or more collaborators	76.1%
Data collected by people working independently of you	68.4%

Figure 3. Likelihood Respondents Would Use a Shared Data Repository to Access Someone Else's Data in the Next 12 months

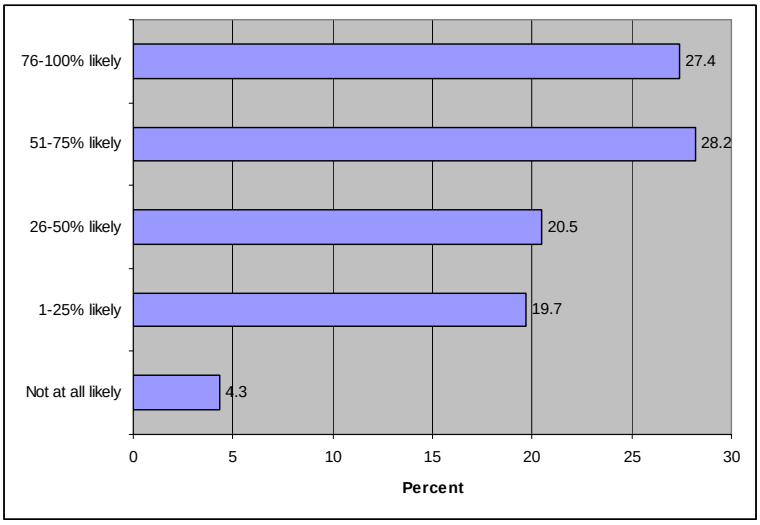


Table 7. Benefits of Data Reuse

Question Stem: Please indicate the extent to which you agree with the following statements.	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Reusing someone else's data costs less than collecting new data.	47.9%	37.6%	8.5%	6.0%	0.0%
Reusing someone else's data provides opportunities to conduct a broader range of research.	40.2%	52.1%	5.1%	2.6%	0.0%
Reusing someone else's data takes less time than collecting new data.	35.0%	37.6%	18.8%	8.5%	0.0%
Reusing someone else's data provides opportunities for novel research.	20.5%	35.0%	34.2%	9.4%	0.9%
Reusing someone else's data takes less effort than collecting new data.	24.8%	41.9%	26.5%	6.8%	0.0%

At the time of the interviews, several experiments were at or near completion. Data were being curated, but no data were available to the public for reuse. Both NEES personnel and NEESR researchers have been focused on uploading and documenting data from NEESR projects. Findings indicate that the primary challenge with this undertaking is managing the EE researchers' transition from personal, local data management, sharing, and reuse practices to community-wide, global data management, sharing, and reuse practices. Prior to using NEESCentral to store data, NEESR researchers have stored their data and documentation locally on hard drives and file servers, along with several backup copies. EE researchers who do not have NEESR awards still work this way. The personal data management practices are informal. There are no formal data retention policies, standard documentation procedures, or standard data formats. The transition from data management, sharing, and reuse practices that are personal and local to those that are community-wide and global is especially acute for the NEESR researchers, because it has prompted changes in how they capture, care for, and document data stored in NEESCentral.

4.3.1 Data Uploads

Currently each NEES equipment site has a data acquisition system to capture the data produced during NEESR projects. Captured data are then uploaded to NEESCentral. Reactions to uploading data to NEESCentral are mixed. There are some NEESR researchers who immediately upload data to NEESCentral to share with collaborators. Most others seem to delay uploading data to NEESCentral, opting to email data and reports to collaborators instead. Several site personnel mention that NEESR researchers are reluctant to upload their data because they are afraid of getting scooped.

> […] PIs are naturally reluctant to publish things until they get their final report done because they don't want someone else picking up stuff without them getting the credit for it […].

Other respondents are less concerned with this issue, since NEESR researchers agree in advance to publish their data in exchange for NSF funding. Moreover, NEESR researchers express few reservations about sharing their data with others. Most of the EE researchers that were interviewed have shared their data in the past. Those using NEESCentral view it as a safe, centralized place to store their data.

> With NEES, [the very large text file], it's stored in a safe place on NEESCentral. Instead of emailing or sending hard drives back and forth, everyone can access it from that one location, which is kind of nice compared to the way it was earlier.

Findings indicate that it is more likely that the different reactions to uploading data to NEESCentral are due to NEESR researchers' experiences with and expectations about the upload process. For example, one respondent explains that the first upload is difficult, but subsequent uploads are easier once the metadata files are set up, because the tests for the project are very similar.

> I guess, usually, at the beginning everything is more difficult because you need to learn new ways to process data or new tools. But [with this NEESR project] it has been very systematic. It was really difficult for the first test we did in the project, but then when we had that, now it's really easy because all the tests are really similar. The location of the sensors changed a little bit, but then we have all the metadata files ready to use so it's easy now.

Similarly, another NEESR researcher does not have trouble getting data into NEESCentral. However, he does have trouble getting his data back out. He and several NEESR researchers discuss problems with the NEESCentral interfaces. Although he has begun to find his way around, he thinks it will be impossible for someone not involved with his project to do the same.

> …getting data into the repository [NEESCentral] is not hard. Getting anything back out is hard for me as the owner of that data and at this stage I would say next to impossible for a conventional user. […] For example, I know where all my data resides and what format my data is on. A stranger wouldn't know that from anything. […] for example if I look at a diagram for my test specimen and there's a certain instrument that I'm interested in

> looking at what the data was, it takes me several steps to go from that diagram to the data. Lots of clicks in other words. Now I'm beginning to get a feel for the system so I sort of know what the clicks are but a regular user wouldn't know that and there's very little guidance. And I guess what I would say is the IT tools that are there are not very intuitive.

Several NEESR researchers avoid uploading data to NEESCentral for a year or more after the data are produced for similar reasons. For example, staff at one equipment site typically work closely with NEESR researchers to upload the data, because the system is hard to figure out.

> The PIs do it [upload the data] but I have a staff member [at the equipment site] that is actively involved and helps significantly with the researchers trying to do that because I don't think any researcher could figure that out on their own. […] I would say a year plus after the data is gathered [the PIs are getting back in touch with us to get help uploading their data to NEESCentral].

NEESR researchers also avoid uploading data to NEESCentral because the process is time and labor intensive. One NEESR researcher explains why he and his collaborators rely on their old way of doing things.

> But I think one thing is just finding the time. When we create large enough data it just seems like an extra effort to actually upload the information. I think going along with that in order to document what that file is or what that information is also requires a lot of effort on our part in order to really make it understandable for the next person to look at the information. […] So creating the metadata for each file is part of the extra effort. Another thing is maybe several revisions. Maybe [I] create a file and I'm going to modify it or go through several revisions I don't want to have to go and upload each version multiple times so I think that's probably something that keeps me from uploading files. […].

The respondent notes that there are some NEESR researchers who are still storing their data on separate databases at each of their universities and emailing data files and reports back and forth, rather than uploading everything to NEESCentral to share. NEES management agrees that poorly designed interfaces and labor intensive data uploads have limited NEESR researchers' use of NEESCentral. Interview findings suggest that NEESit has begun to address some of these issues. One example is moving from manual to more automated data uploads.

> In other words they [the NEESR researchers] don't use NEESCentral to the fullest extent. The reason being they complain it's too much work – they have to go to web page after web page to put stuff in – so NEESit is talking about things like using spreadsheets to sort of expedite data uploading and stuff like that so we'll see what works out.
>
> We should be there [at a point where things are up and humming] within a year. […NEESit] is working hard for more animated

> means [to upload and archive data]. When the sites are all uploading data automatically, that will help a lot.

In short, some NEESR researchers upload their data as soon as it is produced to share it with their collaborators. Typically, they have difficulty at first, but find it easier to do when their tests are similar. However this is not true for the majority of NEESR researchers. Many have difficulties and attribute the difficulties to poorly designed interfaces and time and labor intensive data uploads.

4.3.2 Documentation Requirements

Even if NEESit has to begun to address issues related to data uploads, NEESR researchers also have problems adjusting to the amount of documentation requirements. Several of the NEESR researchers use the word "more" to describe their experience documenting NEESR data.

> Normally, I would not have organized and kept everything. [Because of obligations with NEES] we had to keep data I wouldn't usually keep. Usually, I'd use my judgment and say, no set this aside. Usually a student has drawings in a thesis of where instruments were during the test, and that's it [for documenting that information]. Due to NEES contractual obligations, we documented more carefully. It took a graduate student about 1-1 ½ months full time just to document the data.

Specifically EE researchers say they spend "more" time on documentation, not only because they have to be "more" careful how they document data, but also because they have to provide "more" data and documentation about the NEESR project. Several respondents think that the amount of documentation required is excessive.

> Sufficient is when metadata is descriptive. When I write a word, rather than fill out 10 forms. We need to get it brief and put it in one time. Each one of these ten forms has a lot more information, and does not really apply to what I want to preserve.

There is a general feeling among NEESR researchers that they are creating more documentation than necessary, particularly descriptions that do not apply to their research objectives. The additional documentation requirements are expected to make NEESR data more readily reusable for everyone within the EE community. However, some NEESR researchers question the soundness of this goal. One respondent thinks that reduced and repackaged data, not raw data may be better for community members whose interest is something other than research.

> For example, [someone] is writing a book on [an earthquake engineering topic], typically taught in the first or second year; she's using some of our data so these students now will have it in their textbook. Will they go to the NEES site to look at it? I doubt it. But the possibility exists for a much lower level user to be accessing the data.

Drawing from the existing way EE researchers capture and document data for their personal use, another respondent believes the primary purpose of documentation should be to support NEESR

researcher objectives. He reasons that attempting to document data in a way that accommodates all members in the EE community is too difficult.

> NEESCentral tried to make it very…anybody can look at the data and go through it, but this goal is very difficult to achieve. I think the researchers should put the data the way they look at it and the second person that's not able to look at it…they're probably not supposed to look at the data.

However, findings also indicate that providing documentation that supports NEESR researchers' objectives may not be enough to support others' reuse of that data, even when the others are EE researchers with similar backgrounds. According to one respondent, there are times when an EE researcher's documentation is good, but not sufficient for someone else's particular needs. Sometimes the subtleties of an experiment are not documented, in part because they are not of interest to the experimentalist who produces the data.

> The documentation alone may not be sufficient. Because the documentation might be like I said in the beginning it will be time histories and where they put the instruments but I'm asking more detailed questions of how they put together their samples on the soil…they put it in there but I needed to know more information about it.

Similarly, one respondent notes the difficulty NEESR researchers are having documenting their data for reuse by others.

> From a data provider perspective, I think they're all struggling about how much information is…how much metadata is needed.

It is difficult for NEESR researchers to determine what to document beyond that which is important to their research objectives, in part because it is beyond how they typically care for data for their own use. Moreover, there is little guidance about documentation beyond sensor placement and test procedures. According to one respondent, those involved with NEES have not yet reached consensus about the documentation requirements.

> […] we have since the inception of NEES went through 3 or 4 cycles of trying to get there and we haven't been able to do that as a community. In terms of having people document it [the data] in a useful way. […] we the researchers need to kind of sort of convene in the sense and we need to be able to describe not only what the test is but what are boundary conditions of that test are. What are the applicability provisions?

Interestingly, findings indicate that an examination of existing data reuse practices may be a useful way to begin developing documentation guidelines. Approximately 63% of survey respondents report that they are most likely to reuse someone else's data to develop and validate computational models or tools (Table 8). Both interview and survey respondents rely heavily on the personal documentation their colleagues create. Interview findings indicate that the experimentalist's personal documentation is critical, because it provides more information than what is found in a journal article. Survey respondents agree. Approximately 82% report that

access to additional documentation about the data, besides what appeared in a peer-reviewed paper was important or very important (Table 9).

Table 8. Most Likely Purpose for Reusing Someone Else's Data

Question Stem: Please select the purpose for which you would be most likely to reuse someone else's data.	
Develop and validate computational models or tools	63.2%
Look at general trends across multiple studies	11.1%
Provide resources for pedagogical purposes (i.e. education, outreach, training)	4.3%
Enhance your own data population	7.7%
Encourage its use in policy formation and evaluation	2.6%
Verify, refute, or refine original results	8.5%
Other	2.6%

Table 9. Data Reuse Considerations

Question Stem: When considering whether to reuse someone else's data, please indicate how important it is to you to…	**Very Important**	**Important**	**Somewhat Important**	**Not Very Important**	**Not At All Important**
have worked with the person before.	12.0%	21.4%	29.9%	24.8%	12.0%
see the data referenced in a peer-reviewed paper (i.e. conference, journal)	21.4%	42.7%	28.2%	6.8%	0.9%
access additional documentation about the data, besides what appears in a peer-reviewed paper (i.e. conference, journal).	47.9%	34.2%	12.8%	4.3%	0.9%
have used similar equipment when conducting your own research.	3.4%	17.9%	36.8%	29.9%	12.0%
be familiar with the person's prior research.	11.1%	28.2%	41.0%	17.1%	2.6%
be familiar with the location (e.g. laboratory, field) where the data were collected.	4.3%	22.2%	33.3%	29.1%	11.1%
find an expert who can help you interpret the data.	8.5%	29.9%	24.8%	27.4%	9.4%
have the person be well known in the field.	6.0%	22.2%	39.3%	23.1%	9.4%
have access to detailed descriptions of how the data were collected (i.e. experimental setup, materials, instrumentation and calibration).	63.2%	26.5%	5.1%	4.3%	0.9%
have prior experience collecting similar data.	10.3%	27.4%	38.5%	18.8%	5.1%
have someone from the data collection team available to answer your questions.	22.2%	35.0%	24.8%	15.4%	2.6%
have the limitations of the data be clearly described (i.e. bad sensors, equipment limitations or malfunctions).	59.0%	29.9%	7.7%	2.6%	0.9%
have colleagues to talk to about the data.	19.7%	29.9%	30.8%	16.2%	3.4%

The personal documentation one creates during the course of a research project can span hundreds of pages and range from basic metadata information such as test set up and type, location, and orientation of instruments (i.e. sensors) to more complex, multilayered explanations of the systems that collect the data. One respondent describes why the location and direction of

the sensors as well as the parameters of the data acquisition system help him understand the limitations of the data (i.e. what can vs. cannot be done with the data).

> Going back to the location of the sensors — that is a key component that has to be addressed. And also, the direction in which the sensor is oriented. From there, how the data is collected is also very important. Sensors are connected to data acquisition systems, and they have parameters, such as frequency (number of data points per second), length of the recording (is each going to be 1 min, 30 seconds), there are filters you can apply to the data, so knowing whether or not they've applied a filter, the number of beats of the system as well. In some cases, you can judge the quality of data for the study you're trying to do based on these parameters. Depending on these, you might be able to do some things, and not other things.

Survey respondents agree that limitations about the data are important to know. Having the data limitations clearly described is important or very important to approximately 89% of the survey respondents (Table 9). Interview respondents say that the assumptions data producers make over the course of the experiment as well as the experimental errors, error resolutions, and resolution rationales are also important.

> [We are] very dependent on the person who ran the test and the assumptions they made about what was important and that they were correct.

Therefore, EE researchers seeking data for reuse want documentation that provides a clear and detailed account of the experimentalist's assumptions and the rationale behind them. Survey respondents agree that these kinds of details are important. Approximately 90% report that access to detailed descriptions of how data are collected is important or very important (Table 9). One respondent explains the problem he encounters trying to get his simulation models to line up with experimental results when these kinds of details are not well documented.

> For example, sometimes we may want to push on a beam and measure the deformation. But sometimes what happens is people might not monitor the deformation of the supports of the beams. So the deformations that they're reporting might be the total deformations, including the deformations that are added on from the supports of the beams. If you don't know something like this, analyzing or interpreting that data effectively becomes a big challenge. Because you don't get your simulation models to line up and that sort of stuff. What's really important is to have a very well defined, very well described, test setup and what exactly that it is we are looking at when we're looking at the data.

There are also occasions when data have to be rejected because the documentation is missing key information. For example, having documentation that does not identify and explain how an error occurs or is corrected during an experiment is cause for rejecting the data for one respondent.

> there were some walls I looked at where they didn't anchor the base to the test floor well enough so they had a lot of rotation. So, I had a choice: I'd either have to correct for the rotation or not use the test; I chose to discard that data [because] I didn't have enough information and it hadn't been tested properly.

In short, EE researchers are used to documenting data locally for their personal use rather than globally for EE community use. With the transition from personal to community-wide data management, sharing, and reuse practices, NEESR researchers are expected to provide more documentation than they create for themselves. However there are no guidelines explaining what additional information should be included. NEESR researchers have had difficulty reconciling their vs. the EE community's documentation needs as a result. Examining existing data management and reuse practices among EE researchers is one way to begin to delineate documentation procedures.

4.3.3 Implications for Data Management, Sharing, and Reuse

To date, the primary challenge of the data management, sharing, and reuse initiative is not an unwillingness to share and/or reuse data. Rather it is the data management process. More specifically findings suggest that uploading and documenting data is burdensome due to lack of automated tools and guidelines. With the transition from personal, local data practices to community-wide, global ones NEESR researchers are expected to change the way they capture, care for, and document their data. They are expected to capture and document "more" data and care for it "more" carefully. Yet no guidelines explain what the "more" constitutes or how they should go about doing things differently. As a result, NEESR researchers remain uncertain about what they should document beyond that which supports their research objectives. This finding confirms prior research which suggests that documenting for others is one of the most difficult parts of sharing and reuse (Markus, 2001). Part of the challenge is defining what is needed to meet some future, yet unknown objectives of data consumers.

Having a better understanding of the existing data documentation practices may be a good starting point for developing documentation guidelines. For NEES this implies capturing data and setting documentation guidelines as they relate to the NEESR researcher's objectives. It is not ideal, because details not meeting the NEESR researcher's objectives get left out, but it is a start. A more detailed understanding of how EE researchers produce and consume data should follow. A user centered approach to contextual design may be useful (Beyer & Holtzblatt, 1998). For example, understanding how EE researchers produce and manage data for their own use will facilitate documentation guidelines as well as the development of automated tools and interfaces that support their work. Similarly a detailed understanding of how data consumers go about reusing others' data will clarify their needs for automated tools that support reuse and a set of documentation guidelines that will help them during reuse. The objective of this approach is to design a data management, sharing, and reuse solution that makes EE researchers' work the focus of the design. To be successful, the approach must consider both ends of the data lifecycle that support the work of producers and consumers.

4.4 Development and Use of NEESit Software and Services

As the primary provider of software and services, NEESit has a large role in the successful operation of NEES. The interviews and survey were used to learn more. The interviews focused

on EE researchers' use of software and services during their research work. Interview respondents describe two broad categories of software and services use: 1) collaboration at a distance and 2) analytic work. In contrast, the survey focused on the extent to which EE researchers valued existing NEES technical capabilities rather than the NEESit software and services that support them. For example rather than ask about the value of the particular remote data viewer to EE researchers' work, survey respondents were asked about the value of viewing historical sensor data with synchronized video images. The survey design choice was based on interview findings that show the value of NEES technical capabilities did not translate to the use of the NEESit software and services provided to support them. Survey findings also indicate that EE researchers value some of the NEES technical capabilities more than others.

4.4.1 Collaboration at a distance

Approximately 80% of survey respondents indicate that collaborating with others who are physically distance is valuable or very valuable to their research work (Table 10). Interview respondents report using WebEx, a 3rd party product NEESit provides. WebEx tends to be used for basic teleconferencing and file transfers during weekly research team meetings, especially during the planning stages of a research project.

> On the IT side – one thing I use all the time is WebEx for meetings.
>
> There is one service provided by NEESit, WebEx, it's a third party product, very good function.
>
> In terms of NEESit, we use WebEx […].

Although respondents who report using WebEx are satisfied, other respondents do not see a need to use it. These other respondents opt for the telephone, email, and FTP instead.

> I've used WebEx, but not to a great extent. I think a telephone is a pretty sufficient means of communication. So just a telephone, and emailing, sending files back and forth on an FTP site.

Approximately 76% of survey respondents report that organizing and sharing data for reuse in other research studies is valuable or very valuable to their research work (Table 10). As reported earlier, some interview respondents report using NEESCentral to store and share documents and data with collaborators during NEESR projects. When compared with the other ways documents and data have been stored and shared in the past they see NEESCentral as a better alternative.

> NEESCentral has been very good as far as providing a home for our documents—our reports and meeting minutes […].

However attitudes toward NEESCentral are mixed. Some interview respondents have continued to email documents and data back and forth with their collaborators. Uploading and documenting data for NEESCentral is viewed as time and labor intensive.

Survey respondents do not place much value on the capability to view experiments at a distance (Table 10). Only 34.2% of survey respondents report viewing active experiments occurring at NEES equipment sites as valuable or very valuable to their research work. Similarly, only 30.8% of survey respondents think controlling video cameras while viewing active experiments occurring at NEES equipment sites is valuable or very valuable to their research work. In

addition, very few interview respondents report using the telepresence or teleoperation tools NEESit provides. Those who do use the tools, find them useful. For example one respondent reports that he uses the telepresence tool to see the progress of an experiment as well as check up on his Ph.D. student.

> I find telepresence useful to check on my PhD students… It's useful for me to see what the progress is…close to testing I'll check once a day to see if anything's wrong.

In short, interview and survey findings indicate that technical capabilities to support collaboration at a distance are important to EE researchers. However the use of existing NEESit software and services for this purpose is limited. Several EE researchers opt to use telephone, email, and FTP in lieu of WebEx and NEESCentral and few researchers use the telepresence and teleoperation tools.

Table 10. Value of NEES Technical Capabilities

Question Stem: Based on your needs for your research work, please rate how valuable the following capabilities are to you.	**Very Valuable**	**Valuable**	**Somewhat Valuable**	**Not Very Valuable**	**Not At All Valuable**	**Don't Know**
Organizing and sharing data for reuse in other research studies	31.6%	44.4%	12.8%	7.7%	0.9%	2.6%
Viewing real time, synchronized, streaming data from NEES equipment sites	12.0%	20.5%	29.9%	30.8%	5.1%	1.7%
Viewing historical sensor data with synchronized video images	20.5%	31.6%	29.1%	14.5%	1.7%	2.6%
Viewing active experiments occurring at NEES equipment sites	9.4%	24.8%	36.8%	23.1%	3.4%	2.6%
Controlling video cameras while viewing active experiments occurring at NEES equipment sites	9.4%	21.4%	29.1%	29.1%	8.5%	2.6%
Performing hybrid simulations	17.1%	20.5%	30.8%	13.7%	11.1%	6.8%
Running multi-site simulations across multiple NEES equipment sites	10.3%	16.2%	29.1%	19.7%	18.8%	6.0%
Performing high performance computing simulations	25.6%	35.0%	28.2%	6.8%	2.6%	1.7%
Simulating the performance of an entire system rather than individual components of the system	36.8%	37.6%	16.2%	3.4%	1.7%	4.3%
Collaborating with others who are physically distant.	30.8%	48.7%	16.2%	0.9%	1.7%	1.7%
Sharing software code with others in the earthquake engineering community	24.8%	43.6%	21.4%	4.3%	2.6%	3.4%

4.4.2 Analytic Work

For analytic work, EE researchers use homegrown (i.e. applications the respondents write themselves) and 3rd party software and tools to analyze their data more frequently than anything

NEESit offers. The 3rd party software EE researchers report using includes MATLAB, OpenFOAM, and tools from Remco, TeraScale, Abacus, and AMSES. Of these, MATLAB is mentioned most often.

> The most important tool we use is MATLAB.
>
> For most things I do I use MATLAB then I write programs within MATLAB for specific test applications.
>
> For analytical work, I primarily use MATLAB software.

Findings indicate that MATLAB or 3rd party software is often used in conjunction with homegrown applications. For example, one respondent uses 3rd party software to validate his work. The respondent also has invested 20 years into building a platform that he knows "inside and out."

> During this analytical work that I do, I am using primarily my homegrown, but also I use some commercial software to validate quickly some of the approaches I do.

Another respondent uses 3rd party software, but develops homegrown software when nothing on the market meets his needs or when he wants to find a better way to do something. Even when the respondent uses 3rd party applications, customizable software is preferred.

> We use homegrown stuff; or oftentimes it's more efficient to buy something that's already built, so we'll go out and buy that, but we want something that's customizable. For experiments we use a lot of homegrown things. For example, if I want to measure a certain shear strength for sediment transfer of soils. There isn't really a good piece of hardware to do that. It's research—you want to find a new or better way to do that.

One third party software NEES offers is OpenSees, but there are not many respondents who report using it. According to one OpenSees user, the software is not amenable to customizability, because its documentation is poor.

> The only reason to use OpenSees was that [the equipment site] required that the building model be programmed in OpenSees. Their hybrid tests were setup to use OpenSees.

In short, EE researchers value 3rd party or homegrown software for their analytic work more than anything NEESit offers. Findings indicate that this is because they have more freedom to customize it to meet their needs.

4.4.3 Additional NEES Capabilities

The following bulleted list highlights the extent to which survey respondents value additional NEES capabilities (Table 10) that interview respondents mention briefly, if at all.

- 74.4% of respondents think simulating the performance of an entire system rather than individual components of the system is valuable or very valuable
- 68.4% of respondents think sharing software code with others in the EE community is valuable or very valuable

- 60.6% of respondents think performing high performance computing simulations is valuable or very valuable
- 52.1% of respondents think viewing historical sensor data with synchronized video images is valuable or very valuable
- 37.6% of survey respondents think performing hybrid simulations is valuable or very valuable
- 32.5% of survey respondents think viewing real time, synchronized, streaming data from NEES equipment sites is valuable or very valuable
- 26.5% of survey respondents think that running multi-site simulations across multiple NEES equipment sites is valuable or very valuable

4.4.4 NEESit's Approach to IT Development

Findings indicate a difference between the value EE researchers place on NEES technical capabilities and the use of NEESit software and services that support them. First, EE researchers do not value all of the capabilities NEES offers. Second, the capabilities that EE researchers do value do not lead to the use of NEESit software and services that support them. The difference is attributed in part to the academic orientation of NEESit. According to some respondents, NEESit's academic approach to IT development results in broad statements of work, little communication and coordination with major stakeholders to understand their needs, and a focus on long-term goals to the exclusion of more immediate needs. Several respondents express their and others' frustration about NEESit's progress to date.

> […] I've heard enough people complaining and there's just a real serious frustration in terms of the users, but probably a greater sense from the sites in terms of what they can't do.

One respondent thinks progress is limited by the broad definitions of work NEESit is able to propose and get funded. According to the respondent they make NEESit less not more accountable for progress on key deliverables important to the EE community.

> They had a real broad stroke statement of work which had all verbs and no nouns, you can't deliver a verb but they're used to doing research – in a university environment where they propose wishy washy gray area stuff and they do get funded, they get a grant, and they work under a grant environment. NEESit by and large should be a product development company, service oriented but really a product development company. Because they're housed at a university, they think like a university.

According to several respondents there is a fundamental difference between the EE community and NEESit's computer scientists when it comes to ways of thinking and speaking about NEES technical capabilities. According to one respondent the difference reduces rather than increases interaction between the two groups.

> […] it's also a matter of expertise…if people at an equipment site are all earthquake engineers they're not that familiar with the IT side. And the IT people aren't that familiar with the earthquake

> engineering side typically. So there's not as much interaction between those two groups as there should be probably.

Another respondent describes the gap between the EE community's needs and NEESit's aspirations. NEESit is described as being focused on long-term development efforts to showcase advanced CI capabilities. In contrast, the EE community is described as having some low level needs that can be met relatively quickly. The respondent equates the difference to EE researchers being promised a Porsche sometime in the future, when what they really need is a Chevy pickup today.

> And the other thing is the engineering users have got very low level needs. The Chevy pickup truck level needs and the IT guys because they're on a NSF funded operation and they have expectation…NSF does as well as the computer science guys, they're provided a Porsche okay. So there's a mismatch in terms of what the IT guys feel that they're mission is versus the using community.

According to another respondent, NEESit is used to setting its own direction and working at its own pace, which makes it difficult for the EE community to communicate and coordinate with NEESit.

> […] how do we get better coordination, better cooperation, for example in the IT area in particular where we have a super computer center that's used to doing things they want to…setting their own pace, setting their own direction, they don't understand the value to finding a work plan that has to be approved by somebody else. That kind of thing. There's some cultural things with working in an academic environment that isn't used to trying to be a coordinated whole […].

The limited communication and coordination between NEESit personnel and major NEES stakeholders may result in software and services being designed and developed in absence of a clear understanding of EE community needs.

> I think there's been all along there's been a little bit of a disconnect between let's say the researchers and some of the people at NEESit or some of the other things at headquarters as to what the researchers need and what's maybe being generated by some of these other people. I know that the IT group in particular has had a tough time getting started. Quite a bit of money has been expended in those areas and I'm not sure that they've really necessarily developed what the users are looking for.

In short, the value of a NEES technical capability does not translate to using the NEESit software and services developed to support it. In other instances, some of the NEES technical capabilities are not valued very highly. Findings indicate that this is partly due to the academic approach NEESit takes to designing and developing software and services. The approach results in broad statements of work that focus on long term goals and limits communication and coordination with the EE community as a means to understand its needs.

4.4.5 Implications for NEESit Software and Services

Highly valuing NEES capabilities does not lead EE researchers to using NEESit software and services that have been developed to support them. For some of the highly valued NEES capabilities, EE researchers are using technologies that already exist (e.g. telephone, email, FTP) and continue using existing technologies rather than adopt the NEESit alternative (e.g. WebEx, NEESCentral). In these instances, it may be that EE researchers need to be motivated to switch from an existing to a new technology. Research on technology adoption found that users often assess the characteristics of technologies in order to determine whether to adopt them (e.g. Moore & Benbasat, 1991; Venkatesh, Morris, Davis, & Davis, 2003). In research on the diffusion of innovation, Rodgers (2003) presents five characteristics people assess when contemplating whether to adopt innovations (e.g. new technologies) over something that already exists.

- Relative advantage is the degree to which a technology is perceived to be better than the one it supersedes.
- Compatibility is the degree to which a technology is perceived as consistent with the existing values, past experiences, and needs of potential adopters.
- Complexity is the degree to which a technology is perceived as difficult to understand and use.
- Trialability is the degree to which technology may be experimented with on a limited basis.
- Observability is the degree to which the results of a technology are visible to others.

These characteristics can be used to explain the limited adoption of some of the NEESit software and services. For example, some of the EE researchers may not see the relative advantage of WebEx. The telephone, email and FTP seem just as good. For analytical work, current NEESit software offerings (e.g. OpenSees) may not be compatible with EE researchers need for customizability. Moreover many of the EE researchers have become very familiar with the homegrown applications they have developed over the years. They may be less likely to switch to something new as a result. In this study, complexity may be the reason why NEESCentral is not being used to its fullest extent. For example, the lack of automated tools and a cumbersome interface are mentioned as reasons why NEESR researchers continue to email data and documents back and forth.

In some instances NEES capabilities are not valued very highly. Take telepresence and teleoperation tools, hybrid simulations, and multi-site simulations as examples. In some cases it may be that EE researchers have a hard time imagining how a NEES capability contributes to their research work, because it is too cutting edge (Lawrence, 2006). Trialability of a capability through the use of NEESit software and services in the early stages of development may help (Spencer Jr., et al., 2008). It may also be helpful for the EE community to observe the improvements of the technology throughout the development period as well as hear and share the benefits of its use. In the case of NEES, trialabilty and observability of the technology alone may not be enough. Take multi-site hybrid simulation as an example. Findings from this study show that some members of the EE community are impressed by the technology behind it. What they question is the scientific contribution multi-site hybrid simulation makes to EE research. In this case, observing the technology behind multi-site hybrid simulation may not be enough. The ways that it can advance EE research and practice may have to be an observable and compelling story as well.

Findings indicate that the limited adoption of some of the NEESit software and services is also due in part to the differences found between the NEESit IT developers and EE community of users. A similar phenomenon is described in the WCS study; IT developers were interested in "technical elegance and sophistication", whereas the users needed "simple capabilities" (Star & Ruhleder, 1996). According to the authors, part of the problem is the different ways IT developers and users talk about technology development and use. The language of the former is formal and focuses on providing a technology that is functionally correct, while the language of the latter is informal and focuses on the effectiveness of the technology in the context of their social and organizational work environments. The authors found that the various messages IT developers and users convey can uncover obvious, unforeseen, and contentious issues, all of which, if addressed, may improve technology develop and use. The authors contend that the problem lies in getting the IT developers and users to learn each other's language and working environments, so that they can value each other's perspective and acknowledge the technical, social, and organizational difficulties inherent in the work they do.

In short, one way to improve the adoption rate of NEESit software and services may be to have a better understanding about how they compare to some of the existing software and services EE researchers currently use in terms of relative advantage, compatibility, and complexity. Another way to improve the adoption rate may be to expose the EE researchers to the technology in the early stages of design and development and articulate both the advantages of the technology itself and how it advances EE research and practice. A third is to have IT developers and EE researchers begin to engage in a meaningful exchange about the technical, social, and organizational aspects of technology development and use. The exchange should include surfacing, understanding, and negotiating the difficulties inherent in the work they all do and what it means for the development and use of the NEESit software and services.

4.6 Education, Outreach, and Training

Findings indicate that there are some successful NEES related EOT activities. For example, equipment sites have the greatest impact generating awareness about NEES and advances in EE research and technology. Undergraduate students work on NEESR projects at equipment sites through the NEES Research Experiences for Undergraduates (REU) program. Practicing engineers have started to attend the NEES Annual Meetings. NEESR researchers are also reaching out to professional societies and institutes to explain how NEESR projects contribute to practice. For example, one respondent notes that the American Institute of Steel Construction "has caught on [to NEES and what NEESR projects have to offer] and is starting to buy-in". In addition, NEES has cosponsored webinars with the Earthquake Engineering Research Institute to keep practicing engineers informed. Even in light of the successes however, several interview respondents think that the EOT achievements are limited. Missing are a consistent set of well coordinated, high impact activities across the broad range of participants.

4.6.1 Future Goals

Interview respondents describe three ways to build on current EOT activities.

- Prepare college graduates to incorporate innovative technologies in research and practice
- Generate interest and buy-in among practitioners, policy makers, and the public
- Develop centralized EOT activities that equipment sites and NEESR researchers can deliver

Prepare College Graduates for Innovative Technologies

The major objective of NEES is to change what and how EE research is done. This is being accomplished by providing EE researchers with advanced equipment and information and communication technologies to perform paradigm shifting science. Several respondents believe that the nationwide civil engineering curriculum needs to change in turn.

> […] civil engineering is probably viewed as a less technical engineering discipline than some of the others because we're building stuff that we've been doing for thousands of years you know we've been building structures for thousands of years. And in some ways the materials haven't changed a whole lot…the ways in which we use them have. But I would say the educational system doesn't prepare people for innovative technologies.

NEES may be more likely to make it into a civil engineering curriculum if faculty is involved in NEESR projects or employed at universities with NEES equipment sites. Even though the faculty may be more likely to discuss NEES and NEESR projects with their students under these circumstances, the discussion is confined to one university and/or faculty member at a time. In other instances, NEES and NEESR projects do not make it into curriculum, in part because it is difficult to do. According to one respondent, these kinds of EOT activities take a huge commitment on the part of the faculty and finding someone who is willing to do it is rare.

> […] stuff is hard to do, it's hard to explain. They're [EE researchers are] very specialized in their field. There's faculty that…[…] I am working with [who] is doing neat EOT stuff. He teaches one class a year because he's so specialized. He's research. […] but he has a commitment to doing [EOT] well and that's very rare.

A future goal is to deliver NEES related EOT activities for undergraduate and graduate curriculum consistently across the country on a large scale.

Generate Interest and Buy-in among Practitioners, Policymakers, and the Public

In changing the way EE research is done, other respondents believe EE researchers have to learn what is at stake for major stakeholders within the EE community and speak to their needs in their language. This is particularly true for practitioners, policy makers, and the public. As one respondent mentions,

> The practitioners are always skeptical of research because it tends to be…it doesn't necessarily address the needs that practitioners have.

One goal is to launch a more concerted EOT effort to generate interest and buy-in from practitioners, policy makers, and the public. Devising EOT activities to increase practicing engineers' involvement with NEESR projects is mentioned as an example. The grand challenge projects are cited for the way they relate EE research to the parameters that business and society care about when making decisions (e.g. death, dollars, destruction). One respondent describes why and how EE researchers need to change the way they talk about their research to policy makers.

> they've [the EE researchers] got to have more vision then maybe what has been shown, partly to interact with these budgeting and policy people because if you go into to talk to a Congressman's staff about boy I really want to go out and test this knee joint in this reinforced concrete building system, they'll get glazed real quick. You've got to have the master plan kind of thing with an idea as to you know if you do this, you're going to have this kind of an impact which goes back to the container throughput kind of thing. That's the kind of approach that a staffer can understand. Earthquake happens, you close down all the ports on the west coast you've got a big problem on your hands. So that's an argument that they [the staffers] can get a hold of.

The sustainability of NEES relies in part on funding and impact. Respondents believe reaching out to educate practitioners, policy makers, and the public about how NEES and NEESR projects contribute to their wellbeing will reduce the time it takes to get research outcomes into practice and secure research funding. According to its mission, NEESinc also has a role in developing relations with government entities, national labs, and the private sector. Survey findings indicate that there is room for NEESinc to improve in this area as well as the management of NEES more generally (Table 11).

- 33.4% agree or strongly agree that NEESinc's current marketing plans and efforts enhance the external visibility of NEES
- 22.2% agree or strongly agree that NEESinc has been effective in establishing ties with industry and users of NEES research
- 24.8% agree or strongly agree that NEESinc has been effective in steering NEES.

Table 11. Perceptions About NEESinc Performance

Question Stem: Please indicate your level of agreement with the following statements	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Don't Know**
NEESinc's current marketing plans and efforts enhance the external visibility of NEES.	2.6%	30.8%	35.9%	9.4%	6.0%	15.4%
NEESinc has been effective in establishing ties with industry and users of NEES research.	1.7%	20.5%	37.6%	15.4%	11.1%	13.7%
NEESinc has been effective in steering NEES.	0.9%	23.9%	36.8%	13.7%	11.1%	13.7%

Develop Centralized EOT Activities for Equipment Sites and NEESR Researchers

Equipment sites and NEESR researchers are engaged in successful EOT activities, but most are low impact activities that generate awareness. Those that are high impact are contained to a single university or civil engineering faculty member. Interview findings indicate that some have been thinking about increasing high impact activities through a "center driven model". One idea is to target a pool of funds toward high impact EOT activities for undergraduate students. Rather than receive funding through the annual budget cycle, equipment site personnel would write proposals to request funding for high impact EOT activities that match their skills and

interests. It is not clear how NEESR researchers fit into this model, if at all. However, one respondent does call for centrally developed EOT activities to reduce the burden and increase the impact of NEESR researchers' effort.

> I think if we could somehow have a more coordinated educational program […] what I don't like is that each [NEESR project] has to have education but I think the impact is almost zero because it's completely upon the researcher to do it. And I see one role … is NEESinc helping to bring the community together? Well one way it could do that is to help come up with really coherent educational programs that everyone can tie into and maybe we could have an impact with that. I think they've done that some with the REU program. I think that has been very successful. But I'm not sure what's happening at the project level […].

This proposed approach to NEESR EOT activity is different than how things are currently done. Moreover, it is not clear from the interview data that all NEESR researchers feel the same way. Currently NEESR researchers voluntarily solicit help from NEESinc when developing EOT activities during the proposal stage. Once awards are received some ask for additional help sorting out details and finding resources as necessary. Again their contact with NEESinc is voluntary. For example, one NEESR researcher learns that a tele-operational shake table is available for use at one of the equipment sites, so students can view the experiment from a distance. Another NEESR researcher learns that someone has video clips about NEES and uses them rather than shoot new ones. Another NEESR researcher finds out that meetings and document exchanges with teachers can be done via WebEx, rather than drive 3 hours for a face-to-face meeting.

> she had to coordinate with the teachers and they were three hour drives away and we said you could use WebEx to share files, presentations, have interactions, she said oh that would be fantastic, so we set her up with an account, talked to her about how to use it.

In short, some are proposing a center driven EOT model. This proposed model is different than the existing way EOT is developed and delivered. Under the proposed model, equipment sites would compete for funding rather than receive it as part of their annual budget cycle. Their autonomy would be preserved. In contrast, NEESR researchers would have less autonomy, but spend less time and effort developing EOT activities.

4.6.2 Current Challenges

Interview findings indicate the desire for well coordinated, high impact EOT activities that reach the broad range of participants. More specifically respondents mention several future goals targeted toward improvements to the: civil engineering curriculum, involvement of practitioners, policy makers, and the public, and development and delivery of EOT activities. Respondents also discuss the challenges related to achieving these future goals. The challenges include:

- Unclear definitions and measures of high impact activity
- An EOT funding model that favors a decentralized approach

- Limited human resources dedicated to EOT

Defining and Measuring High Impact Activity

One of the challenges is moving from the articulated vision of EOT to an action plan designed to achieve it. A few respondents mention that there is the need for more direction and expectation setting when it comes to making the EOT vision a reality.

> It's all kind of this huge vision that sounds so cool but how are we going to get there. You know being realistic about it is what I have a problem with because it doesn't seem like when we go to these annual meetings and we have these monthly teleconferences […] They just seem a little farfetched. We've got all these great ideas but we're not putting any of them to use. We're not given a direction, we're not given steps or any instructions on how do we need to accomplish this.

Findings indicate that understanding how to plan, develop, and assess high impact activities that meet the vision is particularly problematic. Respondents think that the broad objective to "inspire students to pursue degrees in engineering" in combination with little understanding of how the objectives will be measured makes it hard to determine what needs to be done.

> I understand that we should always be innovating and changing but it feels like there's been a really large shift and NSF also will throw out a lot of terms like high impact but will not tell you what's the metric for that. We don't have a metric. What does high impact mean? And if you ask people will tell you 10 different definitions, some of which are the same. And so I feel like I've got a moving target that I don't know what it looks like.

There is disagreement about how to measure high impact activities. As one respondent points out, some people think that the number of people attending an EOT activity is the way to determine the level of impact, while others feel that the intensiveness of the learning experience is most important.

> People have 3,000 people come through their lab and we're saying it would be better to have 50 people who really deeply learned a lot about earthquake engineering or 25. I think there may be some issues there. That's going to be some of the challenges I think we face […].

Given the disagreement over definitions and measures of high impact activities, some respondents are uncomfortable moving forward to develop them, in part because their performance is evaluated against them. As one respondent says, in absence of a clear rubric for EOT the "work is left to the whim of whoever perceives what it is or what it isn't [when it comes to high impact]".

Current EOT Funding Favors a Decentralized Approach

Several respondents believe that the EOT funding model has to change in order to move from isolated EOT activities where people work autonomously to coordinated EOT activities where

people work collaboratively. At the time of the interviews, there was approximately $1M available for EOT activities at the equipment sites. NEESR researchers also receive money for EOT activities based on their proposed budget. This model supports the way EOT activities have been developed and delivered prior to NEES.

> The nature or the way things work is that researchers think of their own projects and work within their own networks. To coordinate with activities of other people throughout a network is something that needs encouragement and I think is a longer process.

Prior to NEES, EOT funding supported a decentralized approach, where equipment sites and EE researchers developed and delivered their own EOT activities. The current EOT funding model for NEES distributes money to each equipment site and NEESR researcher, which reinforces the decentralized approach (i.e. their usual way of working). When asked about whether equipment sites and NEESR researchers currently collaborate on EOT activities, one respondent describes the two groups as being from two different words with little contact.

> What I don't see I think is that the actual NEESR projects…I don't see that outreach coming through our facility at all so we do our outreach…it's sort of like there's two worlds in NEES. There's the NEES sites and then there's the NEESR researchers and I don't see the NEESR researchers participating […] doing a lot of actual outreach here and maybe they do it at their own facilities and their own sites and their own laboratories or things like that or not laboratories, their own universities but I don't see that coming in [our site] and I don't see them having their graduate students help with our open houses or that kind of thing. I don't know if they're just not required to do it or what but that's the one thing that I've always see is this sort of lack of interest by the NEESRs…not lack of interest but lack of involvement I guess – there's definitely been some interest.

For more well coordinated EOT activities among equipment sites and NEESR researchers, findings indicate that the funding model needs to be examined. According to one respondent trying to coordinate EOT activities under the current funding model is like playing 52 card pick-up. Tossing his hands up in the air, he says,

> And NSF goes like this with $5,000, $10,000, $20,000 go like this and we're supposed to try to pull it all together with the people […]. When you spread it out so much it's hard to get it coordinated and people motivated to make progress on big things […].

In sum, a more centralized, collaborative approach to EOT activities at equipment sites is being considered. A NEESR researcher suggests that a similar approach be employed to reduce time and effort and increase the impact NEESR researchers could have on EOT. However, it is not clear whether this is a common sentiment among NEESR researchers. Before such a approach is implemented, the current EOT funding model needs to be examined to ensure that it encourages new ways of working rather than reinforces old ones.

Limited Human Resources Dedicated to EOT

Findings indicate that developing well coordinated, high impact activities to reach the broad range of participants requires a lot of time and a diverse set of skills. EOT coordinators work at most 50% of the time, because they have additional roles and responsibilities that take a large portion of their time (e.g. site manager, PI, or administrator). Others are only hired on a part-time basis. Each EOT coordinator is responsible for EOT activities at their site only. Working independently, each EOT coordinator works on EOT activities that reflect their specific skill set. For example, an EOT coordinator who is also a faculty member develops undergraduate and graduate EOT activities. A EOT coordinator, trained in science education develops lessons for middle school teachers. This results in each site delivering targeted EOT activities for a specific set of participants.

Broadening participation to the wider range of stakeholders under the current ways that EOT coordinators are organized has two consequences. First, as one EOT coordinator reasons something will have to be sacrificed.

> […] that means either adding onto what we're doing now which is increasing our workload without increasing our funding or dumping what we're doing now and having to develop something new and I find that really frustrating […].

The time and effort for which EOT coordinators are being funded limits the number and kind of EOT activities they develop and deliver. Increasing attention on one group of stakeholders means decreasing attention on another group. Moreover EOT coordinators have a focused skill set. Their skill set is deep, rather than broad, which allows them to cater to a particular audience. By contrast, the kind of EOT activities that appeal to a broad audience require a breadth of skills and expertise that no EOT coordinator has on his or her own. For example, the student audience alone ranges from kindergartners to graduate students. Then there is the general public, practitioners, and policy makers each with their own set of interests and expectations. One respondent explains the difficulty in the following quote.

> If […] our objective of outreach is education then you should probably have somebody that can talk the language that the kids can understand unless they're graduate students. It just depends. There's such a wide range of education in there [the EOT audience] that it kind of … one person is not going to fit the whole bill.

Another respondent agrees and notes that the proposed plan to have well coordinated EOT activities across equipment sites and NEESR projects brings up skill building issues that need to be worked through. For example, asking EOT coordinators who have experience creating EOT activities for one audience to do it for another is difficult for a couple of reasons. In some cases, they lack the skill and experience, but in other cases the audiences are not as receptive. For example, one EOT coordinator who works with K-12 students thinks undergraduates prefer that a university professor lead their EOT. An alternative approach is one that takes full advantage of the diverse skills and experience of EOT coordinators, other equipment site personnel, and NEESR researchers. For example, one respondent describes an approach where NEES personnel form teams across equipment sites to develop EOT activities that leverage their skills and expertise.

> Maybe if we had focus groups within our 15 sites. So maybe if I worked with a couple other sites and we were a focus group on creating lessons for the classroom. And there was another focus group for creating activities in the lab. So that you didn't have to work with all 15 sites, you could work with three or four or whatever that may be, but you guys are focusing on that, so you guys have a meeting and you talk.

In short, the future EOT goals require more time, effort, and skill than one EOT coordinator can currently give. Currently EOT coordinators work at most 50% of the time and have a depth rather than a breadth of skills. Yet, the skills and expertise needed to develop the proposed EOT activities vary based on the type of activity and the intended audience. Pooling human resources to work across rather than within equipment sites to develop EOT activities is presented as an option. A range of EOT activities would then be available for use at each equipment site and those involved could leverage existing skills rather than take additional time to build new ones.

4.6.3 Implications for Education, Outreach and Training

In 2005 a EOT strategic plan was published that outlined how EOT should be structured and staffed in the first three years of operation (Anagnos, et al., 2005). During the first three years of operation, there have been some EOT successes. However, both NEES personnel and EE researchers are thinking about the future of EOT. Some see it as delivering a consistent set of well coordinated, high impact activities across the broad range of participants. This goal is quite a shift from the first three years of operation where EOT coordinators and NEESR researchers worked independently on targeted activities based on their skills and interest. The potential shift in strategic focus and the expiration of the 2005 EOT strategic plan, suggest the need for a new strategic plan.

Findings indicate that the new strategic plan may need to focus on how to coordinate the message, the money, and the people. First there has to be agreement about the definition and measurement of consistent, well-coordinated, high impact activities. Specifically, high impact is not a well understood term within the EE community. Coming to a consensus about what it constitutes and how it will be measured is a critical first step. Second, there is talk of moving from a decentralized to a centralized model of EOT development. However it is not clear what that means for the people involved (e.g. equipment site staff, NEESR researchers), particularly what their tasks and responsibilities should be. For example, should sites with similar equipment work together to develop EOT activities? Should equipment sites work only with the NEESR researchers using their sites? Should all equipment sites and NEESR researchers work together to contribute to and reuse from a pool of existing EOT activities? Should a group of EOT coordinators work together to develop EOT activities for equipment sites and NEESR researchers to use? In the current model NEESR researchers and equipment sites work independently. The equipment sites employ very skilled EOT coordinators who focus on targeting a particular audience for their site based on their area of expertise. Under this model, each equipment sites is good at developing and delivering a particular kind of activity (e.g. open houses and site tours, summer programs for undergraduates or middle school students, etc). However, given the goal of broad participation within and across equipment sites it may be that EOT coordinators' skills can be put to better use if they are allowed to work across rather than within equipment sites. An alternative is that their EOT activities are designed for reuse at other

sites. The third issue that needs to be addressed is the EOT funding model. It should follow from the EOT goals as well as how tasks and responsibilities are structured to develop and deliver the EOT activities.

5 DISCUSSION

The findings from this evaluation confirm that NEES is transforming not only what research is done, but also how research is done. The experimental research projects conducted at NEES equipment sites have been larger in scale and more complex, complete, and real than anything that has been done before. The data from these experimental research projects are being captured and documented for future use. Larger more diverse research teams have been proposing and conducting leading edge research into pressing problems related to earthquake hazards and approaches to mitigating earthquake risk and loss, because the state of the art equipment NEES provides can support it. In several instances EE researchers are successfully working with others at NEES equipment sites, NEESit, and NEESinc to get their research done. There are also examples of EE researchers who are having an impact with students, educators, funding agencies, practitioners, policy makers, and the public. As a precursor to current CI initiatives, NEES has shown that it is possible to develop useful CI on a large scale and is working to serve the entire community rather than a select few.

5.1 Growing the NEES CI in the Early Years of Operation

As an early initiative with few examples to draw upon, NEES has also shown that developing CI on a large scale can be a difficult process and does not always go as planned. Drawing from Jackson et al. (2007), NEES should be viewed as a CI environment that is growing. According to the authors, CI becomes more not less dynamic when it moves from development to operation. As CI extends to new participants (transfer), new challenges arise (tensions) and must be resolved (consolidated) before CI is adopted (Jackson, et al., 2007). The challenges tend to arise from differences between the new participants' existing working environment (i.e. technical, social, organizational) and the new working environment within which the CI operates (Jackson, et al., 2007). The authors suggest that recognition and reconciliation between the existing and new working environments is the way forward rather than a strict adoption or rejection of the new. Reconciliation of differences tends to be accomplished through the development of technical, social, and/or organizational gateways that serve as intermediate points of connection (Jackson, et al., 2007). Moreover, the authors suggest that the recognition and reconciliation process can be a source of innovation and improved ways of working as changes are made to the CI environment to accommodate more, new participants.

Findings from this evaluation indicate that NEES is in the transfer stage. Many of the challenges described in this report are a result of the addition of new NEES participants since operation began in 2004. The new participants include EE researchers conducting NEESR projects as well as NEES personnel at the equipment sites, NEESit, and NEESinc, and other major stakeholders. Findings indicate that NEES, in the early years of operation, has been successful in part because NEES participants have worked to recognize and reconcile their differences. Findings also indicate however, that NEES participants have to do more as NEES prepares to begin its second phase of operation. Although NEES participants are motivated to be involved with NEES given the unique research opportunities NEES provides, they are not always motivated to change how they do their daily work.

Several of the challenges discussed in this report are related to differences between how work is done outside vs. inside of the NEES operation. In several cases, findings indicate that NEES participants' incentives need to be better aligned with each other and/or the technical, social, and organizational aspects of the NEES environment. For example, EE researchers do not see the advantage of preparing detailed work plans given the time and effort it takes, their prior experience, and the need to reveal their research ideas to others beyond their close colleagues. As another example, personnel at NEESit (i.e. IT developers) and the EE community of users have not been able to align their views, needs, and goals when it comes to developing software and services. Both challenges, as well as others described in this report, are affecting the NEES operation.

5.2 Preparing for the Second Phase of the NEES Operation

NEES participants need to get better at addressing these kinds of challenges more quickly and completely in the second phase of operation. In the following paragraphs, three approaches that NEES should consider using in the second phase of operation are described in the context of several findings from this evaluation. The three approaches are: 1) negotiating changes to the technical, social, and organizational aspects of NEES that address the multifaceted nature of the challenges NEES participants face, 2) making the recognition and reconciliation process more inclusive of the NEES participants that the challenges affect, 3) sensing and responding to the challenges that are ahead.

5.2.1 Negotiate Changes that Address the Multifaceted Nature of Challenges

The challenges NEES participants face as they become involved with NEES are a complex mix of technical, social, and organizational issues. As such, the changes negotiated to address the challenges have to be equally sophisticated. This requires that all sides of a challenge be surfaced and addressed. Take the EE researchers just in time approach to conducting research in the laboratory as an example. It is not compatible with the advanced planning and scheduling process needed for a shared use environment, such as NEES. NEESinc developed formal reporting requirements to serve as a gateway between new and existing ways of conducting research, but EE researchers have not yet fully embraced them. Findings indicate that this may be due in part to other differences between how EE researchers have typically conducted their research and how they are expected to conduct their research as NEES participants, differences that have not yet been fully recognized and resolved. For example, EE researchers do not tend to share research work plans prior to publication beyond a trusted set of colleagues. In addition, more experienced EE researchers have conducted and continue to conduct successful laboratory experiments without expending time and effort to write research work plans in as much detail as NEESinc requires. NEESinc's reporting requirements seem to have reconciled just one rather than all of the differences related to doing research that is just in time vs. formally planned and scheduled in advance. The EE researchers have not fully committed to doing the reporting requirements as a result. In short, the challenge of advanced planning and scheduling may require reporting requirements as well as establishing trusted information exchange among EE researchers and equipment site personnel and showing how the benefits of reporting requirements outweigh the time and effort related to them. In short, taking the EE researchers' reservations about advanced planning and scheduling into account may have resulted in the development of a more successful gateway to address the challenge.

5.2.2 Make the Recognition and Reconciliation Process More Inclusive

When faced with challenges related to differences between NEES participants' existing way of doing things vs. the way they are expected to do things in the NEES environment, recognizing and reconciling the differences is critical to continued success in the second phase of operation. The recognition and reconciliation process has to not only be more inclusive of the NEES participants affected, but also generate a more meaningful dialogue about the challenges NEES participants are facing. Take the goals and expectations of IT developers and other current NEES participants (e.g. NEESinc, equipment site personnel, and EE researchers, etc.) as an example. Their goals and expectations have been different since the development phase (e.g. Finholt & Birnholtz, 2006; Spencer Jr., et al., 2008) and have yet to be resolved in the operation phase. Moreover, the differences have slowed down progress considerably when it comes to the NEESit software and services being developed to support research work. IT developers have long term goals that are oriented toward advancing their interests. In contrast, other NEES participants have short term goals that are geared toward taking care of their immediate needs, some of which may not be worthy of an IT developer's interest. Several user groups have been established to work with the IT developers, but findings suggest that there is little communication and coordination among the IT developers and other NEES participants. These issues are not uncommon (e.g. Lawrence, 2006; Star & Ruhleder, 1996). However as suggested earlier, the IT developers and the other NEES participants have to begin a meaningful exchange about technology development and use that includes the technologies as well as the social, and organizational contexts within which the technologies are embedded. It should be an exchange that includes surfacing, understanding, and negotiating the difficulties inherent in the work that all NEES participants do (i.e. users, IT developers, equipment site personnel, management, funding agencies, etc.) and what it means for the development and use of the NEESit software and services.

5.2.3 Sense and Respond to the Challenges Ahead

Lastly, NEES participants would do well to anticipate the challenges ahead before more new participants become involved with NEES. This approach requires being a proactive NEES participant, rather than a reactive one that waits for the challenges to arise. Given the nature of CI environments, this approach has the advantage of not waiting to follow a prescribed plan, which may or may not come to fruition. Sensing and responding to challenges among NEES participants requires paying close attention to what is currently going on inside and outside of the NEES environment to determine what might happen next. For example, some NEESR projects are ending and the data from them are being made available for reuse. This means NEES will get extended to new participants (i.e. data consumers). Findings from this evaluation indicate that the early data consumers are most likely to be EE researchers who do numerical computation modeling and are seeking NEESR data to validate their models. Findings also indicate that challenges are likely to arise between the data producers' perceptions about what kind of documentation data consumers need to reuse the data and the data consumers' actual documentation needs when it comes to reusing the data. Given these findings, a critical question for the second phase of NEES operation is what technical, social, and organizational gateways need to be developed to facilitate data reuse for the purpose of model validation.

In sum the early years of the NEES operation have focused on growing the CI and NEES will continue to grow in the second phase of operation as more, new participants become involved.

By adopting the idea that CI is grown not built, the goal for NEES participants specifically, and CI participants more generally should not be to develop CI that minimizes challenges. Without challenges CI does not realize its potential to grow, change, and innovate. Instead CI participants should focus on getting better at recognizing and reconciling challenges by: 1) negotiating changes to the CI that address the multifaceted nature of the challenges, 2) making the recognition and reconciliation process more inclusive of the CI participants affected by the challenges, and 3) sensing and responding to the CI challenges that are ahead.

6 NEXT STEPS

The remainder of the evaluation project will be used to continue to analyze existing data and collect additional data as necessary. The additional data analysis will be used as input into additional reports, conference papers, or journal articles that may focus on one or more of the following:

- Further examination of the changes to EE researchers' data management, sharing, and reuse practices in light of NEES, NEESCentral, and NEESR data.
- Further examination of the relationships between the technology systems and social systems related to NEES and their impact on the NEES operation.
- Early exploration of socio-technical issues common to CI initiatives as they move from the development to the operation phase. For example, there is a possibility to collaborate and compare findings with a colleague conducting an evaluation of TeraGrid.

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APPENDIX A. SURVEY INSTRUMENT

Introduction

You have been selected to complete this questionnaire based on your interest and participation in the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). This study is funded by the National Science Foundation (NSF) and being conducted by the University of Michigan. We would greatly appreciate you taking 15-20 minutes to share your opinions with us.

This survey is part of a larger effort to better understand how to support the needs of the earthquake engineering community. It is not possible for us to understand the relevant factors without responses from individuals engaged in a range of activities, which means that *your response is very important to us.*

Survey results will be reported to NSF and NEESinc to help drive improvements to NEES related tools, technologies, software, and services to support research in your field and others. Data will be presented only in an aggregate form in reports and publications. *Individual responses will not be identifiable.*

Your participation in completing this survey is voluntary. You may skip questions and you are free to withdraw at any point. Your responses will be used for research purposes only and will be kept in secure locations at the University of Michigan. Only primary members of the research team at the University of Michigan will have access to these data.

Research Activities

1. Please select the category that best describes your primary area of research.

   - O Earthquake engineering
   - O Other (please describe):

2. Please select the category that best describes your primary area of earthquake engineering research.

   - O Geotechnical engineering
   - O Structural engineering
   - O Tsunami research
   - O Other (please describe):
   - O Not applicable

3. What percentage of your research uses the following approaches? *(should total to 100).*

   _____ Laboratory experiments
   _____ Field experiments
   _____ Numerical modeling
   _____ Hybrid simulation
   _____ Other (please describe):
   100% Total

4. Which of the following do you think will be most valuable in advancing your research in the next 1-3 years? *(choose up to three)*

   - O Sharing your data with other researchers
   - O Reusing data from other researchers
   - O Collaborating with researchers *outside of your area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research)
   - O Collaborating with researchers *in your area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research)
   - O Collaborating with researchers who use different research approaches (e.g. laboratory experiments, field experiments, numerical computation, hybrid simulation)
   - O Collaborating with practicing engineers
   - O Gaining access to state of the art equipment at other research institutions

Data Reuse

The questions in this section of the survey concern reuse of earthquake engineering data. For the purpose of this survey, ***data*** are defined as that which is generated during a simulation or collected during an experimental research study conducted in the laboratory or field. It includes raw data, processed data, graphs, charts, plots, calculations, parameters etc. ***Data reuse*** is defined as accessing data someone else collected during their research project and using that data in your research project.

5. Please select the purpose for which you would be most likely to reuse someone else's data *(choose one)*.
   - O Develop and validate computational models or tools
   - O Look at general trends across multiple studies
   - O Provide resources for pedagogical purposes (i.e. education, outreach, training)
   - O Enhance your own data population
   - O Encourage its use in policy formation and evaluation
   - O Verify, refute, or refine original results
   - O Other (please describe):

6. Please select the kind of data you would be most likely to reuse from someone else.

O Experimental Data O Simulation Data O Other (please describe):

7. If a shared data repository that provided access to others' data was available to you, how likely would you be to use it in the next 12 months?

O Not at all likely O 1-25% O 26-50% O 51-75% O 76-100%

8. What percentage of your recent research uses data from the following sources? (*should total to 100%)*

_____ Data collected by you alone
_____ Data collected by you and one or more collaborators
_____ Data collected by people working independently of you
100% Total

When considering whether to reuse someone else's data, please indicate how important it is to you to…

	Very Important	Important	Somewhat Important	Not Very Important	Not At All Important
9. have worked with the person before.	O	O	O	O	O
10. see the data referenced in a peer-reviewed paper (i.e. conference, journal)	O	O	O	O	O
11. access additional documentation about the data, besides what appears in a peer-reviewed paper (i.e. conference, journal).	O	O	O	O	O
12. have used similar equipment when conducting your own research.	O	O	O	O	O
13. be familiar with the person's prior research.	O	O	O	O	O
14. be familiar with the location (e.g. laboratory, field) where the data were collected.	O	O	O	O	O
15. find an expert who can help you interpret the data.	O	O	O	O	O
16. have the person be well known in the field.	O	O	O	O	O
17. have access to detailed descriptions of how the data were collected (i.e. experimental setup, materials, instrumentation and calibration).	O	O	O	O	O
18. have prior experience collecting similar data.	O	O	O	O	O
19. have someone from the data collection team available to answer your questions.	O	O	O	O	O
20. have the limitations of the data be clearly described (i.e. bad sensors, equipment limitations or malfunctions).	O	O	O	O	O
21. have colleagues to talk to about the data.	O	O	O	O	O

Please indicate the extent to which you agree with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
22. Reusing someone else's data costs less than collecting new data.	O	O	O	O	O
23. Reusing someone else's data provides opportunities to conduct a broader range of research.	O	O	O	O	O
24. Reusing someone else's data takes less time than collecting new data.	O	O	O	O	O
25. Reusing someone else's data provides opportunities for novel research.	O	O	O	O	O
26. Reusing someone else's data takes less effort than collecting new data.	O	O	O	O	O

NEES Activity

27. Are you a registered user of NEESCentral?

O Yes O No

28. Have you been named as a principal investigator or a co-principal investigator on a *proposal submitted* to the National Science Foundation or other sponsor to use NEES equipment facilities (e.g. Pre-NEESR, NEESR, payload proposals, SUPP, etc.)?

O Yes O No

If you answered "No" to question 28, please skip to question 32.

29. NEES personnel (i.e. NEESinc, NEES equipment facilities) made themselves available to answer any questions I had as I wrote my proposal to use NEES equipment facilities.

O Strongly Agree O Agree O Neutral O Disagree O Strongly Disagree

30. Have you been named as a principal investigator or co-principal investigator on a National Science Foundation or other sponsored *grant awarded* to use NEES equipment facilities (e.g. Pre-NEESR, NEESR, payload grants, SUPP, etc.)?

O Yes O No

If you answered "No" to question 30, please skip to question 32.

31. NEES personnel (i.e. NEESinc, NEES equipment facilities) helped me get my research participation agreement (RPA) signed in a timely manner.

O Strongly Agree O Agree O Neutral O Disagree O Strongly Disagree

32. Have you used any of the NEES equipment facilities for research?

O Yes O No

If you answered "No" to question 32, please skip to question 36.

NEES Equipment Facilities

Please indicate your level of agreement with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
33. Overall I would say the *focus* of my research conducted at NEES equipment facilities is different than if I had been working in a non-NEES facility.	O	O	O	O	O
34. Overall I would say the *quality* of my research conducted at NEES equipment facilities is higher than if I had been working in a non-NEES facility.	O	O	O	O	O
35. Overall, I would say that my experience at NEES equipment facilities has had a significant positive influence on my *research productivity*.	O	O	O	O	O

NEES Impact

Please indicate your level of agreement with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
36. Since I have been affiliated with NEES, the nature of my research has improved through interaction with practicing engineers and other professionals interested in mitigating seismic risks.	O	O	O	O	O
37. Since I have been affiliated with NEES, my research has benefited from collaboration with researchers *within my area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research, etc.).	O	O	O	O	O
38. Since I have been affiliated with NEES, my research has benefited from collaboration with researchers *outside of my area of expertise* (e.g. structural engineering, geotechnical engineering, tsunami research, etc.).	O	O	O	O	O

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
39. My research opportunities have expanded since I have been affiliated with NEES.	O	O	O	O	O
40. I plan to participate in NEES related activities over the next 1-3 years.	O	O	O	O	O

Management & Direction of NEES

Please indicate your level of agreement with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
41. NEESinc's current marketing plans and efforts enhance the external visibility of NEES.	O	O	O	O	O	O
42. NEESinc has been effective in establishing ties with industry and users of NEES research.	O	O	O	O	O	O
43. NEESinc has been effective in steering NEES.	O	O	O	O	O	O
44. The current portfolio of NEES research projects represents the cutting edge research NEES equipment facilities were built to encourage.	O	O	O	O	O	O

NEES Software and Services

Based on *your needs for your research work*, please rate how valuable the following capabilities are to you.

	Very Valuable	Valuable	Somewhat Valuable	Not Very Valuable	Not At All Valuable	Don't Know
45. Organizing and sharing data for reuse in other research studies	O	O	O	O	O	O
46. Viewing real time, synchronized, streaming data from NEES equipment sites	O	O	O	O	O	O

	Very Valuable	Valuable	Somewhat Valuable	Not Very Valuable	Not At All Valuable	Don't Know
47. Viewing historical sensor data with synchronized video images	O	O	O	O	O	O
48. Viewing active experiments occurring at NEES equipment sites	O	O	O	O	O	O
49. Controlling video cameras while viewing active experiments occurring at NEES equipment sites	O	O	O	O	O	O
50. Performing hybrid simulations	O	O	O	O	O	O
51. Running multi-site simulations across multiple NEES equipment sites	O	O	O	O	O	O
52. Performing high performance computing simulations	O	O	O	O	O	O
53. Simulating the performance of an entire system rather than individual components of the system	O	O	O	O	O	O
54. Collaborating with others who are physically distant.	O	O	O	O	O	O
55. Sharing software code with others in the earthquake engineering community	O	O	O	O	O	O

Open Ended Question

56. What can be done to improve your experience with NEES related resources?

Demographics

57. Which of the following best describes your current professional status?
    - O Practitioner
    - O Professor
    - O Associate Professor
    - O Assistant Professor
    - O Senior Research Scientist
    - O Junior Research Scientist
    - O Research Assistant
    - O Postdoc
    - O Graduate Student
    - O Undergraduate Student
    - O Other, please describe:

58. What is your institutional affiliation?

59. What kind of institution is it?
    - O Research university (PhD granting institution)
    - O Teaching university or college
    - O Government
    - O Nonprofit organization
    - O Commercial business or service provider
    - O Other, please specify:

60. What is the highest academic degree you have obtained?
    - O Bachelor's degree
    - O Master's degree
    - O PhD or equivalent
    - O Other, please specify:

61. In what year did you obtained your highest degree?

62. What is your gender?
    - O Male
    - O Female

63. In what year were you born?