Leadership at a Distance

Research in Technologically-Supported Work

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Cultural Challenges to Leadership in Cyberinfrastructure Development

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OVERVIEW

In this chapter, we show how Hofstede's cultural constructs help explain the leadership dysfunction we observed in the early history of NEESgrid, the cyberinfrastructure component of the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES). The goal of the NEESgrid effort was to design and deploy a collaboratory to link researchers and students with earthquake engineering data, experimental facilities, and computational simulations. The NEESgrid project involved participants from three distinct professional cultures: civil engineering, computer science, and program managers at the National Science Foundation (NSF). Using Hofestede's categories, we demonstrate how miscommunication arising from orthogonal orientations on Hofstede's dimensions complicated leadership within the NEESgrid team. In particular, NEESgrid succeeded only when the leadership shifted from cyberinfrastructure developers to civil engineers. In the discussion we consider why this leadership succession worked and suggest general leadership principles that will help future cyberinfrastructure projects avoid the problems we observed within the NEESgrid effort.

Geographically distributed project teams repeatedly experience difficulties when compared with their collocated counterparts (e.g., Cummings & Kiesler, 2003; Herbsleb, Mockus, Finholt, & Grinter, 2001; 2002; Jarvenpaa & Leidner, 1999; Olson & Olson, 2000). For example, the visibility and informal communication afforded by collocation can dramatically increase team effectiveness through constant monitoring of and participation in coworkers' activities (Teasley, Covi, Krishnan, & Olson, 2000; 2002). Another benefit of collocation is that workers have or develop shared cultural orientations, such as similar attitudes toward risk, equality, and collectivism (Hofstede, 1980). These shared orientations can play an important role in team members' ability to communicate and work effectively by creating a common ground for interpreting others' actions and statements (Clark, 1996). In the absence of common ground, communication breaks down with corresponding reductions in levels of trust and performance. Specifically, we believe that the dysfunction observed in the NEESgird project was in large part a result of diminished common ground among the project participants. The lack of common ground was exacerbated by conflicting cultural orientations among the target users of NEESgrid (civil engineers), the funders of NEESgrid (NSF program officers), and the initial NEESgrid leadership (cyberinfrastructure developers).

RESEARCH CONTEXT AND METHODS: AN EXPERIENTIAL CASE STUDY

The creation of NEES was an $89 million cyberinfrastructure project funded by the NSF engineering directorate. Cyberinfrastructure is a concept used to describe the combination of computers, networks, services, and applications that scientists and engineers increasingly rely on to conduct their research (Atkins et al., 2003). In the NEES case, the cyberinfrastructure activity focused on a $10 million effort over the period 2001–4 to build NEESgrid. NEESgrid was envisioned to be a collaboratory for earthquake engineering, where a collaboratory uses cyberinfrastructure to join resources (e.g., instruments), people, and data via computer-supported systems (Finholt, 2003).

In addition to NEESgrid, during the development phase, NEES consisted of two other critical elements. First, $66 million went to construct 16 new earthquake engineering research laboratories at 15 universities. Figure 10–1 shows the location and capabilities of these new labs. Second, $3 million went to the Consortium for University Research in Earthquake Engineering to build and launch the NEES Consortium, Inc., or the nonprofit entity that NSF would fund over the period 2004–14 to maintain and operate the NEES systems. As of October 1, 2004, operational control of NEES passed to the NEES Consortium, and the grand opening ceremony for NEES was held on November 15, 2004.

Our role in the NEES program was to investigate and enumerate the user requirements for NEESgrid. Thus, we were an interface between the earthquake engineers (the target users of the system), the NSF program managers (the funders), and the cyberinfrastructure developers (the system integrators

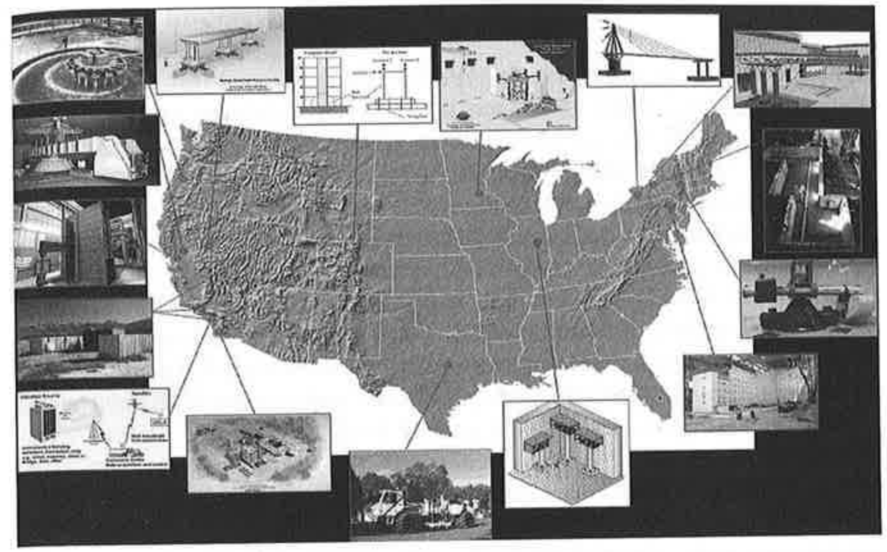

FIGURE 10–1. Type and geographic distribution of the sixteen NEES sites.

and initial leaders of the NEESgrid team). In the process of gathering user requirements during the period 2000–3, we attended 10 national meetings and workshops of engineers, program managers, and cyberinfrastructure developers; attended six site reviews of the project by an independent panel; and participated in weekly videoconferences on the progress of the project with engineers, developers, and program managers. We also visited each of the 15 NEES equipment sites and conducted over 75 semistructured interviews with earthquake engineers, and conducted four national surveys of communication and collaboration practices within the earthquake engineering (EE) community. All of our data gathering activities were approved by the behavioral science institutional review board (i.e., human subjects) at the University of Michigan. All data collection, observation, and interviews were conducted with the informed consent of the NEES participants. Through these activities we had many opportunities to observe key participants in the NEES program and to catalog various breakdowns of communication and trust.

The conclusions drawn from the data are our own and do not reflect official positions of the leadership of the various NEES projects or of the National Science Foundation. The object of our analysis is to highlight general problems that can arise in interdisciplinary collaborations around the development of cyberinfrastructure and not to cast blame on specific individuals or groups. Finally, consistent with ethical social science research practice, we have removed any information that might identify specific individuals or groups.

CULTURAL ORIENTATION

In his famous analysis, Hofstede (1980, 1991), proposed four fundamental dimensions—uncertainty avoidance, power distance, gender, and individualism—that reliably differentiate national cultures. With some modest adjustment, these same dimensions can be used to describe differences in what might be called "professional cultures." Professional cultures are to people who work and were socialized in different fields as national cultures are to people who live and were socialized in different countries. In this case, we argue that the NEES project brought together participants from three areas of work, each area with its own unique professional culture (i.e., earthquake engineers, NSF program managers, and cyberinfrastructure developers). Despite broad endorsement of NEES by all participants, early interactions between the main groups were problematic and quickly led to mistrust.

Difficulties in NEES had the character of a "first contact gone awry." That is, in accounts of European exploration in the New World (e.g., Diamond, 2004; Ruby, 2001), a recurring theme is the inability of the Europeans to step outside their own cultural framework—with one result being a history of disastrous relations with native populations, such as the struggle (a depiction of first contact between the English explorer Frobisher and Inuit natives). Similarly, in the NEES project, representatives of the three key groups entered their initial collaborations assuming a common worldview. Subsequent discovery of divergent perspectives was initially a cause of communication failures and later the basis for open hostility. Hofstede's dimensions, when applied to the professional cultures represented in NEES, provide a helpful starting place for understanding why the start of the NEES project was so hard—and also why changes to the project over time eventually corrected some of the early problems and increased the likelihood of success.

While Hofstede provides four dimensions on which cultures can be distinguished, we found two of these to be particularly relevant in characterizing the NEES participants:

- Uncertainty avoidance: The extent to which individuals take steps to control risk and the unknown.
- Power distance: The extent to which individuals prefer formal and hierarchical relationships compared to more informal and egalitarian relationships.

The subsections that follow characterize each type of NEES participant according to these two dimensions with particular attention to how groups differed and how these differences led to negative consequences for project development.

Earthquake Engineers

Earthquake engineering is concerned with the seismic performance of the built environment (Sims, 1999). The research work of EEs typically consists of experiments conducted on large, physical models of buildings, bridges, and soil retaining structures (e.g., retaining walls, building foundations) that are outfitted with hundreds of sensors that record details of strain and motion in simulated earthquakes generated by means of large shaking platforms or hydraulic actuators. EE researchers are trained as civil engineers (and many are certified as professional engineers) and tend to apply computational simulations in support of physical simulations (rather than as substitutes, which is to say there isn't any analog yet in EE research for the computationally based subdisciplines that have emerged in other fields, such as computational chemistry or biology).

Uncertainty Avoidance. Earthquake engineers generally seek to avoid or control uncertainty. Experimental specimens in EE are typically built of steel or reinforced concrete, as are the real-world structures that these specimens represent. Such materials are difficult to modify once constructed, and there is therefore a tremendous amount of planning and analysis that goes into the design of an experimental specimen. Uncertainty, and the accompanying potential for changes, errors, and unpredictable structural behavior, are thus seen as significant potential liabilities in this community and are actively avoided. This risk aversion in experimental work is indicative of a generally conservative orientation among earthquake engineers that makes them suspicious of tools and methods that are new and untested.

Power Distance. Earthquake engineering is generally distinguished by high power distance. Among earthquake engineers there is a tendency to defer to authority figures both within local laboratories and in the field more generally. Power distance is reflected at the field level in the distribution of experimental apparatus. A small number of large-scale facilities define a clear set of elite institutions that are better ranked (e.g., by the National Research Council), publish more, obtain more funding, and attract better graduate students. At the local level power distance is reflected in the division of labor in the laboratories with some tasks clearly intended for masters-level students versus doctoral students versus technical staff and faculty. Additionally, graduate students work primarily on projects initiated and led by their advisors, rather than on projects they devise independently.

Cyberinfrastructure Developers

The NEES cyberinfrastructure development effort was based on a number of open source software codes, notably those needed to enable "grid-based" systems

(Foster & Kesselman, 1999). As a result, although not strictly an open source project, NEES developers did resemble open source programmers described elsewhere (DiBona, Ockman, & Stone, 1999). In other words, they exhibited an egalitarian orientation with a preference for informal organization.

Uncertainty Avoidance. The cyberinfrastructure developers were not risk averse and can therefore be characterized as low on the uncertainty avoidance dimension. Specifically, the developers worked using spiral software development models (Boehm, 1995) that advocated rapid iteration and prototyping. The spiral approach encourages risk taking and sometimes underspecified development activities because it is assumed that problems can be eliminated in the next iteration, which is never far away and does not have a high cost. Thus there was little perceived need to eliminate uncertainty early in the project because errors were expected and would be addressed in the subsequent development cycles. This is captured well in one of the NEES software developers' frequent use of the motto "don't worry, be crappy" to describe the incremental approach to risk inherent in the spiral model.

Power Distance. Power distance among cyberinfrastructure developers was low. Individual programmers often had broad latitude to determine how to proceed with development, provided they remained consistent with overarching design directions. Furthermore, in interactions among the developers, people participated largely independent of their status or seniority with the exception of sometimes deferring to others with deeper technical expertise.

NSF Program Managers

Program officers in the National Science Foundation are responsible for overseeing the distribution and management of resources in ways that promote the goals of the foundation. With much grant-based research, this tends to be accomplished via a reasonably "hands-off" approach. NEES, however, differed from typical grants in critical respects. First, NEES was a high profile project in terms of funding level and was awarded as a "cooperative agreement" which imposed a higher than typical oversight burden on NSF. Second, NEES was the first major research equipment and facility construction (MREFC) project in the engineering directorate. MREFC projects are line items in the NSF appropriation and are therefore subject to special congressional scrutiny. And finally, NEES was the first attempt by NSF to build a network of facilities linked by cyberinfrastructure and intended to be operated primarily as a collaboratory.

Uncertainty Avoidance. Uncertainty avoidance was high among the NSF managers. First, many came from the earthquake engineering and civil engineering cultures and shared the pervasive risk aversion of colleagues from these communities. Second, because of the cost and visibility of NEES, the stakes were quite high for individual managers, particularly in terms of career advancement.

Power Distance. Power distance among the NSF managers was high. That is, particularly because of the cooperative agreement governing NEES, NSF managers intervened more actively in the conduct of the project. Because this differed from the usual experience with grant-based research, NEES investigators chafed under the closer scrutiny of the NSF staff. For example, rather than the collegial relationship characteristic of grant-based activity, the cooperative agreement created a hierarchical relationship. In some cases, particularly around NSF requests for documentation and justification, NEES investigators felt they were treated as subordinates or mere contractors rather than as leading researchers in computer science or earthquake engineering

Consequences of Cultural Differences

One episode that illustrated the gulf between earthquake engineers and cyberinfrastructure developers emerged around the release of the initial user requirements report by the cyberinfrastructure development team. The report, grounded in the principles of user-centered design and based on substantial interview and survey data, outlined at a high level the comprehensive user requirements for the NEESgrid collaboratory. The earthquake engineers were almost universally disappointed with the user requirements report. Specifically, the earthquake engineers and the cyberinfrastructure developers had divergent notions of what constitute "requirements" that at least partially reflected differences in their professional cultures.

The engineering notion of requirements was specific with detailed characterization of functionality, implementation, and relationship to other requirements. This approach to user requirements was consistent with both the engineers' cultural bias against uncertainty and their preference for formal and hierarchical relationships. That is, a precise and exhaustive requirements document early in a project allows for elimination of potential problems and for clear division of labor. The cyberinfrastructure developers, on the other hand, had a less rigid view of requirements. The spiral development model they adopted suggested that it would be difficult or impossible to resolve all uncertainties early on, so the best approach was to specify requirements at a high level, implement to satisfy these initial requirements, and then iterate to improve both requirements specification and implementation. This approach struck the earthquake engineers as sloppy and unnecessarily risky. Differences about the meaning of requirements served to create a rift between the developers and earthquake engineers because neither side believed the other knew what "requirements" were or how to correctly document them. This fostered mistrust and vastly increased the need for communication and bridge-building between the communities. Similar conflict and dysfunction between engineers and physicists is discussed by Galison (1997) in his discussion of the increasingly complex design and construction of particle accelerators.

Another episode that underlined the difficulty of negotiating cultural differences among the NEES players was the emergency "all hands" meeting convened by NSF program managers just a few months after the project began. The primary issue at this meeting was a misunderstanding over the nature of project deliverables. The cyberinfrastructure developers argued that they had received funding to produce a set of grid-based telecontrol protocols and Application Program Interfaces (API's) for integrating equipment at different laboratories and for providing telepresence functionality (i.e., the ability to remotely observe and control laboratory equipment). The earthquake engineers, and to some extent the NSF program managers, thought they were getting a turn-key system and were shocked to learn that they would have to hire programmers and learn to use API's in order to make the NEES system functional. After one long discussion in which the cyberinfrastructure developers fended off a growing list of deliverables as "out of scope," a disgusted earthquake engineer observed of the cyberinfrastructure developers that "we wouldn't buy a used car from you guys," reflecting the sense that, with respect to NEESgrid, the engineers had been sold a "lemon."

Again, this conflict can be explained along cultural lines. The desire of the earthquake engineers to avoid costly uncertainty explains the extent to which they bristled at the surprising discovery of what they perceived as the deficient scope of the cyberinfrastructure development activity. Similarly, the response of the cyberinfrastructure developers reflected their cultural orientation toward maintaining flexibility to address interesting issues as they arose rather than being firmly committed to carry out tasks that might prove to be dead ends or time sinks. One measure of the cultural disconnect between the two sides was that at this meeting, and other subsequent sessions, the cyberinfrastructure developers brushed off the engineers' concerns (often using humor), not realizing the growing irritation on the part of the engineers. Specifically, at a moment when both sides needed to develop common ground, their cultural dispositions caused them to dig in and oppose each other. At this point, NSF program managers understood that significant steps were needed to bridge the deepening cultural gulfs and unite the team around a shared understanding and interpretive framework.

LEADERSHIP: BRINGING THE GROUP TOGETHER

After a problematic start to the NEES development and deployment, key players from each of the participating groups explored and adopted strategies to help overcome cultural differences. Many of these strategies involved participants stepping forward to exercise leadership. First, there was a general agreement that all parties needed more opportunities to communicate informally and in real time. One important step, therefore, was taken halfway through the first year of NEES development when a set of cyberinfrastructure developers, earthquake engineers, and NSF program managers took the initiative to convene a weekly multipoint videoconference (Hofer, Finholt, Hajjar, & Reinhorn, 2004). The format of these conferences allowed for presentation and discussion of a specific concern each week along with some time for general discussion. Responsibility for these meetings was traded off between the earthquake engineers and the cyberinfrastructure developers. These weekly conferences were widely viewed as tremendously helpful in getting the NEES project participants to understand each other better and to negotiate a shared understanding of the project.

A second strategy for overcoming cultural differences involved explicit efforts to increase the diversity of the overall project leadership. For the first two years, the project directors for the NEES collaboratory effort were part of the cyberinfrastructure development team and strongly aligned with the computer science culture. As the project progressed and relations between groups became more strained, the lack of a strong earthquake engineering voice in the NEESgrid development process became a focus for criticism from both earthquake engineers and the NSF program managers. This motivated a critical leadership change at the start of the third year of the project. The new leader of the collaboratory effort was a prominent earthquake engineer who was affiliated with the same university as much of the development team and had cultivated strong relationships with all three communities. This had a tremendously positive impact on relations between the participating groups in ways that are important for the present discussion of leadership. In particular, the new project director was able to do two things.

First, he was able to utilize his existing relationships with key players in all three communities and serve as a translator or broker between the groups. When one group made demands of another that were perceived as "unreasonable," for example, the new project leader was able to talk with members of both groups and negotiate an effective solution. In his review of similar approaches in the high-energy physics community, Birnholtz (2006) observes that this is called "managing by having coffee." This broker–translator function also proved useful when the development team presented ideas to the earthquake engineers and the NSF program managers. These ideas could be run past the new director, to gauge their likely reaction, or they could even presented by him to avoid potential conflict. A key component of this broker–translator role is the notion of what might be called "translated awareness." As was noted above, awareness information and communication exchanged between the three groups prior to the changed management approach were largely used in negative ways that hindered the project. One key role of the new project leader was to help all groups interpret and use this information in more productive ways. In part, of course, this was a function of increased opportunities (e.g., the weekly videoconferences) for informal interaction. At the same time, however, it was up to the new project director to help all three groups stay focused on shared goals.

Second, the new project director provided the earthquake engineers (and, to a lesser extent, the NSF program managers with whom he had a strong relationship) with an important sense of representation on the development team. As the "we wouldn't buy a used car from you guys" comment mentioned earlier strongly suggests, there was a great deal of mistrust between the earthquake engineers and the cyberinfrastructure developers. This stemmed, in part, from the fact that the engineers felt their interests were not well represented on the NEESgrid development team and that the cyberinfrastructure developers did not share the engineers' interests. In particular, this was fueled by the developers' desire to carry out "interesting" computer science tasks (such as the development of novel technologies and APIs) and define the more mundane tasks, such as figuring out how to make the software work with existing lab equipment, as "out of scope." Having an earthquake engineer leading the project gave the earthquake engineers a much stronger sense that their interests were being represented. Given the existing strong relationship between the new project leader and the development team, the developers generally did not feel that they were being "infiltrated" or lead by an outsider. Under different circumstances, though, this could clearly be cause for concern.

LESSONS LEARNED FROM THE NEES EXPERIENCE

We believe the experience with NEES during the period 2001–4 offers a set of general lessons that can be applied to other collaborative, multisite, multidisciplinary projects.

First, we have shown the role that significant differences in professional culture played in complicating the development of NEESgrid. These cultural gaps meant that even when information was communicated in seemingly objective ways common to project management (i.e., reports, requirements documents), this information was interpreted differently by the different groups involved in the project. In some cases this was detrimental to the progress of the project. This suggests that in carrying out projects that involve communities that may come from different professional cultures, it is important to identify cultural gaps. We found Hofstede's (1980) framework helpful in this analysis, but additional dimensions of culture may prove useful in other settings. This is an area ripe for future work, as multidisciplinary collaboration becomes increasingly common in research.

Second, we observed the importance of strong leadership in bridging these cultural gaps, once they had been identified. The new project leader in

this case had two critical functions. First, he was able to leverage strong relationships with key players in all groups to act as a translator and broker between the groups, thereby ensuring that communicated information did not contribute to the "vicious cycle" identified here. That is, effective leadership helped the participating groups to constructively utilize shared information rather than to continue to view this information as evidence of deficiencies on the part of the other groups. Second, he increased the representative nature of the project leadership team by simultaneously being a part of the earthquake engineering and development teams. This gave the earthquake engineers the important sense that their needs and interests were being taken into consideration by the cyberinfrastructure developers and, for the same reason, afforded increased legitimacy to the development team in the eyes of the earthquake engineers.

Third, we observed the importance of not just formal project-related communication and encouragement but informal communication and negotiation as well. The cultural gaps between groups involved in the project meant that additional opportunities for interaction were necessary to ensure that the groups understood each other. This communication was encouraged by the new project leadership.

CONCLUSION

This chapter highlights professional culture conflict as an important and largely unexplored source of risk in multidisciplinary project initiatives, particularly with regard to cyberinfrastructure. Because this project involved the blending of effort between cyberinfrastructure developers and one or more communities of domain scientists or engineers, there was a greater than normal chance for misunderstanding and mistrust arising from cultural differences. Furthermore, because of the cost and visibility of this and other cyberinfrastructure projects, federal program managers may typically represent a third cultural perspective, often at odds with the other perspectives. As the preceding sections have shown, failure to understand and accommodate cultural differences can result in awkward first contacts and subsequent difficulty in building understanding and confidence among participants from separate professional cultures. We have described some of the steps taken to overcome cultural barriers in the NEES project and then use these experiences to describe a general set of lessons learned that can help other cyberinfrastructure efforts to avoid repeating the NEES mistakes.

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