Supporting Successful Design and Management of Research Centers

(NSF Award ID: OCI- 1059153)

Nicholas Berente
University of Georgia

Project Summary

Advances in computational technology are transforming science. An increasing portion of scientific research is being done in large-scale, cyberinfrastructure-enabled teams distributed across a growing number of research centers*. These large-scale scientific collaborations represent a radically innovative form of organizing that involves unprecedented complexity and a variety of unique challenges (Atkins et al 2003). The existing body of knowledge, however, does not attend to the specific ways that these unique organizations can be successfully managed.

There are two broad domains of challenges to the delivery of large-scale computational science: technical and organizational. The technical domain is comprised of engineering tasks that network, configure, develop, and deliver the computational resources upon which scientific activity takes place. The organizational domain involves the roles, responsibilities, practices, and interactions that enable and manage the technical activity. To deliver on cyberinfrastructure projects successfully and consistently, it is important to execute on both the technical and the organizational domains. While the technical elements of cyberinfrastructure represent formidable tasks, the organizational challenges are perhaps even more complex and problematic (David 2006; Bowker et al 2010).

Cyberinfrastructure-related practices are typically managed using well-established project management standards (i.e. PMI) and software development methodologies (e.g. Boehm 1988) that are associated with discrete projects and predetermined organizational structures. While this has been adequate for smaller-scale, shorter duration science, contemporary computationally-intensive science often involves radically large-scale, cross-disciplinary, and distributed collaborations across multiple organizations (Zimmerman & Finholt 2007). These projects are marked by dynamic networks, indefinitely long project horizons, and unpredictable and emergent outcomes. Organizational structures, processes, and governance should be flexible and adaptive, and also robust enough to facilitate enduring outcomes.

* For an introduction to cyberinfrastructure, see:
http://www.nsf.gov/news/special_reports/cyber/index.jsp
For an example of the type of work performed by computationally-intensive research centers, see “From Supercomputing to the TeraGrid” under the “Discovery, Learning, and Leadership” tab. For images from TeraGrid projects, see:
https://www.teragrid.org/web/science-gateways/gallery2

Statement of Objectives

The proposed research involves a detailed analysis of managerial practices in computationally-intensive, collaborative scientific research centers to assess those practices in relation to the literature on organizational design, project and process management, software development, and social studies of science. Based on this analysis, the researchers will identify beneficial practices and management techniques in order to develop a set of guidelines and materials to support the effective design of organizational structures, processes, and methods in such centers.

Research Method

In the first year, the study will involve exploratory qualitative research (Yin 2003), to assess current practices and capabilities. The research will involve visits to a variety of computationally intensive research centers and will culminate in a workshop involving an expert panel. The second year will involve focused qualitative work combined with the development of a survey instrument to validate findings using quantitative survey-based methods (Tashakkori & Teddlie 2003).

Intellectual merit

This work will extend the growing body of social analysis on large scale research environments, collaborations and cyberinfrastructure (e.g., Olson et al 2008; Edwards et al 2009), which typically takes a descriptive and broadly sociological view. In the proposed work we look to extend this literature in two fundamental ways: (1) by explicitly rooting our analysis in organizational research, particularly in the work relating to organization design, standardized processes, and management information systems; and (2) identify and develop an appropriate set of materials which can effectively prepare center directors to navigate the complex organizational issues that they face.

Broader impacts

Center directors and their teams could benefit from management guidelines that focus on this unique form of organizing. The science that leverages cyberinfrastructure will benefit as a result. Further, both the social studies of science and the organizational management literatures could benefit from the exploration of this emerging type of organization.

Project Description: Supporting Successful Design and Management of Research Centers

> *"A vast opportunity exists for creating new research environments based upon cyberinfrastructure, but there are also real dangers of disappointing results and wasted investment for a variety of reasons including … lack of appreciation of social/cultural barriers, lack of appropriate organizational structures, inadequate related educational activities... The opportunity is enormous, but also enormously complex…" (*Atkins et al 2003, p.4)

This excerpt from the Atkins Report emphasizes the way in which ineffective management practices can waste resources and jeopardize large-scale computational research centers and collaborative environments. The management or such research centers should not be taken lightly – especially since the social and organizational elements may be the "hardest part" of these endeavors (David 2006). While the technical issues are critically important, it is equally important not to neglect the organizational and social elements.

Computational science environments are typically run as projects (Karasti et al 2010), and many of the available prescriptive advice and 'lessons learned' emphasize the need for strong project management practices (e.g., Spencer et al 2006). While strong project management is certainly important, these environments represent novel, lasting organizational forms that go beyond contemporary notions of project organization –the scale of some of the larger projects constitute mid-sized organizations in their own right. Further, these research centers produce a variety of software artifacts and other standards, the impact of which extends far beyond the project at hand (Spencer et al 2006).

Teams who win funding for developing the infrastructure for large-scale computational science (i.e. "cyberinfrastructure" Atkins et al 2003) are not simply managing a single project - they are designing and managing persistent organizations and developing long-lasting artifacts. These teams are involved with multiple projects (both NSF-funded and otherwise) and must reconcile competing resource demands while ensuring continuity across projects. They engage in a variety of activities beyond the design and delivery of research, including human resource management, customer service, quality improvement, strategic planning, accounting, and often software engineering. Most research center management teams, however, have little formal training in organizational management.

The proposed research involves a twofold effort: (1) to assess the practices, needs, and competencies of a variety of research centers with respect to organizational structures, standardized processes, and software methods; and (2) based on these findings, identify concepts and practices from the organizational and social science literature that are generalizable to this form of scientific organization, and then develop and deliver materials to guide center directors and their teams in these concepts and practices.

Next we briefly attend to existing studies of computational research centers and collaborative environments in order to contextualize this proposed effort. Then we briefly address domains where organizational science might potentially offer insight, followed by our proposed work plan.

Social Studies of Cyberinfrastructure

Much of the empirical work into computationally-intensive research centers and collaborative environments does so under the rubrick of studying "cyberinfrastructure" – the form of infrastructure that is designed to support "big science" (Ribes & Finholt 2009). This body of research finds its roots in the broader studies of infrastructure in general (Edwards et al 2009), but with one critical difference – typically cybernifrastructures are not yet embedded in scientific activity, but are being designed with the intention of one day becoming infrastructure (Bietz et al 2010). Therefore, it is important for center

managers – particularly those that aspire to the development of environments and technologies that will one day be described as "infrastructure" – to go beyond traditional project management practice and look toward the wider, foundational scope of such projects. Among the many insights from this literature, there are three critical issues that we have identified as particularly relevant to the long-term success of such systems: (1) the social elements of infrastructure; (2) the long duration of the projects and their effects; and (3) the emergent aspects of cyberinfrastructural projects. Next we briefly address each in turn.

Social elements of infrastructure

Traditional project management practices generally assume some sort of discrete technical goal as the outcome of the project. While social and organizational aspects of the project are sometimes considered, they are considered in the service of the technical goal which is the main goal of the project. Cyberinfrastructure projects aspire to create what will one day be infrastructural environments that are embedded in the practice of science (NSF 2007). But it is important to keep in mind that infrastructural environments are only partly technical, they are also social and political. Star and Ruhleder (1996) referred to technical issues as the level 1 contexts of infrastructure, which can be quite complex in their own right. However, they indicate that social and political elements of infrastructural design organization comprise level 2 and 3 contexts of infrastructure, which can be significantly more unpredictable, discontinuous, and complex.

As authentic infrastructure, then, the outcome is not entirely technical. Rather, the social and organizational aspects of the future infrastructure comprise just as important a component as the technical hardware and software infrastructure. Perhaps more important, since the software and hardware components can often be readily changed but the social elements of the future infrastructure will be institutionalized prior to being embedded, and therefore resist change (Ribes & Finholt 2007; Bietz et al 2010). Thus it is imperative that center managers look at cyberinfrastructure projects not only in terms of building the hardware and software platform of the future, but also building the path dependent organizational forms and institutionalized processes (routines) of the infrastructure.

The long duration of infrastructure

The need for long-term perspectives associated with infrastructural projects is the source of a significant tension in cyberinfrastructure projects (Ribes & Finholt 2009; Karasti et al 2010). The projects themselves require generally technical outcomes that must be delivered in specific time frames on a fixed budget. As Ribes & Finholt (2009, p. 378) indicate:

> *In thinking of persistent infrastructure, we must expand beyond the "tubes and wires" of technology to organizational arrangements. Just as Brand's clock [the 'clock of the long now' that rings once a millennium] does not stand apart from its community (the clock in Venice), a physical infrastructure is enmeshed with the routines and practical work of its use, upkeep, and repair.*

While cyberinfrastructure project managers are focused on "tubes and wires," the future organizational arrangements may be deemphasized or ignored. There is no certainty that cyberinfrastructure project managers will be funded beyond the current project, and attention and resources are scarce. Therefore, while it is critically important that the long-term view pervades efforts to design and grow the nation's future cyberinfrastructure, the natural way that projects are organized directly contradict this long-term perspective. Unless the NSF explicitly addresses the social and organizational issues, as well as longer-horizon issues associated with ethical organizing and sustainability, there is a real danger that many of these issues will go unaddressed. Specific attention to organizational forms and standardized processes – as well as the architectures and routines for changing processes – are critical to superior outcomes resulting from cyberinfrastructure projects.

Emergent elements of cyberinfrastructure

Hardware and software technologies are constantly changing in unpredictable ways and thus any long-term standards or architecture-based approach will necessarily be a complicated endeavor. Cyberinfrastructure projects compound this complexity because they are distributed geographically and across-disciplines (Edwards et al 2007) and distributed collaboration is necessarily a challenging task under any circumstances, but especially under conditions of groundbreaking science (Olson et al 2008). Further, cyberinfrastructure projects enable particularly open-ended opportunities for application (Atkins et al 2003). Because of the extreme complexity, cyberinfrastructure cannot possibly be comprehensively "designed" in the sense that some anticipated situation becomes realized, but instead should be nurtured or "grown" from a series of local adaptations enabled and integrated by key "gateway" organizations (Edwards et al 2007; Zimmerman & Finholt 2007). Therefore, flexible organizational forms do more to accommodate the emergent properties of cyberinfrastructure projects (Lee et al 2006), but this flexibility cannot come at the expense of critically important standard making (Lyytinen & King 2006).

Organizations aspiring to generate elements of infrastructure act as complex adaptive systems, and those that establish the processes for continually changing routines will be better equipped for adequately dealing with unpredictable, emergent activity (Hanseth & Lyytinen 2010). Thus, to handle emergence simultaneously with delivering value real-time, organizations need to develop robust routines (business processes) and at the same time intentionally develop routines for changing and adapting these routines. Organizational science refers to the routines that adapt and change existing routines as "metaroutines" (e.g., Feldman & Pentland 2003; Eisenhardt & Martin 2000; Adler et al 1999). Understanding metaroutines as they apply to cyberinfrastructure would be critical for effectively "growing" cyberinfrastructure.

The concept of metaroutines is one of many organizational insights that might apply in some way to cyberinfrastructure projects. Organizational scholarship has produced a body of knowledge that might be adapted to inform managerial activities in cyberinfrastructure projects. Next we briefly touch upon a variety of potential topics within organizational scholarship that may be adapted to inform cyberinfrastructural organizations.

Organizational Scholarship

For over half a century, a legion of scholars has studied organizational design and management. While organizational management is a complex task with no clear set of standard "best practices," there are a variety of well-established trade-offs, tensions, and guidelines associated with organizational design decisions and management practices. Although organizational researchers have not addressed the particular needs of cyberinfrastructure organizations, many of the key ideas from this body of literature might be adapted to the cyberinfrastructure context in some way.

In the domain of organizational design, for example, many of the canonical 'best practices' that address the traditional ways that managers should structure organizations offer timeless lessons for managers (e.g., Galbraith 1977, Mintzberg 1979). Beyond this, there is the work that addresses specific challenges such as interorganizational governance (e.g., Dyer & Singh 1998; Helper et al 2000), and collaborative, network forms of organizations (Moller & Halinan 1999; Yoo et al 2006). There are specialized prescriptions for managerial activities based on different types of organizations, as well, including high reliability organizations (Weick & Sutcliffe 2001), organizations focusing on different forms of product innovations (Baldwin & Clark 2000), research & development organizations (Thamhain 2003), and organizations looking to capitalize on "open" innovation (von Hippel & Von Krogh 2003).

A similar body of scholarship can be found across a variety of other organizational domains, including leadership (Miner 2005), business process management (Grover & Markus 2007), change management (Burnes 1996), and virtual teams (Martins et al 2004). In addition to this general work on organizational practices, there is a great deal of work that address different elements of software-related activities in organizations, including analysis of various software risk management practices (Lyytinen et al 1998), requirements elicitation techniques (Hansen et al 2008), IT project management (Mahring 2002), and software development methodologies in general (Hirscheim et al 1995; Berente & Lyytinen 2007).

To complement the (potentially) actionable management practices listed above, organizational scholarship also provides practicing managers a vocabulary which enables them to make sense of complex organizational pheonomena (Astley & Zammuto 1992). Popular examples of such sensitizing devices include March's (1991) distinction between exploratory and exploitative learning; Christensen's (1997) characterization of the "innovator's dilemma"; Weick & Roberts (1995) description of mindfulness, and Boland's (1995) perspective making and taking between different communities.

It is important to reiterate that cyberinfrastructural organizations embody radically novel ways of organizing, whereas most organizational research focuses on industrial corporations, so one must be cautious applying the lessons of this research directly. It is important to draw upon the emerging descriptive social studies of cyberinfrastructural organizations in combination with widespread data collection to identify which elements of organization research can be adapted to cyberinfrastructural purposes, and which practices might offer the most leverage.`

Study Activities

Before one can identify which managerial practices and ideas most apply to large scale computational research centers and collaborative environments, it is important to assess those environments: their current practices, their needs, and their managerial competencies. After assessing all of these factors and relating them to the relevant literature, we will then look to validate observations through quantitative analysis of the entire population of NSF-funded computationally intensive research centers. Only then can the appropriate materials be assembled to best guide center directors and their teams. Following we briefly describe each of these steps of the proposed research:

1. Exploratory Qualitative Research – Assessing Managerial Practices
The first phase of research will involve face-to-face interviews with managers and key personnel in a variety of computationally-intensive research centers. Centers included in the sample will be selected in an effort to maximize variety in an effort to gain understanding across the variety of types of centers – thus maximize the benefit of cross-case analysis (Yin 2003). Analysis will ensue throughout data collection generally following the Strauss & Corbin (1998) method for coding qualitative data (i.e., rounds of open, axial, and selective coding), combined with a constant comparison among the cases and between these findings and the relevant literature (Eisenhardt 1989) to identify areas where this literature may apply. This research will focus on assessing managerial practices, needs, and capabilities. Following we briefly address each.

- ***Assess current practices***
  The first step in the analysis will involve exploring the current practices of center managers and understanding the ways in which contemporary centers are organized. This will involve direct data collection and analysis across a variety of research centers. Although this research will be similar to existing studies on such projects (e.g., Zimmerman 2007; Zimmerman & Finholt 2007; Ribes & Finholt 2009; Bietz et al 2010, see also articles in Olson et al 2008), it will be different

across three key dimensions. First, the proposed study involves the assessment of as many different centers as possible, thus goes broader than these earlier studies. Second, the data collection will be more focused on managerial practices and challenges. Third, the goal of this research involves identifying relevant actionable concepts and prescriptions from the organizational literature. Although the data collection will necessarily be broader than previous empirical studies, we look to mitigate any lack of depth by drawing upon these previous studies and by narrowly focusing on managerial practices.

- ***Assess needs***
  While assessing current practices we will also actively seek to identify needs – both explicit and latent needs – for ideas and practices that might improve outcomes. We will identify these needs through constant comparison of those that were already identified by the literature, those we observe, and those mentioned by the interviewees. We will also cross-check identified needs with informants and across contexts (Yin 2003).

- ***Assessing capabilities***
  Throughout the data collection, we will be exploring the areas that center management teams are strong, and the areas they are weak. While data will be aggregated and anonymized, by understanding the educational backgrounds, experiences, and strengths and weaknesses of center management teams with respect to managerial practice, we would be able to potentially inform the recruitment of future directors and also to provide some evidence as to the managerial capabilities or lack thereof of center management beyond the anecdotal.

2. Workshop with Expert Panel

To leverage this exploratory effort, we will also host a panel of experts in an effort to begin validating and extending findings, as well as to further identify relevant knowledge and areas for further exploration. The expert panel will involve roughly 16 participants from two broad groups: (1) researchers who study cyberinfrastructure, and (2) organizational researchers from the relevant domains (organizational design, process management, software development, etc.). The main goal of this workshop will be to advise, critique, and extend the thinking of the researchers and help set the agenda for the second year of focused data collection.

3. Validating findings

Although the goal of the exploratory qualitative work will be to cast as wide a net as possible, it will not be possible to speak with all relevant individuals from all research centers. To address this issue, in line with mixed-methods research standards (Tashakkori & Teddlie 2003), following the analysis we will develop a survey instrument intended primarily to validate our perspectives about current practices, needs, and capabilities. We also might use this opportunity to test theoretical propositions identified in the qualitative case analysis. The goal will be to survey as many members of computationally-intensive research centers as possible. Concurrent with the survey administration, we will engage in a second round of exploratory qualitative research to address the areas that were identified in the first two steps as areas that merit further exploration.

4. Prepare materials

As a result of our assessment and validation activities, we will prepare a set of materials rooted in organizational scholarship intended to address the needs identified in the research. The focus of this step will be to amass a body of relevant and actionable organizational research with the intention of disseminating this work to NSF-funded managers and directors either directly or through educational workshops

Thus this study seeks to extend existing empirical work on computationally-intensive research centers and to identify relevant bodies of literature based on this analysis. Table 1 describes the work plan.

Table 1: Work Plan for Supporting Successful Design and Management of Research Centers Proposal

	Activities	***Deliverables***
Month 1	Identify sample personnel and contact centers	schedule appointments
Months 2-8	Qualitative data collection 1 / simultaneous analysis	transcriptions
Months 8-12	Data analysis / recruit postdoc	conference paper 1
Month 12	Workshop – expert panel	status report to NSF
Months 13-16	Quantitative (survey) development; Qualitative data collection 2 / simultaneous analysis	Transcriptions / survey instrument & pilot study
Months 17-21	Quantitative (survey) administration & qualitative data collection & analysis	conference paper 2
Months 22-24	Quantitative results analysis, prepare materials	report / materials for NSF; postdoc-led conference paper

Good fit for EAGER Funding

This research is appropriate for EAGER funding for two reasons. First, neither social studies of science nor organizational science research studies this particular form of computationally-intensive, collaborative research center, so this study is not a good candidate for support from other existing programs. Second, the studies of infrastructure that do exist do not look systematically at cyberinfrastructure from a perspective of organization science, so it is not clear what research is applicable and how to translate research into guidelines and support materials for those involved with cyberinfrastructure centers and teams. The impact of this research could be dramatic for the success of cyberinfrastructure projects. Managerial practices are a point of significant potential leverage within cyberinfrastructure projects, and even moderate improvements in managerial practices and designs of future cyberinfrastructure organizations can have a significant impact on society overall because at this critical time, those practices that are designed by contemporary cyberinfrastructure managers will be precisely the decisions that form the path-dependent organizational forms of the future.

Research Dissemination

There will be two distinct targets for research dissemination. The first will be NSF managers and the center managers of cyberinfrastructural projects funded by the NSF. In addition to the two reports to the NSF outlined in the work plan, the researchers will produce materials intended to guide cyberinfrastructure manager in applying certain practices to their projects, and to equip them with handling the complex tasks that accompany their cyberinfrastructural organizations. Secondly, because cyberinfrastructure projects represent such novel and unusual organizational forms in computationally intensive environments, we look to publish research in both organizational and information systems outlets. Organizational outlets include conferences like the Academy of Management Annual Meeting and journals like *Organization Science*. Information systems outlets include conferences like the International Conference on Information Systems and journals like *Information Systems Research*.

References

Adler, P. S., Goldoftas, B., & Levine, D. I. 1999. Flexibility versus efficiency? A case study of model changeovers in the Toyota production system. *Organization Science*, 10 (1): 43-68.

Astley W.G., and Zammuto R.F. (1992) "Organization Science, Managers, and Language Games," *Organization Science*, vol.3, n.4, pp. 443-460

Atkins, D. E., Droegemeier, K. K., Feldman, S. I., Garcia-Molina, H., Klein, M. L., Messerschmitt, D. G., Messina, P., Ostriker, J. P. & Wright, M. H. 2003 Revolutionizing science and engineering through cyberinfrastructure. Report of the National Science Foundation blue-ribbon advisory panel on cyberinfrastructure. Arlington, VA: US National Science Foundation.

Baldwin, C., and Clark, K., (2000) *Design Rules Vol. 1: The Power of Modularity*, MIT Press, Cambridge, Massachusetts.

Berente, N. and Lyytinen, K. (2007), "What is Being Iterated? Reflections on Iteration in Information Systems Engineering Processes," in Krogstie, J., Opdahl, A., and Brinkkemper, S., eds, *Conceptual Modeling in Information Systems Engineering*, Springer-Verlag Berlin Heidelberg (ISE Series Vol. 6), 2007.

Bietz, M.J., Baumer, E.P.S., and Lee, C.P. (2010) Synergizing in Cyberinfrastructure Development, *Computer Supported Cooperative Work*, July 7 2010.

Boehm, B. (1988) "A Spiral Model of Software Development and Enhancement," *IEEE Computer*, May 1988.

Boland Jr, RJ. And Tenkasi, R.V. (1995) "Perspective making and perspective taking in communities of knowing." *Organization Science*, v. 6 issue 4, 1995, p. 350.

Bowker, G.C., Baker, K., Millerand, F., and Ribes, D. (2010) "Towards Information Infrastructure Studies: Ways of Knowing in a Networked Environment," (in J.Hunsinger, M.Allen, L.Klasrup eds) *International Handbook of Internet Research*, Springer

Burnes, B. (1996) "No such thing as… a "one best way" to manage organizational change," *Management Decision*, 34(10), 11-18.

Christensen, C. (1997) *The Innovator's Dilemma: when new technologies cause great firms to fail*, Harvard Business School Press, Cambridge Mass.

David, P.A. (2006) "Towards a cyberinfrastructure for enhanced scientific collaboration: providing its 'soft'' foundations may be the hardest part." in D. Foray and B. Kahin (eds), *Advancing Knowledge and the Knowledge-Economy*, MIT Press, Cambridge, Mass.

Dyer, JH. and Singh, H. (1998)"The relational view: Cooperative strategy and sources of interorganizational competitive advantage." *Academy of Management Review*, v. 23 issue 4, 1998, p. 660.

Edwards, P., Jackson, S., Bowker, G. and Knobel, C. (2007). "Report to the NSF of a Workshop on 'History and Theory of Infrastructures: Lessons for new scientific infrastructures'," University of Michigan, School of Information.

Edwards, P., Jackson, S., Bowker, G. and Williams, R. (2009) "Introduction: An Agenda for Infrastructure Studies," *Journal of the Association for Information Systems*, 10(5): 364-374.

Eisenhardt, K.M. (1989) "Building Theories from Case Study Research," Academy of Management Review, 14(4):532-550.

Eisenhardt, K.M. and Martin, J.A. (2000) "Dynamic Capabilities: What are they?" *Strategic Management Journal*, 21(10-11):1105-1121.

Feldman, M.S. and Pentland, B.T. (2003) "Reconceptualizing Organizational Routines as a Source of Flexibility and Change," *Administrative Science Quarterly*, 48(1):94-118.

Galbraith, J. (1977) *Organizational Design*, Addison-Wesley, Reading, MA.

Grover, V and Markus, ML (2007) *Business Process Transformation* (Advances in Management Information Systems). M.E.Sharpe, Armonk NY.

Hansen, S., Berente N. and Lyytinen, K., (2009) "Requirements in the 21st Century: Current Practice & Emerging Trends," in Lyytinen, Loucopoulos, Mylopoulos, Robinson eds, Design Requirements

Engireering: A Ten-Year Perspective, Springer-Verlag (Lecture Notes in Business Information Processing Series Vol.14), 2009.
Hanseth, O. and Lyytinen, K. (2010) “Design theory for dynamic complexity in information infrastructures: the case of building internet.” *Journal of Information Technology,*, 2010, p. 1.
Helper, S., J.P. MacDuffie, and Sabel, C. “Pragmatic collaborations: advancing knowledge while controlling opportunism.” *Industrial and Corporate Change*, (9:3), 2000, p. 443. (Hirscheim et al 1995;
Karasti, H., Baker, K.S., and Millerant, F. (2010) “Infrastructure Time: Long-term Matters in Collaborative Development,” *Computer Supported Cooperative Work*, May 30, 2010
Lee, C., Dourish, P. and Mark, G. (2006): 'The Human Infrastructure of Cyberinfrastructure', *In Proceedings of the Conference on Computer Supported Cooperative Work* (CSCW '06), ACM Press, New York, NY, pp. 483-492.
Lyytinen, K., and King, J.L. (2006) “Standard making: a critical research frontier for information systems research,” *MIS Quarterly*, 30:405-411.
Lyytinen, K., Mathiassen, L. and Ropponen, J. (1998) “Attention shaping and software risk-A categorical analysis of four classical risk management approaches.” *Information Systems Research*, v. 9, 1998, p. 233.
Mahring, M. (2002) *IT Project Governance*, Elanders Gotab, Stockholm, 2002.
March, J.G. (1991) “Exploration and Exploitation in Organizational Learning,” *Organization Science*, 2(1):71-87.
Martins, L.L, Gilson, L.L. and Maynard, M.T. (2004) “Virtual teams: What do we know and where do we go from here?.” *Journal of Management*, v. 30 issue 6, 2004, p. 805.
Miner, J.B. (2005) *Essential Theories of Motivation and Leadership*, M.E. Sharpe Inc.
Mintzberg, H. (1981) *The Structuring of Organizations: a synthesis of the research*, Prentice-Hall.
Moller, K.K. & Halinan, A. (1999) “Business Relationships and Networks: Managerial Challenges of Network Era,” *Industrial Marketing Management*, 28:413-427.
NSF (2007) “Cyberinfrastructure Vision for 21st Century Discovery,” National Science Foundation, Cyberinfrastructure Council, March 2007.
Olson, G.M., Zimmerman, A., and Bos, N. (2008) *Scientific Collaboration on the Internet*, The MIT Press, Cambridge, Massachusetts.
Ribes, D. and Finholt, T. A. (2007): 'Tensions Across the Scales: Planning Infrastructure for the Long-Term', in Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work (GROUP ’07), ACM Press, New York, NY.
Ribes, D. and Finholt, T.A. (2009). “The Long Now of Technology Infrastructure: Articulating Tensions in Development,” *Journal of the Association for Information Systems*, 10(5): 375-398.
Spencer Jr, B.; Butler, R.; Ricker, K.; Marcusiu, D.; Finholt, T.; Foster, I. & Kesselman, C. (2006),'Cyberenvironment project management: lessons learned’. Technical report, NSF Grant CMS-0117853.
Star, S.L. and Ruhleder, K.(1996) “Steps toward an ecology of infrastructure: Problems of design and access in large information systems.” *Information Systems Research*, v. 7, 1996, p. 111.
Strauss, A. L. and J. M. Corbin (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, Sage Publications Inc.
Tashakkori, A. and Teddlie, C. (2003), *Handbook of Mixed Methods in Social & Behavioral Research*, Sage Publications.
Thamhain, H.J. (2003) “Managing innovative R&D teams.” *R and D Management*, v. 33 issue 3, 2003, p.297.
Von Hippel, E. and Von Krogh, G (2003) “Open source software and the" private-collective" innovation model: Issues for organization science.” *Organization Science*, v. 14 issue 2, 2003, p. 209.
Weick, K. E., & Roberts, K. H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly*, 38(3), 357-381.
Weick, K.E. and Sutcliffe. K.M. (2001), *Managing the Unexpected*, John Wiley and Sons.

Yoo, Y., Boland, R.J., and Lyytinen (2006) “From organization design to organization designing.” *Organization Science*, v. 17 issue 2, 2006, p. 215.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed. Vol. 5). Thousand Oaks: Sage Publications.

Zimmerman, A. S. (2007). A socio-technical framework for cyberinfrastructure design. *In Proceedings of e-Social Science*. Ann Arbor, MI, USA, October 7–9 2007, p. 10.

Zimmerman, A. and Finholt, T. A. (2007): 'Growing an Infrastructure: The Role of Gateway Organizations in Cultivating New Communities of Users,' *in Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work* (GROUP ’07), ACM Press, New York, NY.