Managing Cyberinfrastructure Centers in a Demanding Era:
The Development of Science Executives
Proposal for 4-year award

PI: Nicholas Berente, University of Georgia
Co-PI: John Leslie King, University of Michigan

Intellectual Merit

Systematically establish what science executives need to know about running centers for science and engineering work. Build a knowledge base required by leaders of cyberinfrastructure centers (hereafter referred to as CI center executives), mapping the growing body of scholarship from organization science to relevant, prescriptive understanding that will improve center outcomes. In the process, create a cadre of skilled science executives as well as those who can educate them in the work of the science executive.

Project Summary

The growing importance and spread of cyberinfrastructure across disciplines is driving center growth. This work builds on earlier studies to help center leaders move beyond project management and into organization science, making them "science executives." Science executives need special skills (Lloyd and Simpson 2005; Spencer *et al.*, 2011), and knowledge from business organizations does not simply transfer to this context. A custom curriculum must be crafted for the needs of science executives. The goal of this proposal is to develop and deliver customized executive education for CI center executives who are responsible for cross-disciplinary coordination as well as generation and administration of innovative technologies and practices. CI center executives are representative of next-generation science executives more generally, and this curriculum will translate to that broader audience.

Statement of Objectives

The objectives will be achieved through four activities in an adapted "spiral" strategy of iterative project management (Boehm 1988): (1) Identify the points of leverage within centers where improved executive leadership might affect science and engineering outcomes. This work is underway already through a two-year project (see Berente 2010 – NSF OCI EAGER Award 1059153); (2) Identify and disseminate "best practices" based on organization science to equip CI center executives with the skills, tools, and techniques; (3) Deliver effective, focused training to CI center executives through a modified "science executive education" strategy, followed by cyber-enabled learning and tutorials and classes dedicated to specific subjects; and (4) Conduct workshops, conference panels, and tutorials to evaluate and improve the curriculum and to disseminate knowledge gained throughout the project, in conjunction with a Research Coordination Network grant bringing together organization scientists and science executives in a series of workshops (see Berente and Howison 2011 – NSF OCI RCN Award 1148966). The final product will be a tested, standard curriculum for CI center executives along with a plan for continued delivery without direct NSF support after project completion.

Broader Impacts

Science executives will become better educated to run science and engineering centers, starting with CI center executives, enabling more and better science and a higher level of engineering accomplishment. Creation of a "science executive education" curriculum and a body of "best practices" will enable CI center executives and other science executives to become more efficient and effective, maximizing outcomes per dollar of funding to science and engineering centers.

Managing Cyberinfrastructure Centers in a Demanding Era:
The Development of Science Executives

1. Project Description

> *"…as managers rise, they must think more broadly, understand more comprehensively, and act in a more sophisticated manner. They must shift from tactical thinking to strategic thinking, from meeting objectives to conceptualizing the nature of the business. They must balance multiple forces, allocate scarce resources, and maintain the cohesive integrity of larger numbers of people and functions… In short, the executive function is radically different from the managerial function…" – Harry Levinson[1] (1981, p.84)*

1.1 Introduction

Science and engineering work is increasingly done in or through *centers*, which are a particular form of enterprise. Such centers should not be confused with either scientific projects or larger science and engineering institutions. Centers are broader and more enduring than projects, which are, by definition, temporary (PMI 2012). But centers are narrower in focus and more specialized than large science or engineering institutions such as universities, national labs and institutes, government agencies, or firms. Science and engineering centers span multiple projects and are typically components of larger institutions. They are increasingly the locus of contemporary collaborative, interdisciplinary, and computationally-intensive science and engineering work – a "middle-range" organizational form that is increasingly vital but not well-understood.

Most center leaders are scientists or engineers with strong project management skills. Few have been exposed to practices, frameworks, and theories from organization science that can potentially improve the effectiveness of their centers (Cummings and Keisler 2011). In short, as center managers evolve into executives (see Levinson's quote above), they do so with minimal formal guidance. Center executives learn how to manage and lead on-the-job, through a process of trial-and-error learning, much as entrepreneurs learn (Claggett and Berente 2012). Just as entrepreneurial organizations benefit from professional management as they grow, science and engineering centers can undoubtedly benefit from the lessons of organization science (Cummings and Keisler 2011; Berente and Claggett 2011). However, one must be careful transferring lessons from organization science to the management of centers, because, while centers are similar to other organizations in some regards, they are unique in others.

Science and engineering centers are complex hybrids of traditional and novel organizational structures, nested social networks, transitory roles, and ever-changing, "drifting" arrangements (Lee *et al*., 2006; Ribes and Lee 2010; Spencer *et al*., 2011). Contemporary science and engineering work is different than in the past, because such work is increasingly interdisciplinary, collaborative, distributed geographically, and computation and data intensive (Finholt 2003). It is increasingly complex and continually evolving. A century of organization science has shown how to achieve organizational effectiveness in a variety of complex contexts, and has covered a variety of topics that CI center executives face, such as: organizational governance; innovation management;

[1] Harry Levinson was a leader in the rise of contemporary executive education, serving in the 1960s and 1970s as a distinguished visiting professor of business at both the Sloan School of Management at MIT and the Harvard Graduate School of Business before moving to the Harvard Medical School in the 1980s. He founded the Levinson Institute on Leadership, which continues his work following his retirement.

resource provisioning; workforce development and turnover reduction; process improvement; and strategic leadership. Also, there is a strong tradition of "executive education" in management schools that has a successful track record in enabling executives to deal with complex organizational situations (*e.g.,* Vicere 1989; Mintzberg and Gosling 2002; Clegg and Smith 2003). However, explicit attention to science and engineering centers is sparse, so it is as yet unclear which lessons apply best, and which afford the most leverage to affect scientific outcomes.

This project will adapt relevant lessons of organization science to the needs of CI center executives through the iterative development and evaluation of a "science executive" education curriculum covering the skills necessary to improve the executive function in complex organizational contexts (*e.g.,* universities, government laboratories, industry). It will identify key issues and points of leverage for contemporary CI center executives, and draw upon organization science to develop and test a curriculum to increase the efficiency and effectiveness of these centers. As shown in Table 1, it builds on an EAGER award (NSF OCI-1059153) to Nicholas Berente of the University of Georgia, who is researching key challenges facing CI centers and mapping learning from organization science onto the needs of these centers. Thus far, the research shows that CI centers have proven effective for addressing the challenges of collaborative, interdisciplinary science and the centers that enable such science and engineering, but much remains to be done (Berente and Claggett 2011; 2012; Berente *et al*., 2011; Claggett and Berente 2012; Rubleske and Berente 2012).

	EAGER 1059153 (2010-2012)	RCN 1149866 (2011-2016)	Proposed project (2012-2016)
Needs assessment	Feasibility: - Interest - Initial requirements - Planning & scoping - Initial validation		
Requirements refinement, verification, validation		Workshops between organization scientists and CI center executives. Themes: - Virtual Organizing - Managing CI Centers - Scientific Software & CI Innovation	
Prototype development, implementation			Curriculum development Education sessions - Face-to-face full sessions & short sessions - CI enabled - Special classes & tutorials

Table 1: Objectives of the Work

The project will also build on the Research Coordination Network award to Nicholas Berente of the University of Georgia and James Howison of the University of Texas at Austin (NSF OCI-1148966). This RCN, which also enlists John Leslie King from the University of Michigan, includes a series of workshops bringing together diverse stakeholders from disciplinary domains, cyberinfrastructure experts, and organization scientists to build a community of expertise around leading collaborative research centers. Among the goals of the RCN is to determine which lessons from the NSF's Virtual Organizations as Sociotechnical Systems (VOSS) program apply to this domain, and to begin diffusing this knowledge. RCN workshops will be organized under three broad themes: (1) virtual organizations, (2) managing CI centers, and (3) scientific software & CI innovation.

Year	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**
EAGER 1059153	Interviews Literature review	Interviews Literature Review Workshop: Managing CI Survey				
RCN 1149866		Birds-of-a-Feather (SC11) Workshop: *Virtual Organizations*	2 Workshops: *Managing CI Centers & Scientific Software* Requirements validation & verification	Workshop: *Virtual Organizations* Requirements validation & verification	Workshop: *Managing CI Centers* Requirements validation & verification	Workshop: *Scientific Software & CI Innovation* Requirements validation & verification
This Project			SC12 short session executive education Preliminary full session executive education - Atlanta	SC13 short session executive education Full session executive education – Atlanta Testing of cyber-enabled learning	SC14 short session executive education Full session executive education – Atlanta Cyber-enabled learning Testing of special courses & tutorials	SC15 short session executive education Full session executive education – Atlanta Cyber-enabled learning Special courses & tutorials Move to sustainable model

Table 2: Events of the Projects

A lesson from the current projects is that effective understanding of the needs and key points of leverage for CI center executives could benefit from a concrete mechanism that can be used to: (1) test our understanding of the match between what science executives need and what they already know; and (2) translate and transfer relevant organization science knowledge effectively. As such a mechanism, we propose to develop a series of "prototypes" of formal (3-5 days) science executive education sessions, which will be complemented with shorter (half day) sessions. Further we will investigate CI enabled learning, and sessions for special topics as the project progresses. It is, as yet, unclear which forms of science executive education will apply to which audiences and for which purposes, but these are the lessons we will acquire throughout this project in conjunction with the RCN workshops described above (NSF OCI-1148966). The two projects will be tightly coordinated, and the RCN will serve to verify and validate the scope and lessons for the sessions, and also to help evaluate feedback. Table 1 shows the general scheme of the work in preparation for and within the spiral development strategy described in this proposal, and how the three projects will be integrated together.

The proposed project will be administered by the University of Georgia, and will run for four years. The period July 2012 through June 2013 will be used to assess key issues for CI center executives, and to develop and evaluate curriculum and delivery mechanisms. As shown in Table 2, a pilot executive education session will take place in June of 2013. A full executive education session will be provided in June of each year 2014 through 2016, and will be held at the University of Georgia's Executive Education Center in Atlanta's "Buckhead" neighborhood (http://www.terry.uga.edu/atlanta/).[2] Throughout the project, the curriculum will leverage the RCN workshops and annual sessions at appropriate scientific conferences, including one being proposed for SC12 in November of 2012. During 2014-2016 plans will be made for a transition away from core NSF support toward a new scheme in which participating organizations support ongoing training.

1.2 Background

Over the past 30 years science and engineering have become increasingly interdisciplinary, dependent on data and computation, and engaged with virtual, distributed teams. Cyberinfrastructure is an essential component enabling these trends. The landmark Atkins Report of 2003 states: "If *infrastructure* is required for an *industrial* economy, then we could say that *cyberinfrastructure* is required for a *knowledge* economy." By the time that report was released, cyberinfrastructure had already altered the landscape of science and engineering work. Scientific computation had become important in a wide range of fields by the 1980s, including integrated circuit design (Fitchner, *et al*., 1984), materials science (NMAB, 1988), and nuclear physics (Press, *et al*., 1981). NSF created a number of Supercomputer Centers as well as the Directorate for Computer and Information and Science and Engineering (CISE) in the 1980s to help build the bases of cyberinfrastructure for all of the sciences (Lax, *et al*., 1982; Bardon, *et al*., 1983). The Supercomputer Centers played a critical role in NSFNet, a key building block of what became the Internet (livinginternet, 2012). The Atkins report recommended that NSF create an Advanced

[2] Atlanta is a good location in part due to the Atlanta-Hartsfield Airport (ATL), the nation's busiest airport with more direct flights to locations around the world than any other airport in the U.S. ATL is rated the most efficiently run airport in the U.S. by the Air Transport Research Society, enabling carriers to provide reasonable flight rates and enabling travelers to move through the airport quickly. ATL has good direct connections via public transportation with many points in Atlanta.

Cyberinfrastructure Program to consolidate leadership (Atkins, 2003:ES6). The Office of Cyberinfrastructure was created for this purpose in 2007.

CI centers exhibit a common pattern: skilled domain scientists, engineers, or cyberinfrastructure experts become leaders through on-the-job learning. These individuals are talented in their fields of study, but they are seldom prepared to manage CI centers in complex organizational environments. Their skills in project management for medium and large-scale scientific and engineering endeavors are aimed at answering particular questions within given budgetary and time constraints. They run centers with core contracts for service provision (*e.g.,* "cooperative agreements") plus ancillary grants as concatenated projects, rather than as organizations facing ongoing challenges over an extended period of time. Contemporary scientific and engineering work is intertwined with the infrastructural innovation that is central to CI centers (Berente and Claggett 2012; Claggett and Berente 2012). Distributed and computationally-intensive work relies on provision of and continuous innovation in cyberinfrastructure, creating "generative tensions" that confuse the relationship between organizational and social phenomena, on one hand, and the technical innovation and research imperatives that underlie the work on the other (Ribes and Finholt 2009; Berente and Claggett 2011; Berente *et al*., 2011). Executives and users of computationally-intensive centers show classic entrepreneurial behaviors, acting as stewards of cyberinfrastructure and providing semi-stable structures to coordinate and integrate required interdisciplinary knowledge (Rubleske and Berente 2012). CI center executives must find ways to innovate while dealing with resource instability (mixes of scarcity and abundance) over time (Berente and Claggett 2012).

These centers draw their executives from a host of different disciplinary and technical backgrounds. They are faced with a variety of technical and organizational issues that increasingly face science and engineering more generally (*i.e.,* computational, distributed, interdisciplinary). As Table 1 shows, the RCN Award (Berente and Howison 2011) is building a community of organizational researchers and CI center executives who will work together on challenges, identify best practices, and apply relevant organization science to the special needs of collaborative research centers. A particular focus of the RCN is to determine which OCI VOSS-funded research might be most important to informing the practices of science executives. CI centers represent an exemplary case for developing and piloting a curriculum for science executives that can later be adapted to non-CI centers.

A needs assessment is already underway through six workshops that are part of the RCN Award. These will cover topics including: (1) virtual organizations for leadership and governance of distributed collaboration, (2) management of scientific software ecologies, and (3) the challenges of leading infrastructural innovation. The first of these workshops, focused on virtual organizations as sociotechnical systems, will take place in May, 2012 at Case-Western Reserve University in Cleveland. The second will take place in early November of 2012 at the University of Michigan in Ann Arbor, and if this proposal is funded, will focus in part on the development of a curriculum for the pilot course in Atlanta.

The broader CI center community has also been engaged in discussion of the needs of CI center executives through a "birds of a feather" session that was held by the RCN project at the 2011 International Conference for High Performance Computing, Networking, Storage and Analysis in Seattle (SC11). The standing-room-only crowd of more than 100 participants recommended that a tutorial be held at SC12. Attendees suggested going beyond tutorials to focused training to improve leadership of CI centers as "going concerns." Specific challenges identified at the BoF session at SC 11 included the following four issues, mapped into the RCN design:

- **Matching sources and uses for funds over time.** CI centers that operate on cooperative agreement and grant funds (common in academic centers) or as line-items in budgets (common in industry and in some government laboratories) have difficulty reconciling project-based strategies with ongoing CI center needs. This becomes more difficult as expectations of compliance increase and funds cannot be spent for needs not strictly specified by funders. CI centers that got “up and running” find it difficult to “stay in business.” The end of a project does not mean the end of the CI center, which often provides ongoing services to clients who cannot afford to or are not allowed to cover center costs that exceed the services they receive. Making ends meet is difficult for CI center executives. This is seen as exemplary of “Managing CI Centers” from the RCN proposal.

- **Explaining the “value-added” of CI centers to various constituencies.** CI center beneficiaries understand the importance of the center. CI centers increasingly face pressure from to explain the value they provide and why their host organization should fund them. This pressure can come from higher-level administrators, board members, public officials or shareholders. Center executives are seldom prepared to address such questions. This is another example of Managing CI Centers as noted in the RCN proposal.

- **Hiring and retaining the right experts and employees.** CI centers need people who can stay at the leading edge while cyberinfrastructure changes rapidly. Computer systems at the top of the Top 500 list of supercomputers (http://top500.org/) quickly sink to the middle or even the bottom. People at the leading edge know they are valuable. They might or might not be motivated only by or even mainly by monetary compensation. They can better their situation by moving. As cyberinfrastructure becomes more important competitive pressures increase. CI centers are already raiding each other, bidding up salaries, and raising expectations among top employees. CI center executives are increasingly called on to be sophisticated workforce executives. This is yet another example of Managing CI Centers as discussed in the RCN proposal.

- **Managing the socio in socio-technical.** CI centers are socio-technical. Technology often does not work well in context, is complicated to use, or is unreliable, inconsistent, resisted, or worked-around. People are confused when power relationships change, incentives are distorted, and communication problems arise. As CI-related work becomes more important, socio-technical challenges increase. This fits with both the issues of Virtual Organizing and Scientific Software and CI Innovation as discussed in the RCN proposal.

The work of the EAGER and RCN awards is benefiting from greater exposure to the specific needs of CI center executives. To a greater extent than anticipated, the challenges facing practitioners focus specifically on managing CI centers. The need for improved skills in CI center executives is a rate-limiter for cyber-enabled science and engineering. Hiring people already skilled in center management is prohibitive because there are few such people available at a time when demand is growing. Putting general managers without cyberinfrastructure or domain science and engineering skills in charge is unwise. CI center executives cannot stop their jobs and go for extended executive training. A mix of science executive education as found in the realm of business and public administration, followed by ongoing reinforcement through collaboration infrastructure and networking, will permit practicing CI center executives to strengthen their skills and augment their learning over time. The remainder of this proposal explores the prototyping strategy for improving CI center executive skills, suggests how it might be applied, and outlines a plan to strengthen CI center management.

1.3 The Project Approach

The first question is whether there is good reason to believe that CI center executives can be prepared to do the difficult work that lies before them. The evidence suggests that this can be done through executive education. Formal executive education began in the late nineteenth century but was extended dramatically during World War II to help manufacturing managers shift to wartime production (Crotty and Soule 1997). Between 1890 and 1940 knowledge about how to run industrial organizations expanded, especially regarding the multidivisional (M-Form) organizations pioneered in the US automobile industry in the early 20th century (*c.f.* GM CEO Alfred Sloan's memoirs, 1957). Chandler (1962) and Williamson (1975) enshrined this knowledge, reinforcing the insight that managerial knowhow could be *taught.* Globalization and the rapid scaling of industry between 1960 and 1990 caused growth in executive education (Vicere 1989). Executive education exploded in the 1990s as the digital revolution, cost-cutting, business process reengineering, mergers and acquisitions, and new partnerships and alliances became common (Conger and Zin 2000). As a result of increasing turbulence from competition and technological change, executive education focused on the skills, tactics, and mindsets required to help business leaders cope with complex change (Ready *et al*., 1993).

Contemporary executive education focuses on experienced senior executives who are already mature, knowledgeable, successful, and highly motivated (Crotty and Soule 1997). It has moved away from unidirectional teaching of established rules for managing that were common in the earlier era, and toward new technologies and new ways of organizing production that enable executives to transform and revitalize organizations and keep pace with continuous innovation (Crotty and Soule 1997; Clegg and Smith 2003). Contemporary executive education explores organizational issues through collaborative sessions with veteran faculty members and other senior executives; allows executives to analyze and reflect on the applicability of their ideas to their organization's contexts; and encourages executives to explore analogous contexts (Clegg and Smith 2003). In the words of two executive education leaders:

> *"Learning occurs where concepts meet experiences through reflection. The faculty may need to teach, but mostly the participating managers need to learn. In other words, they are not vessels to be filled with knowledge, but active learners who must be fully engaged in the process… [executive education involves] confronting old beliefs with new ideas… managers have at least as much to learn from each other as they do from us." (Mintzberg and Gosling 2002, p.66)*

Unlike MBA programs, contemporary executive education leverages senior executive experience for leading innovation and change in situations that seldom welcome innovation or change. It touches every aspect of organizing, transcending the disciplinary silos of "function" (*e.g.,* accounting, marketing, finance) and emphasizing multidisciplinarity (Pfeffer and Fong 2002). The best candidates for such education are experienced executives with sufficient authority and accountability to effect change and who can be removed from everyday activity on a periodic basis (Tushman *et al*., 2007). Such education develops executive skills in leadership, the administrative mindset, and human and organizational values (Mintzberg and Gosling 2002; Doh 2003; Grey 2004). Its goals are ambitious, but it meets those ambitious goals through customized, specialized programs that have replaced all-purpose, open admission programs. The best programs are tailored to particular industries and organizations, organized around initial research into the issues of concern, initial delivery of the program, assessment of the program, and ongoing delivery across multiple years (Tushman *et al*., 2007). Clinical or "action" components allow executives to collaborate, identifying and solving real organizational problems by applying new ideas (Pfeffer and Fong 2002). A research component focused on evidence-based management builds sophisticated views of organizational phenomena, and provides tactics by which executives can debunk popular but ineffective fads encouraged by consulting firms (Burke and Rau 2010; Tushman and O'Reillley 2007; Tushman *et al*., 2007). Those running the program and those benefiting from it must commit to the program over time, ideally through a cohort structure (Tushman *et al*., 2007; Conger and Zin 2000).

Ongoing research into what works and what does not separates the best executive education programs from the many offered by more than 500 AACSB-accredited business/management schools in the US. These programs serve as guidance for this proposal, proving that senior executives can be prepared to address change through targeted education. This research also emphasizes the importance of face-to-face learning (Mintzberg and Gosling 2002) – a finding consistent with research on scientific collaboration that shows the importance of early face-to-face engagement for subsequent "on-line" learning components (Olson, et. al., 2008). Unfortunately, the materials developed for business-oriented executive education programs do not map onto the needs of CI center executives. Business/management schools focus on organizations in competitive industries, while most CI centers focus on pre-competitive work in the basic sciences and engineering. Nor is it just a matter of business competition: the few high-quality executive education programs in public administration do not focus on problems faced by CI center executives. Most executive education is aimed at organizations with command-and-control structures in which clear lines of authority radiate down to low-level workers and upwards toward elected officials or the board. CI center executives, in contrast, work with skilled researchers who operate more like franchisees than employees. Referent authority (authority from a person's substantive knowledge) is often more important than formal authority. Some of these researchers have secure employment (*e.g.,* academic tenure), and cannot simply be told what to do. CI center executives need executive education materials developed for the challenges they face. This project will develop those materials.

The proposed project follows a strategy for the development of three series of prototypes, each of which is discussed below. See Table 2 for a summary of the activities each year for the project, but note that these activities do not coincide precisely with specific events and the activities mentioned here sometimes "bracket" events listed in Table 2.

- **Prototype Series 1: Full Session "Science Executive" Education.** The primary deliverable of the project is expected to be a full-session science executive education program. Each session is 3-5 days in length, to be held in Atlanta each June. The development of this program will entail the generation and testing of "prototype" sessions over the course of the project, with each preceeding session a "prototype." Each session will benefit from the lessons of the previous session, combined with the other activities from the project, and the result will be a robust and validated baseline science executive education session with an initial crop of trained scientists and a number of experienced educators who can deliver subsequent sessions.

  There are two dimensions to the formal education of science executives. First is a pedagogical dimension, the importance of face-to-face engagement to start the process. Research on successful collaboration has shown that early, co-located experience is necessary to prepare groups for ongoing learning through collaboration technologies (Olson, *et al*., 2008; Mintzberg and Gosling 2002). The other is content – having the right materials to study. Both come together under executive education. Executive education, as used in this proposal, builds on the proven success of business-oriented programs over the past half-century, but develops curriculum relevant to baseline and advanced knowledge that all CI center executives must have.

The principals in the proposed project have considerable executive education experience. Nicholas Berente has taught in the executive education programs at the Weatherhead School of Management at Case Western Reserve University. John Leslie King was on the faculties of computer science and management at the University of California, Irvine for 20 years. He taught in executive programs at UCI's Paul Merage School of Business as well as in other business schools (*e.g.,* the Haas School of Business at UC Berkeley, Harvard Business School, the Fuqua School at Duke University), and participated in many executive education programs provided by major consulting firms. Berente has been learning about the needs of science executives through his research, and King has been serving for a number of years on key advisory and review committees related to new approaches to science and engineering.

- **Prototype Series 2: Short Sessions, Tutorials and Special Courses.** To complement the longer, formal science executive education sessions, we will run a shorter session in the form of yearly tutorials at major meetings (*e.g.*, that proposed for SC 12). These shorter sessions will test the efficacy of smaller, directed training in conjunction with a major event, and will also facilitate collection of information to guide the development of the executive education component. The tutorials will also provide a venue for special courses on particular topics, which will be developed in the latter half of the project on topics found to be particularly relevant in the first portion of the project. It is hoped that SC or a similar meeting might be a primary venue for delivery of short session executive education component. The risks associated with this course are primarily associated with the cooperation of the organizers of such meetings – they may not agree to make the tutorials part of the official conference agenda. If such cooperation is not forthcoming, a secondary course of action would be to arrange sessions before or after the conference with local hotels to capitalize on the conference without formally being part of it.

- **Prototype Series 3: Cyberinfrastructure-Enabled Learning.** Cyberinfrastructure-enabled learning has precursors in "distributed" learning that has been around for many decades (*e.g.,* correspondence courses), but differs in important ways. Relatively slow forms of communication such as physical mail meant that successful learners needed strong autodidactic skills (self-direction, the ability to figure things out for themselves). Cyberinfrastructure-enabled learning benefits from rapid, interactive communication such as real-time, two-way video conferencing as well as rich media that allow modeling, simulation, and visualization. Emerging techniques allow instructors and learners to take advantage of these technological affordances.

  Details for cyberinfrastructure-enabled learning in this project remain to be developed. Content will be produced by the instructors and by early participants in the project, and will be delivered through a combination of webinars, on-line courses, and wiki or blog materials produced by and for the community. A potential outcome would be for the participants to eventually take over with less frequent input from the instructors. Both Berente and King have extensive experience in such learning, with Berente having pioneered use of web-based learning in his earlier teaching and consulting work, and King having played a significant role in the development of the University of Michigan's on-line learning capabilities.

1.4 Curriculum Development

There is a growing body of work in organization science that can potentially inform the science executive. Contemporary scientific and engineering practice is moving away from disciplinary, single-location, individualistic research, and toward interdisciplinary work in distributed teams (Cummings and Keisler 2011). Organizational learning, innovation, knowledge integration, coordination, and social influences in organizing are key themes of this work. Of special interest to this proposal are coordination and collaboration. Both are important for CI centers because the scientists and engineers who lead research collaborations are usually not experienced in running large-scale, distributed organizations that must strike a balance among a variety of competing pressures or "tensions" (Cummings and Keisler 2007; Ribes and Finholt 2009). Balance must be struck between: long-term and short-term goals; temporary projects and permanent organizations; planning and spontaneous action; and standardization and fluid technical innovation (Ribes and Finholt 2009). The findings from this earlier work have been reinforced by the results of the EAGER and RCN projects. Three aspects of organization science inform curriculum development with mapping to the topic areas developed in the RCN workshops:

- ***Organization Design:***
  Traditional knowledge about how best to structure organizations (*e.g.*, Galbraith 1977, Mintzberg 1979) remain relevant, but contemporary research on business models (*e.g.*, Osterwalder *et al*., 2005) can help center executives bring resources to bear on contemporary organizational strategies. Challenges of interorganizational governance (*e.g.*, Dyer and Singh 1998; Helper *et al*., 2000), collaborative, network forms of organizations (Moller and Halinan 1999; Yoo *et al*., 2006), "virtual teams" (Martins *et al*., 2004), and distributed team collaboration (Boh *et al*., 2007) must be engaged. Special attention will be paid to prescriptions for executive activities in high-reliability organizations (Weick and Sutcliffe 2001), organizations involved in product innovation (Baldwin and Clark 2000), organizations doing research and development (Thamhain 2003), and organizations looking to capitalize on "open" innovation (von Hippel and Von Krogh 2003).

- ***Managing Innovation and System Development:***
  The management of innovation involves understanding organizational learning and organizational memory, as well as the nature of trial-and-error problem solving which is rife with unpredictable outcomes (March 1991; Cohen and Levinthal 1990). Although outcomes are unpredictable, innovation can be guided by structuring applicable processes, and by anticipating those patterns of innovative activity that occur with regularity (Van de Ven *et al*., 1999; Baldwin and Clark 2000; Christensen 1997). Innovation entails engagement among knowledge communities, and embedding knowledge in organizational practices (Dougherty 1992; Boland and Tenkasi 1995; Kogut and Zander 1994). Executives must continually change routines to provide the ability for organizations to deal with unpredictable, emergent activities. They do this by creating robust "metaroutines" that include mechanisms to change and adapt routines to new circumstances (Hanseth and Lyytinen 2010; Feldman and Pentland 2003; Eisenhardt and Martin 2000; Adler *et al*., 1999; Grover and Markus 2007; Cooper 1990). Examples of metaroutines include system development methodologies that address emergent concerns associated with software risk management, requirements elicitation techniques, IT project management, distributed software development, and software development methodologies in general (Lyytinen *et al*., 1998; Hansen *et al*., 2008; Hirscheim *et al*., 1995; Mahring 2002; Herbsleb and Mockus, 2003; Berente and Lyytinen 2007).

- ***Leadership:***
  Leadership in CI centers is usually associated with project management (Cummings and Keisler 2007; 2011; Karasti *et al.*, 2010), although in practice it more accurately resembles entrepreneurial leadership (Claggett and Berente 2012). Certain entrepreneurial practices can be taught and shared and broad leadership skills are best improved through education on commonalities across organizations that sensitize leaders to appropriate leadership approaches (Suchman 2000, Garud and Karnoe 2003; Doh 2003; Miner 2005). Change management is a critical area for entrepreneurial leadership, since executives must initiate and garner the commitment of organizational opinion leaders while overseeing complex organizational transitions (Burnes 1996).

Organization science covers organizational design, innovation, and leadership, but not in the particular way these challenges are faced by CI center executives. CI centers often embody novel ways of organizing that work well, and the curriculum must guide executives so they can stay with and reinforce what is working well, while changing that which does not work well. Close collaboration with CI center directors during the curriculum development process is in order. For this purpose, we will appoint an Advisory Committee of four people with specific knowledge about such centers. Illustrative prospects might include Stan Ahalt, Dan Atkins, Fran Berman, Jay Bouisseau, Deborah Crawford, Thom Dunning, Michael Levine, Tinsley Oden, Dan Reed, Ralph Roskies, Jim Bottum, Larry Smarr, and others.

2 Project Plan and Timeline

2.1 Project Plan: Spiral Development

The project will adapt the spiral strategy of development, pioneered by Boehm (1988) for development of complex software artifacts. This strategy has been used successfully in a variety of development projects, including the NSF GENI Project (http://www.geni.net/). Figure 1 below shows the strategy, which illustrates the multiple "rounds," or iterations, through the generation and testing in a solution development process. The main advantage of the spiral development strategy is that the project is seen as a set of iterations through (1) objective determination and scope setting, (2) evaluation of alternatives and risk management, (3) development and evaluation, and (4) planning for the next iteration. This is in contrast to the concept of linear development, proceeding from requirements analysis through specification and design, development, implementation, and evaluation. When the precise shape of the complex solution is not known at the outset of the design process, iterative development is appropriate for learning about both the problem and its solution, particularly where high visibility to the process is in order (Berente & Lyytinen 2008). In normal development practice, development actually occurs through a series of prototypes that explore and prove concepts, give the intended beneficiaries a sense of what they will get, elicit detailed feedback from the intended beneficiaries, and implement that feedback in the design of the operational prototype and eventually the deployed system. We anticipate that an adaptation of the spiral strategy will be appropriate for this project.

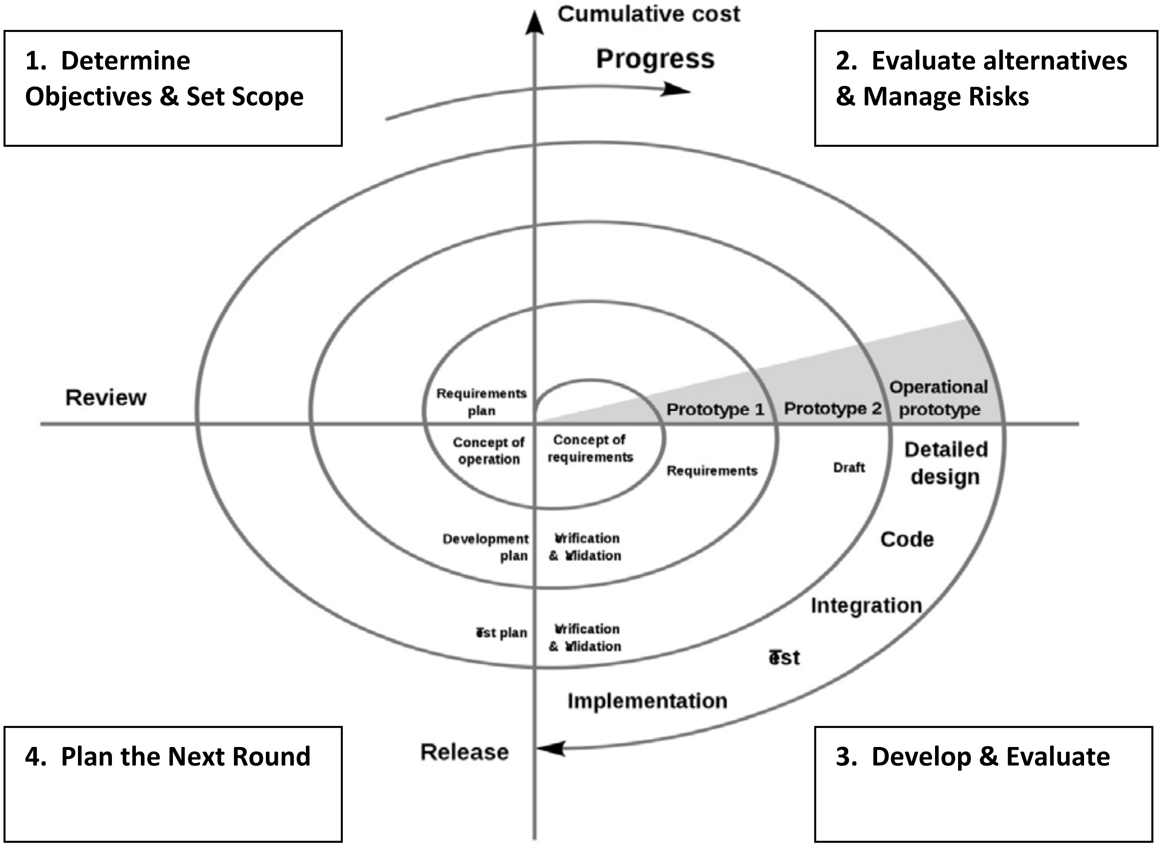

Figure 1: The Spiral Strategy
(Image adapted from: http://en.wikipedia.org/wiki/Barry_Boehm)

2.2 Timeline

The project will run from July 1, 2012 through June 30, 2016. Each year represents one round, or a single iteration in the spiral strategy. Note that this is an emergent process and, according to the spiral strategy "next steps" are to be developed at the end of each round. Therefore the following is subject to change upon learning on the part of the investigators. The current plan for the work on the project is as follows:

Round 1: July 2012 – June 2013

1.1 Determine Objectives & Set Scope

- April 2012 – Propose tutorial session for SC 2012.
- April – June 2012 – Document focal areas of concern for CI Center managers which have the potential to be addressed through executive education. Not all areas can be equally addressed through executive education, and in the early scoping the investigators will work with center managers through the RCN, in addition to exploring the results from the previous research, to identify the key domains that can be addressed through executive education and can provide the most leverage to drive results.

1.2 Evaluate Alternatives & Manage Risk

- July – September 2012 – Determine the appropriate sources of organization science to address the areas identified in the first round (with PhD student research assistance); also identify relevant materials and best practices for executive education in these topics.
- October 2012 – Present early stage materials and ideas for evaluation and risk assessment at the Ann Arbor workshop under the RCN Award. Focus on collaborative curriculum development with organization scientists and CI center executives for the SC12 Tutorial in November and the first stage executive education courses for the pilot offering in Atlanta in June of 2013.
- November 2012 – Tutorial at SC 2012 .

1.3 Develop & Evaluate

- December 2012 - May 2013 – Complete development of first year curriculum. Identify and recruit likely candidates for the pilot workshop in Atlanta. Provide materials to stakeholders.
- April 2013 – Propose tutorial session for SC 2013 (or alternative venue).
- June 2013 – Pilot executive session in Atlanta. The final half-day of the executive session will be devoted to evaluation of the session and guidance for the remainder of the project.

1.4 Plan the Next Round

- July 2013 – Write a report to NSF detailing the first round and the curriculum, relevant lessons learned, and identifying the plan and any relevant adjustments for Round 2.

Round 2: July 2013 – June 2014

2.1 Determine Objectives & Set Scope

- April – June 2013 – Refinement of focal areas of concern for CI Center managers that can be addressed through executive education.

2.2 Evaluate Alternatives & Manage Risk

- July – September 2013 – Determine additional sources of organization science to address the areas identified in the first round (with PhD student research assistance); also identify additional materials and best practices for executive education in these topics.
- October 2013 – Present early stage materials and ideas for evaluation and risk assessment at the Austin workshop under the RCN Award. Focus on collaborative curriculum development with organization scientists and CI center executives for the SC13 Tutorial in November (or alternative venue) and the second stage executive education courses for the pilot offering in Atlanta in June of 2014.
- November 2013 – Tutorial at SC 2012 (or alternative venue) .

2.3 Develop & Evaluate

- December 2013 - May 2014 – Complete development of second year curriculum. Identify and recruit likely candidates for the pilot workshop in Atlanta. Provide materials to stakeholders.
- April 2014 – Propose tutorial session for SC14 (or alternative venue).

- June 2014 – Deliver executive session in Atlanta. The final half-day of the executive session will be devoted to evaluation of the session and guidance for the remainder of the project.

2.4 Plan the Next Round
- July 2014 – Write a report to NSF detailing the early rounds and the curriculum, relevant lessons learned, and identifying the plan and any relevant adjustments for subsequent rounds.

Round 3: July 2014 – June 2015
- Similar pattern and timing as Round 2 with greater emphasis on longer-term sustainability of science executive education. Coincides with 3rd year of RCN.

Round 4: July 2015 – June 2016
- Similar pattern and timing as previous rounds. Coincides with 4th year of RCN.
- June 2016 - Final full executive session in Atlanta; transition to self-sustaining business scheme.
- July 2016 - Final report to NSF with evaluation of entire project and self-sustaining plan going forward.

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.

Atkins, D., et al., (2003) Revolutionizing Science and Engineering Through Cyberinfrastructure: Report of the National Science Foundation Blue-Ribbon Advisory Panel on Cyberinfrastructure. Washington DC: National Science Foundation. Online as of February 14, 2012 at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=cise051203

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

Bardon, M. and Curtis, K.K. 1983. A National Computing Environment for Academic Research. Washington, D.C.: National Science Foundation. Available on-line as of February 14, 2012 at www.lib.muohio.edu/multifacet/record/mu3ugb3447607

Berente, N. (2010) Supporting Successful Design and Management of Research Centers, NSF VOSS project: http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=1059153&WT.z_pims_id=503256

Berente, N. and Claggett, J. (2012) “Feast and Famine: Resource scarcity, slack, and digital infrastructure innovation,” Academy of Management (AOM) Annual Meeting, Boston, Mass, August 3-7, 2012.

Berente, N. and Claggett, J. (2011) “"Challenges in the Management of High-Performance Computing Centers: An Organizational Perspective,” Supercomputing 2011, Seattle, WA, Nov.12-18, 2011.

Berente, N.; Claggett, J. and Rubleske, J. (2011) "Generative Tension and the Management of Infrastructural Innovation,” INFORMS Annual Meeting, Charlotte, NC, Nov.14-16, 2011.

Berente, N. and Howison, J. (2011) Research Collaboration Network for Managing Collaborative Research Centers, NSF VOSS Project: http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=1148996&WT.z_pims_id=503256

Berente, N. and Lyytinen, K., (2009), "Iteration in Systems Analysis and Design: Cognitive Processes and Representational Artifacts," in Chiang, Siau, & Hardgrave eds, Information Systems Analysis and Design: Techniques, Methodologies, Approaches, and Architectures, M.E. Sharpe, Inc. (AMIS Monograph Series, Volume 15), 2009.

Boehm, B. “A Spiral Model of Software Development and Enhancement” IEEE Computer Volume 21 Issue 5, May 1988, pp 61 - 72.

Boh, W.F., Ren, Y., Kiesler, S., and Bussjaeger, R. (2007) Expertise and Collaboration in the Geographically Dispersed Organization. Organization Science 4: 595-612.

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.

Burke, L.A. and Rau, B. (2010) “The Research-Teaching Gap in Management,” Academy of Management Learning & Education, Vol.9, No.1, 132-143.

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

Chandler, A. (1962). Strategy and Structure: Chapters in the history of the American industrial enterprise, Cambridge, MA: MIT Press.

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

Claggett, J. and Berente, N. (2012) “Organizing for Digital Infrastructure Innovation: The Interplay of Initiated and Sustained Attention,” Hawaiian International Conference on System Sciences (HICSS-45), Maui, Hawaii, Jan. 4-7, 2012.

Clegg, S.R. and Smith, A.R. (2003) “Revising the Boundaries: Management Education and Learning in a Postpositivist World,” Academy of Management Learning & Education, Vol.2, No.1, 85-98.

Cohen, W.M. and Levinthal, D.A. (1990) “Absorptive Capacity: A New Perspective on Lerning and Innovation,” Administrative Science Quarterly, Vol.35, No.1, 128-152.

Conger, J.A. and Xin, K. (2000) “Executive Education in the 21st Century,” Journal of Management Education, 24:73.

Cooper, R.G. (1990) “Stage-Gate Systems: A New Tool for Managing New Products,” Business Horizons, May-June 1990.

Crotty, P.T. and Soule, A.J. (1997) “Executive Education: yesterday and today, with a look at tomorrow,” Journal of Management Development, Vol.16, No.1.

Cummings, J. N., & Kiesler, S. (2007). Coordination costs and project outcomes in multi-university collaborations. Research Policy, 36(10), 1620-1634.

Cummings, J. and Keisler, S. (2011) “Organization Theory and New Ways of Working in Science,” Atlanta Conference on Science and Innovation Policy, 2011

Dougherty, D. (1992) "A Practice-Centered Model of Organizational Renewal Through Product Innovation," Strategic Management Journal (13), pp. 77-92.

Doh, J.P. (2003) “Can Leadership Be Taught? Perspectives from Management Educators,” Academy of Management Learning and Education, Vol. 2, No.1, 54-67.

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.

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.

Fitchner, W. Nagel, L.W., Pneumalli, B.R., Petersen, W.P., and D’Arcy, J.L. (1984) The Impact of Supercomputers on IC Technology Development and Design. Proceedings of the IEEE, Vol. 75, No 1., January, pp. 96-112. Available on-line as of February 14, 2012 at http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=01457090

Finholt, T.A. (2003) Collaboratories as a New Form of Scientific Organization, Econ. Innov. New Techn.12(1), 5-25

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

Garud, R. and Karnoe, P. (2003) “Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship,” Research Policy 32, 277-300.

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.

Herbsleb, J. and Mockus, A. (2003). An empirical study of speed and communication in globally-distributed software development. IEEE Transactions on Software Engineering, 29(3):1–14.

Hirschheim, R., Klein, H.K., Lyytinen, K. (1995) Information Systems Development and Data Modeling: Conceptual and Philosophical Foundations, Cambridge University Press

Karasti, H., Baker, K.S., and Millerant, F. (2010) "Infrastructure Time: Long-term Matters in Collaborative Development," Computer Supported Cooperative Work, May 30, 2010

Kogut, B. and Zander, U. (1996) "What Firms Do? Coordination, Identity, and Learning, Organization Science, Vol.7, No.5, 502-518.

Lax, P.D. (1982). Report of the Panel on Large Scale Computing in Science and Engineering. Washington, D.C.: Department of Defense and National Science Foundation. Available on-line as of February 14, 2012 at www.pnl.gov/scales/docs/lax_report1982.pdf

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.

Levinson, H. (1981) "Executive Development: What You Need to Know," Training and Deelopment Journal, 1981, 84-95.

Livinginternet (2012) "NSFNet: National Science Foundation Network." Available on-line as of March 1, 2012 at http://www.livinginternet.com/i/ii_nsfnet.htm

Lloyd, S. and Simpson, A. (2005) "Project management in multidisciplinary collaborative research," IEEE International Professional Communications Conference, Limerick, Ireland, 2005, 602-611.

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.

Mintzberg, H. and Gosling, J. (2002) "Educating Managers Beyond Borders," Academy of Management Learning and Education, Vol.1, No.1, 64-76.

Moller, K.K. & Halinan, A. (1999) "Business Relationships and Networks: Managerial Challenges of Network Era," Industrial Marketing Management, 28:413-427.

NMAB (National Materials Advisory Board) 1988 The Impact of Supercomputing Capabilities on US Materials Science and Technology. Washington, DC: National Research Council Committee on Computer Simulation and Analysis of Complex Material Phenomena. Available on-line as of February 14, 2012 at http://hdl.handle.net/2027.42/27783

Olson, G., Zimmerman, A., and Bos, N. (Eds.) Scientific Collaboration on the Internet. Cambridge, MA: MIT Press, 2008.

Osterwalder, A., Pigneur, Y., and Tucci, C.L. (2005) "Clarifying Business Models: Origins, Present, and Future of the Concept," Communications of the AIS, Vol.15, May 2005

Pfeffer, J. and Fong, C.T. (2002) "The End of Business Schools? Less Success Than Meets the Eye," Academy of Management Learning and Education, Vol.1 No.1, 78-95.

PMI (2012) Project Management Book of Knowledge (PMBOK), Project Management Institute (PMI), www.pmi.org

Press, W.H., Bardsley, J.N., Freeman, A.J., Killeen, J. McBryan, O., MacDonald, W.M., Max, C.E., Orszag, S., Smarr, L.L., Wilson, K.G. (1981) Prospectus for Computational Physics: Report by the Subcommittee on Computational Facilities for Theoretical Research, Advisory Committee for Physics, Division of Physics. Washington, DC: National Science Foundation. Available on-line as of February 14, 2012 at www.nr.com/whp/NSFCompPhys1981.pdf

Ready, D.A., Vicere, A.A., and White, A.F. (1993) "Executive Education: Can Universities Deliver?" Human Resource Planning, Vol.16, No.4, 1-11.

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.

Ribes, D. and Lee, C. (2010) "Sociotechnical Studies o Cyberinfrastructure and e-Research," Computer Supported Cooperative Work, Vol.19, No.3-4, 231-244.

Rubleske, J. and Berente, N. (2012). Foregrounding the cyberinfrastructure center as cyberinfrastructure steward. Fifth Annual Workshop on Data-Intensive Collaboration in Science and Engineering (DICOSE), Bellevue, WA, 11 February 2012.

Sloan, A. (1957). My Years at General Motors, New York: Doubleday

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.

Spencer, D., Zimmerman, A., and Abramson, D. (2011) "Project Management in E-Science: Challenges and Opportunities," Computer Supported Cooperative Work, Vol.20, No.3, 155-163.

Suchman, L. (2000) "Organizing Alignment: A Case of Bridge-building," Organization, Vol.7(2), 311-327.

Thamhain, H.J. (2003) "Managing innovative R&D teams." R and D Management, v. 33 issue 3, 2003, p.297.

Tushman, M. and O'Reillly, C. (2007) "Research and Relevance: Implications of Pasteur's Quadrant for Doctoral Programs and Faculty Development," Academy of Management Journal, Vol.50, No.4, 769-774.

Tushman, M., O'Reillly, C., Fenollosa, A., Kleinbaum, A.M., and McGrath, D. (2007) "Relevance and Rigor: Executive Education as a Lever in Shaping Practice and Research," Academy of Management Learning and Education, Vol.6, No.3, 345-362.

Van de Ven, A.H., Polley, D.E., Garud, R. and Venkataraman, S. (1999) The Innovation Journey, Oxford University Press.

Vicere, A.A. (1989) Executive Education: Process, Practice, and Evaluation, Peterson's Guides.

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. and Sutcliffe. K.M. (2001), Managing the Unexpected, John Wiley and Sons.

Williamson, O. (1975). Markets and Hierarchies, Analysis and Antitrust Implications: A study in the economics of internal organization, New York: Free Press.

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