TRANSLATIONAL SCIENCE AND ITS EFFECTS ON ORGANIZATIONAL STRUCTURE AND PROGRAM MANAGEMENT

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Executive Summary

A multimethod study was conducted involving academic medical center research. Project management processes were among the top critical factors found for scientific teams, but project management tools were not well utilized and not equally implemented at all stages of the project management life cycle. Pilot study survey results indicate high agreement with previous studies involving project management success factors, with the following leadership qualities ranked most important: innovation, gathering information, and managing team commitments. In addition, the most frequently used project management tools by scientific teams were brainstorming, analogous estimates, focus groups, bottom-up estimation, flow charting, account charting, and performance reporting, along with best practices and lessons learned.
Introduction and Literature Review

In the United States, academic research in science and medicine is in the midst of a major transition. Traditionally, in the area of scientific research, basic research was performed by academia and applied research was performed largely by industry (Nathan, 2002). This distinction continued until the 1980s when the Bayh-Dole Act, the first iteration of change, gave universities and small businesses the right to own and patent their inventions obtained through federal funding. Under the act, universities have been very successful in commercializing their inventions, earning over US $1 billion annually in revenues (Raubitschek, 2005).

In the mid-2000s a second paradigm shift, known as translational research, occurred in the way new medical discoveries are invented and brought to market (Curry, 2008). Translational research has been defined as the “process of applying ideas, insights, and discoveries generated through basic scientific inquiry to the treatment or prevention of human disease” (Morrison, 2010, p. 565). This represented a significant departure from the way scientific exploration is accomplished at medical institutions. The old model called for a lone scientist pursuing research for the sole sake of acquiring knowledge with little interest in the practical use of the scientific findings (Baba, Shichijo, & Sedita, 2009). Under the translational research framework, research is conducted on a collaborative basis with the goal of discovering cures or therapies for patients. The National Institutes of Health (NIH) made translational research a priority by forming centers of translational research at its institutes and developing a series of initiatives referred to as the NIH Roadmap for Medical Research. Under this road map is the Clinical and Translational Science Awards (CTSA) program, which is focused on the re-engineering of clinical research. When it was fully implemented in 2012, the CTSA program consisted of a consortium of 61 academic centers dedicated to ensuring that new treatments and research knowledge reach the patients who can benefit from such discoveries (Woolf, 2008). According to former NIH Director Zerhouni (2007), the development of this consortium “represents the first systematic change in our approach to clinical research in 50 years” (p. 126).

Collaborative research plays a critical role in the NIH directives. With the new direction for multidisciplinary scientific inquiry, a fairly recent line of social research has developed investigating team science. In addition, the application of project management tools and techniques has become increasingly interesting to scientific investigators. This section of the paper reviews both areas of study, including the benefits of project management and project life cycle. We also review the literature on using a mixed-method model in academic research, including both case study and survey analysis.

Team Science

Collaborative research among scientific researchers is not a new phenomenon, yet its adoption and implementation at research institutions has been slow to evolve. Over 70 years ago, researchers advocated the interdisciplinary approach to scientific research as a means to overcome obstacles resulting from the departmentalized frameworks of universities (Brozek & Keys, 1944). More recently, calls for team-based science have stemmed from the recognition that the complexity involved in solving current social and public health problems requires input from several disciplines (Abrams, 2006; Stokols, Hall, Taylor, & Moser, 2008). The technological challenges of “big science” require a collaborative approach to interpret and analyze the vast amounts of data collected (Börner et al., 2010; Esparza & Yamada, 2007). Although the National Institutes of Health have encouraged and even mandated interdisciplinary research at medical schools, the culture of these institutions has been slow to embrace collaborative research teams and their productive outcomes.
There is evidence that multi-investigator studies and multi-institutional collaborations studies produce high scientific impact and high utility (Jones, Wuchty, & Uzzi, 2008; Wuchty, Jones, & Uzzi, 2007). Research teams that are truly multidisciplinary are more successful in their performance, as measured by scientific discoveries, publications, grants, and patents. Interdisciplinary research has been defined as an integration of “information, data, techniques, tools, perspectives, concepts and/or theories from two or more disciplines” (National Academies of Science, 2005, p. 188), with the goal of addressing a common research question (Stokols, Hall, Taylor, & Moser, 2008). Much of the existing literature on scientific collaboration addresses the problem of integration: the difficulty of communication across disciplines and the need to establish a social intelligence for successful collaboration (Fiore, 2008).

Stokols, Hall, Taylor, and Moser (2008) suggest that collaboration among scientists should follow a hierarchy of integration. Multidisciplinary teamwork encompasses the lowest degree of integration, where scholars from disparate arenas work independently or sequentially, but “remain firmly anchored in the concepts and methods of their respective fields” (p. 578). Interdisciplinary teams are a more robust approach to scientific integration (Stokols, Hall, Taylor, & Moser, 2008) and are comprised of researchers from various fields who work jointly or reciprocally with one another and where there is more of an attempt to integrate divergent perspectives (Klein, 2008). Transdisciplinary research involves the highest degree of integration, where researchers develop a shared understanding and communication of concepts and methods (Stokols, Hall, Taylor, & Moser, 2008). They often work together over a long period of time and have the greatest potential for making important scientific breakthroughs. With respect to the impact of collaboration on individual scientists’ careers, the evidence is mixed, suggesting that although a higher degree of collaboration is associated with less output in terms of volume, quality is improved (Leahey, Beckman, & Stanko, 2014).

**Team Science and the Need for Project Management**

Though the development of collaborative team science is progressing, team science scholars (Börner et al., 2010; Cummings & Kielser, 2005; Fiore, 2008; Spring, Hall, Moller, & Falk-Krzesinski, 2012; Stokols, Misra, Moser, Hall, & Taylor, 2008) have indicated a number of issues that illustrate the need to incorporate project management concepts into scientific teams. Among these are the multilevel nature of team science, the lack of common definitions, few theoretical models and frameworks, and a lack of integration among disciplines. Related to the potential use of project management, several other team science scholars (Hall, Feng, Moser, Stokols, & Taylor, 2008) have articulated a greater need for a precise taxonomy and curricular models to train leaders and project managers in science.

Expanded investment in team science and training has promoted greater demands for evidence that scientific teams be cost-effective and justifiable in terms of their scientific and clinical training and health outcomes (Stokols, Misra, Moser, Hall, & Taylor, 2008). In the academic environment, the application of project management concepts has been slow to evolve; nevertheless, scientists agree that it could foster collaboration and, in turn, innovation. In their study of CTSA teams, Calhoun and his colleagues (2013) have suggested a developmental stage model of multidisciplinary scientific teams that resembles the project management life-cycle framework. These stages represent the broad activity areas of concept development, planning, implementation, and outcome assessment (see Table 1).

There is an emerging literature base concerning the development of project and team leadership for translational science. Bennett, Gadlin, and Levine-Finley (2010) have produced a field guide for collaborative team science, with a focus on team building, communication, trust building, conflict resolution, and managing networks. There have been other suggestions by translational team educators (Rubio et al., 2010) that focus on the
development of collaborative leadership. Rosen et al. (Rosen, Bedwell, Wildman, Fritzsche, Salas, & Burke, 2011) have articulated potential training needs concerning specific attitudes, behaviors, and cognitions. Wooten, Dann, Finnerty, and Kotarba (2014) identified five essential tasks for translational science team project leaders: (1) reporting, (2) managing meetings, (3) agenda development, (4) reporting of progress, and (5) accounting and financial reporting. Unfortunately, as noted by Begg et al. (2014), only about half of all institutions that support academic translational teams provide any form of training in leadership and project management.

Project Management

Project management is the application of knowledge, skills, tools, and techniques to project activities to achieve project requirements (Project Management Institute [PMI], 2008). This method offers a systematic approach to all stages of a project by ensuring that every step is carefully planned, monitored, and measured (Murphy & Ledwith, 2007) because project teams often encounter constraints, barriers, and uncertainty when they attempt to achieve their goals and objectives (Chapman & Ward, 2003). A review of the literature puts forth a broad array of benefits that accrue to firms that adopt project management methodology (see Table 2).

As shown in Table 2, Pinto (2010) identified four major benefits of project management. The management of new product development and risks plays a critical role in the drug development process, because only one out of 10,000 compounds that are identified in the lab will successfully complete the Federal Drug Administration’s review process (PRMA, 2007). Thus, the benefits of project management highlight the importance of systematic planning to control the potential process losses associated with scientific research. When developing new therapies, there is inherent uncertainty related to the novel organization and unique scope of work, which requires attention as a central part of effective project management (Chapman & Ward, 2003). Building on Pinto’s (2010) list of benefits, Naybour’s (2013) and Hartman’s (2011) lists of benefits include process efficiencies and customer- and teamwork-related factors (see Table 2).

Adams and Barndt (1978) introduced the concept of “life cycle” into the project management literature. The life-cycle methodology provides organizations with a framework that structures the work into distinct phases to meet project goals and achieve project benefits. Structure is important because it provides managers with a road map to determine what steps to take and when to take them (Hrebiniaik, 2006) while simultaneously dealing with the constraints of scope, time, and budget (Philips, 2003).

The life-cycle model is generally defined as having four distinct stages: initiation, planning, execution, and termination. The initiation stage is the conceptualization of the project during which the scope and project leadership are identified, and the project team forecasts and develops possible solutions for risks and barriers

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<th>Identification of Scientific Opportunity or Need</th>
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<tr>
<td>Team and Network Establishment</td>
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Table 1: Developmental Stages of Multidisciplinary Teams (adopted from Calhoun et al., 2013).
that might hinder goal attainment (Westland, 2006). The planning stage involves the creation of a formal set of plans to accomplish the initially developed goals (Pinto & Prescott, 1988). The execution stage is when the actual work of the project is performed (Pinto, 2010). The termination stage involves closing the project. In this last stage, the project is complete, the teams are disbanded, the members are reassigned, and the project is evaluated (Shriberg, Shriberg, & Lloyd, 2002).

The project life cycle (PLC) represents a linear model with specified milestones or deadlines on which documentation, budgets, and information controls are based (Cicmil, Williams, Thomas, & Hodgson, 2006). The PLC framework is based on assumptions that conceptualize project reality as a cumulative sequence of events or phases. This hard systems model emphasizes the importance of planning, control, and chronological scheduling (Winter, Smith, Moris, & Cicmil, 2006). Another important attribute of the PLC model is that it helps managers identify when they should devote resources to a project and how to evaluate progress (Pinto, 2010). An understanding of PLC has been identified as an important factor in choosing the appropriate methodologies and tools for a project at various stages of its development (Labuschagne & Brent, 2005).

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<td>1. Reduces time for new product development cycles</td>
<td>1. Better efficiency in delivering services</td>
<td>1. Increased budget management effectiveness</td>
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<td>2. Enhances a firm’s ability to compete globally</td>
<td>2. Improved customer satisfaction</td>
<td>2. Better assessment of risk</td>
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<td>3. Narrows product launch windows</td>
<td>3. Enhanced efficacy in delivering services</td>
<td>3. Increased efficiency to meet deadlines</td>
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<td>4. Manages risk of developing increasingly complex and technical products</td>
<td>4. Improved team growth and development</td>
<td>4. Improved teamwork</td>
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<td>5. Greater competitive edge</td>
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<td>6. Increased opportunities to succeed</td>
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<td>7. Better flexibility</td>
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<td>9. Better risk assessment</td>
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<td>10. Increased productivity</td>
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Table 2: Project Management Benefits.
The project life cycle has become a universal model for a systematic approach to managing project work. PLC models vary based on product or process focus, organizational norms, or industry specificity. However, most PLCs utilize a staged approach that specifies major activities and deliverables for each project phase as well as guideline questions for end-of-phase reviews and stage gates (Labuschagne & Brent, 2005).

A key attribute of PLC that would benefit university scientific teams is the strict adherence to goals and objectives. The PLC model leads to a specified outcome or a final result that is defined and quantified at the beginning of the project. Furthermore, project management methodologies often produce universal best practices, contained in mainstream manuals and procedures (Cicmil et al., 2006). The standardization of practices would benefit a multidisciplinary team, where different members often follow discipline-specific rules to achieve mutual goals and objectives. In the following section, we will present qualitative data to assess how PLC fits interdisciplinary research, disproving the hypothesis that not achieving expected outcomes or results is fatal; in fact, scientific research often does not produce the intended findings, but nevertheless is not necessarily considered a failure. Thus, the final stage is not necessarily termination but can be considered a transition process, where the end of a funded project does not necessarily mean the end of the team or the scientific inquiry.

When analyzing the application of project management to interdisciplinary scientific research teams, we suggest that the traditional linear life-cycle model does not fit well. We can suggest several explanations for this. First, the team itself is made up of individuals with very different backgrounds and methodological orientations. Thus, there are several differing and competing views of how research should be conducted, when phases are complete, and which resources are most beneficial at any given stage. Second, the nature of scientific research does not ensure a deliverable, and time sequences are often murky at best. Third, the failure to attain identified goals does not necessarily signify the failure of the team or the project; research findings may establish a relationship that was previously unknown or that can be used in other research contexts.

For the purposes of collaborative team science, we propose a circular model of the project management life cycle that might be applicable to the scientific research arena. This model considers recursive steps and stages of projects and is more sensitive to the nature of scientific tasks. Figure 1 illustrates the nature of this model. Our qualitative and quantitative research will delve more specifically into scientific project teams to ascertain the critical factors, leadership qualities, project management tools, and outcomes at each stage of the PLC.

Developing Theory Through Case Study Analysis

Translational science represents a significant change in the way academic research is conducted. The assumptions and rules that once governed academic research may no longer apply in the new paradigm of scientific inquiry. To investigate this shift, we will use grounded theory to discover theory from data (Partington, 2000). The goal of grounded theory building is to tease out, identify, name, and explicate themes that capture the underlying dynamics and patterns in the organization (Dougherty, 2001). Grounded theory building provides the means through which researchers can assess the complexity of the organizational social system, where actors and institutions together constitute social reality (Giddens, 1984). Thus, the institution’s social systems are produced and reproduced by human actors employing structure (rules and resources) when they engage in social interactions.

Translational science changed the academic research process. To investigate the extent of these changes, we will explore how institutional actors make sense of the new rules and then use their toolkits—administrators
Grounded theory building would change policies and principal investigators (PIs) would use project management processes—to adapt to these new changes. Grounded theory building would be considered a “process” approach because it involves examining the emergent qualities of the change process, such as how organizational actors make sense of change (Van de Ven & Poole, 2005).

Grounded theory building plays a significant role in our methodology because translational science is a new phenomenon; therefore, existing theories may be inadequate to describe how institutions and their actors will respond to this change (Eisenhardt & Graebner, 2007). Grounded theory building is a form of qualitative research that seeks to provide an understanding of complex issues that arise from answering “why” and “how” research questions (Marshall & Rossman, 2014). There is a rich history of qualitative research methods being used to explore punctuated or radical changes (Barley, 1996; Eisenhardt, 1989; Tripsas, 1997, 2008). For example, Barley (1986) used qualitative research to explore how the adoption of a radical technology changed the power dynamics, roles, rules, and work procedures at a Boston hospital. Interviews are an appropriate method to collect data to assess punctuated change because they allow researchers to gather rich, empirical data, especially when the phenomenon of interest is episodic and infrequent (Eisenhardt & Graebner, 2007).

Once theory is developed, it can be tested within a large sample by employing deductive, hypotheses-driven, quantitative techniques through survey administration. Surveys are quantitative methods that seek to convert data into numbers to support generalizations (Babbie, 2004). We will use a survey to identify the extent to
which research institutions changed (or did not change) their administrative systems and project management processes to support collaborative research. Surveys have long been used in project management studies (El Emam & Koru, 2008; Seiler, Lent, Pinkowska, & Pinazza, 2012). Survey administration highlights the variant approach to examining change phenomena. The goal of the variant approach is to explain and/or predict the occurrence and magnitude of change, or the effects of change, on other variables (Van de Ven & Poole, 2005). Such studies use change as the context in which other phenomena occur, such as to test theories of individual units’ reactions to change in higher-level units (Van de Ven & Poole, 2005).

Grounded theory building and survey administration represent a mixed-method approach to research that includes qualitative (i.e., grounded theory building) and quantitative (i.e., survey administration) methods. Our goal is to promote triangulation by using different ways to explore the same phenomenon in order to gain new insights. Triangulation is the combination of methodologies when studying the same phenomenon (Denzin, 2012). Jick (1979) proposed that organizational researchers can improve the accuracy of their judgments by collecting different kinds of data bearing on the same phenomenon. There are various types of triangulation: sources (i.e., participants), theories, methods (i.e., interview, observations, documents), and among different investigators (Creswell & Miller, 2000). In our research program, we will use these methods to generate theory, identify common themes and outliers, and validate or disconfirm our research assumptions.
Research Question and Objectives

University scientific research and implementation of project management methodology is a relatively new partnership. Funding changes have led university research teams to search for methods that will enhance their research effectiveness and efficiency. Specifically, the National Institutes of Health have embodied translational science—a new initiative aimed at improving public health innovations. The goal of translational science is to fund interdisciplinary research with the goal of moving an idea from bench to bedside by encouraging medical schools to engage in preclinical and clinical applied research (Curry, 2008). Project management is a tool that can be used to enable interdisciplinary research teams to achieve translational science goals in order to secure and maintain their funding.

For many years, universities had virtually unlimited freedom to conduct basic research that involved “experimenting with new alternatives that had returns that were often distant, uncertain, and negative” (March, 1991, p. 85). If an outcome (i.e., prototype) from an exploratory experiment possessed any commercial potential, then a university would license it to a pharmaceutical firm, where it would undergo further development, including preclinical and clinical trials (Rothaermel & Deeds, 2004). The NIH’s translational science initiative requires universities to transition from being solely the creators of innovation to being its developers. This challenge might require them to adopt business-like practices, such as adopting project management methodologies to engage in commercial drug development activities such as preclinical trials.

Commercial drug development firms use project management methodologies to manage their resources and achieve project goals and objectives (Liberatore & Titus, 1983) and to improve project decision making (Kennedy, 1997). A project is defined as a temporary activity designed to achieve a specific task and typically involves many functional areas (Shriberg, Shriberg, & Lloyd, 2002). A brief review of the extant literature reveals that pharmaceutical firms rely on project management methodologies, including planning and resource allocation tools and communications systems, to manage projects across multiple knowledge centers. Project management tools also enable pharmaceutical firms to coordinate projects, share results, and evaluate projects once they are completed (Chiesa, 2000). Clearly, project management tools play a critical role in the drug development process in commercial R&D firms. The question remains: How can universities adopt project management tools and methodologies to adhere to the goals and objectives of translational science “to improve medical care by applying new scientific advances to real-world practice” (Zerhouni, 2007, p. 126)?

Translational science is a complex and challenging process that will benefit from employing project management methodologies and tools. On the one hand, previous studies have shown that teams that are truly interdisciplinary are more successful in their performance, as measured by scientific discoveries, publications, grants, and patents. On the other hand, critics argue that translational initiatives have yet to yield identifiable returns that justify the multiyear commitments of financial, material, and human resources (Stokols, Hall, Taylor, & Moser, 2008). Furthermore, interdisciplinary teams might be breeding grounds for conflicts because members possess different theoretical and methodological perspectives that define problem-setting and problem-solving approaches (Cronin & Weingart, 2007; Lovelace, Shapiro, & Weingart, 2001). Ineffective project management processes, such as ambiguous goals, outcomes, and tasks, are the primary causes of conflict within interdisciplinary teams (Stokols, 2006). Conflict impedes goal attainment and leads to underutilized resources because team members attend to the conflict rather than the work.
As the concept of interdisciplinary science continues to take shape, methods and processes to improve and expedite results have been proposed, including the application of project management techniques (Letouze, 2011). This paper explores whether university research teams can use project management methodologies and tools as they begin to conduct commercial activities. To do this, we focus on the project management life cycle (PLC). Studies have found that the key to project performance lies in adhering to the well-accepted functions of initiating, planning, execution, and control (e.g., Humaidi & Said, 2011; Nenonen, Kivistö-Rahnasto & Vasara, 2012; Sinha, 2014; Yani, 2014). PLC supports planning, scheduling, budgeting, and better monitoring/evaluation, and addresses people issues, including conflict management, negotiations, and leadership (Pinto, 2010). Interdisciplinary teams that adopt project management tools may be able to secure funding by meeting the translational science goals and objectives.

**Research Question**

The proposed research project will address the following question: How have universities employed project management methodologies to adapt to the National Institutes of Health’s adoption of the translational science approach to clinical research? This research question can be further segmented into two subquestions:

- **Subquestions #1:** What are the critical success factors that will foster and enhance collaborative academic research?
- **Subquestions #2:** To what extent have these administrative changes influenced and been influenced by the adoption of new or the modification of existing project management methodologies, processes, and tools?

**Objectives**

Our first project aim is to investigate the management, institutional, and process implications that emerge to support the development of a new organizational form—translational research centers—and the changes that will occur in program management. To date, most of the literature on change and project management focuses on first-order changes or changes that impact only the project. Our research is novel because it examines how second-order changes impact program and project management functions. Second, we will explore whether and how the NIH’s directive toward collaborative research will expedite knowledge discovery through the creation of interorganizational project management teams. Third, we seek to expand existing project management theory by examining institutions’ transition from product- to process-based research and develop a reciprocal model of how research institutions adapt their administrations and project management methodologies, processes, and tools to meet the NIH’s translational science directive.

Given the multifunctional and multidisciplinary nature of the translational project and the “home” offices from which they will be driven, there are several key Knowledge Areas in *A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Fifth Edition* (PMI, 2013), including human resource management, communications, and stakeholder management, where the key research questions will be most visible and where the successful management of these areas will be integral in driving the success of the home centers. We believe that our study can have ancillary objectives beyond the scope of our research and can have benefits to the scientific teams under investigation. First, our study has the ability to influence the direction of the change. As academic researchers are transitioning to a translational science paradigm, this study affords us an opportunity to investigate how research institutions adapt their existing routines and processes to promote translational
research and the degree to which these new routines conflict with existing routines. We also seek to identify best project management practices across CTSA centers. Second, the goal of translational science is to ensure that new treatments and research knowledge actually reach the patients or populations for whom they are intended (Woolf, 2008). Exploring how research institutions adapt their existing administration policies and the extent to which they embrace project management approaches may provide NIH policymakers and CTSA directors with information they can use to create or amend existing policies that target technological growth. Third, our research offers insight into how to implement project management methodologies, tools, and processes into an academic environment—specifically, which tools are appropriate for usage in an academic environment and how administrators assess the value and benefits of project management tools.

Although it may appear that university scientific research and project management methodologies are not mutually compatible, nonprofit entities such as social service organizations and universities have begun to engage in business-like activities to ensure their survival. Many stakeholders believe that social-serving nonprofits are unable to bring about lasting social changes because they possess inefficient processes and ineffective operating models (Dart, 2004). Social-serving nonprofit organizations have responded to this criticism by creating for-profit subsidiaries in order reduce their reliance on external funding agencies (Christensen, Baumann, Ruggles, & Sadtler, 2006). Similarly, universities are patenting and commercializing faculty research to generate licensing income (Siegel, Waldman, & Link, 2003). As nonprofit entities begin to engage in economic activities, we argue that they can benefit by adopting project management methodologies to bring discipline, coordination, standardization, and effective and efficient resource practices into the research process.
Research Design

To investigate our research questions, we implemented a multimethod research plan incorporating both a qualitative study (interviews) and a quantitative study (surveys). Our study incorporated the case study method to explore the implementation of project management to translational science multidisciplinary teams. Yin (2009) defines a case study as an empirical investigation of an event or series of events in a real-life context that is especially useful when controls presented in an experiment are not available. A case study is a richly detailed story about a specific organization, event, or situation, or several organizations and events or situations. Qualitative case studies have been used to examine project management settings focusing on a number of research questions (e.g., Engwall & Jerbrant, 2003). Given the novel nature of establishing cross-disciplinary scientific teams, we suggest that the case study method is an appropriate approach for learning about the internal operations of the teams and the incorporation of project management tools by team members. We also use case studies as a technique to analyze the way knowledge is shared among members of a multidisciplinary (MD) team and across teams in a university setting. Thus, the first part of our study—collecting data through interviews—was designed to both (1) answer research Subquestion #1 (What are the critical success factors that will foster and enhance collaborative research?) and (2) guide us in developing the survey questions that will be used in the quantitative part of the study.

Methods

For the qualitative portion of the study, we first developed a series of semistructured interview questions, based on our literature review discussed above (see Exhibit 1 for the interview questions). The questions were pretested with a principal investigator of a CTSA institute, and modifications were made in accordance with his recommendations. In the second phase, we conducted the interviews. We selected four CTSA centers in the Southwest and conducted 14 semistructured, in-depth interviews. The centers were identified through prior interactions with one of the PIs of this study who indicated a willingness to participate in the study. Nine of the interviewees were either principal investigators or co-PIs from nine different MD teams. In addition, five administrative leaders were interviewed, including two associate vice presidents of research and three program directors. Thus, the interviewees represented a broad cross-section of high-level management typical of any CTSA across the country. Each interview lasted approximately one hour and, with one exception, the interviews were conducted by at least two of the researchers involved in the study. Each interview was transcribed and analyzed using NVivo content analysis software. Two of the researchers coded the responses into 27 agreed-upon nodes, or general topic areas that were common to several of the interviews. A listing of these nodes is shown in Table 3.

Based on the responses from the interviews, we developed a comprehensive survey for pilot testing in a clinical research environment. Initial biographical items included team participation (i.e., tenure), team role (e.g., PI/leader, project manager, team member, etc.), participation in other scientific teams, size of the team considered, team experience, and team successes over the past 24 months (e.g., amount of funding, patents, refereed publications, etc.).

Using Adams and Barndt’s (1978) project management life-cycle phases (i.e., conceptual, planning, executing, and transitional), items were developed using an edited version of critical success factors in project management as developed by Somers and Nelson (2004). Here, items were constructed for respondents to identify and rank the top 10 critical factors (e.g., clear goals, end-user commitment, contextual awareness, etc.) for each project management life-cycle phase (see Table 4).
<table>
<thead>
<tr>
<th>Barriers</th>
<th>Evaluation</th>
<th>Institutionalism</th>
<th>Specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Career Development</td>
<td>External Focus</td>
<td>Knowledge Transfer</td>
<td>Streamline</td>
</tr>
<tr>
<td>Change</td>
<td>Fit</td>
<td>Leadership</td>
<td>Support</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Funding</td>
<td>Planning</td>
<td>Team Development</td>
</tr>
<tr>
<td>Communication</td>
<td>Impact</td>
<td>Process</td>
<td>Teams</td>
</tr>
<tr>
<td>Culture</td>
<td>Infrastructure</td>
<td>Projects</td>
<td>Transformation</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Innovation</td>
<td>Promotion/Tenure</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Classification of Nodes (Topics) from Interviews.

<table>
<thead>
<tr>
<th>Clear Goal/Objectives</th>
<th>Clear Communication Channels</th>
<th>Effective Team Building/Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support from Senior Management</td>
<td>Taking Account of Past Experience</td>
<td>Training</td>
</tr>
<tr>
<td>Adequate Funds and Resources</td>
<td>Effective Management of Risk</td>
<td>Considering Multiple Views of Project</td>
</tr>
<tr>
<td>Realistic Schedule</td>
<td>Contextual Awareness</td>
<td>Access to Talented People</td>
</tr>
<tr>
<td>End-User Commitment</td>
<td>Effective Monitoring and Feedback</td>
<td>Appreciating Effect of Human Error</td>
</tr>
<tr>
<td>Effective Leadership</td>
<td>Recognizing Complexity</td>
<td>Support from Stakeholders</td>
</tr>
<tr>
<td>Conflict Resolution</td>
<td>Provision of Planning and Control Systems</td>
<td>Clear Project Boundaries</td>
</tr>
<tr>
<td>Flexible Approach to Changes</td>
<td>Taking Account of External Influences</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Critical Success Factors (adopted from Somers & Nelson, 2004).
Leadership qualities were measured in relation to the four project stages using the 15 leadership competencies and three leadership styles as developed by Dulewicz and Higgs (2005) and used in prior studies of project management leadership (e.g., Müller & Turner, 2007, 2010). The three leadership styles were grouped under the categories of intellectual, managerial, and emotional, and under each were the competencies associated with that style, as shown in Table 5. Many of the dimensions of leadership under this model are the same as those identified by transformational and authentic leadership theories and were deemed a parsimonious model of leadership behaviors. Items to determine the association between project leader actions and characteristics and the project management phases were also developed for testing. In total, 47 leadership measures (e.g., leader identifies opportunities, leader gives encouragement, etc.) were utilized in developing items to be associated with the four project management phases.

<table>
<thead>
<tr>
<th>Style</th>
<th>Competency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual</td>
<td>Critical analysis and judgment</td>
</tr>
<tr>
<td></td>
<td>Vision and imagination</td>
</tr>
<tr>
<td></td>
<td>Strategic perspective</td>
</tr>
<tr>
<td>Managerial</td>
<td>Engaging communication</td>
</tr>
<tr>
<td></td>
<td>Managing resources</td>
</tr>
<tr>
<td></td>
<td>Empowering</td>
</tr>
<tr>
<td></td>
<td>Developing</td>
</tr>
<tr>
<td></td>
<td>Achieving</td>
</tr>
<tr>
<td>Emotional</td>
<td>Self-awareness</td>
</tr>
<tr>
<td></td>
<td>Emotional resilience</td>
</tr>
<tr>
<td></td>
<td>Motivation</td>
</tr>
<tr>
<td></td>
<td>Sensitivity</td>
</tr>
<tr>
<td></td>
<td>Influence</td>
</tr>
<tr>
<td></td>
<td>Intuitiveness</td>
</tr>
<tr>
<td></td>
<td>Conscientiousness</td>
</tr>
</tbody>
</table>

Table 5: Leadership Styles and Competencies (adopted from Dulewicz & Higgs, 2005).
Project management tools included those methods, techniques, and analytical procedures that are typically used in project management (Milosevic, 2003). Survey items were also developed relating to knowledge measurement and project life cycle. We utilized Yazici’s (2009) conceptualization of PMI’s (2008) body of knowledge constructs. Here, items were developed to associate life-cycle phase with integration management, scope management, cost management, quality management, time management, risk management, human resource management, communications management, and procurement management. Patanakul, leuwongcharoen, and Milosevic’s (2010) taxonomy of 39 project management tools (e.g., bar chart, cause-and-effect diagram, contingency plan) were also utilized for analysis of their association to the project life cycle. Items were developed so that respondents could use drop-down boxes to associate project management tools with discrete PLC stages (see Table 6).

To assess the collaboration of each team, items from Hall, Feng, Moser, Stokols, and Taylor’s (2008) Collaboration Index were used. These questions included in this team scale examine communications, use of members’ strengths, conflict resolution, as well as activity and team productivity. This scale includes items that assess the frequency of collaborative actions (e.g., communication among team members, resolution of conflict) and general collaborative activities.

<table>
<thead>
<tr>
<th>Analogous Estimate</th>
<th>Earned Value Management</th>
<th>Project Change Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar Chart</td>
<td>Flowchart</td>
<td>Project Charter</td>
</tr>
<tr>
<td>Bottom-up Estimate</td>
<td>Focus Group</td>
<td>Responsibility Matrix</td>
</tr>
<tr>
<td>Brainstorming</td>
<td>Hierarchical Schedule</td>
<td>Risk Response Plan</td>
</tr>
<tr>
<td>Cause-and-Effect Diagram</td>
<td>Lessons Learned</td>
<td>Schedule Crashing</td>
</tr>
<tr>
<td>Chart of Accounts</td>
<td>Milestone Analysis</td>
<td>Scope Statement</td>
</tr>
<tr>
<td>Checklist</td>
<td>Milestone Chart</td>
<td>Skill Inventory</td>
</tr>
<tr>
<td>Communication Plan</td>
<td>Milestone Production Chart</td>
<td>Stop Chart</td>
</tr>
<tr>
<td>Contingency Plan</td>
<td>Monte Carlo Analysis</td>
<td>Shareholder Analysis</td>
</tr>
<tr>
<td>Cost Baseline</td>
<td>Pareto Diagram</td>
<td>Shareholder Matrix</td>
</tr>
<tr>
<td>Critical Path Method</td>
<td>Performance Measurement Baseline</td>
<td>Time-Scaled Arrow Diagram</td>
</tr>
<tr>
<td>Customer Road map</td>
<td>Performance Reports</td>
<td>Top-down Estimate</td>
</tr>
<tr>
<td>Customer Visits</td>
<td>Project Change Log</td>
<td>Work Breakdown Schedule</td>
</tr>
</tbody>
</table>

Table 6: Project Management Tools (adopted from Patanakul et al., 2010).
Items were also developed in relation to team member participation in knowledge transfer (e.g., coauthorship), meeting participation (e.g., face-to-face interactions with students), and communication techniques (e.g., email) based on the work of Cummings and Kiesler (2005). Using modified items developed by Cummings and Kiesler (2005), we also employed team member participation in knowledge outcomes (e.g., started new field or area of research), tools utilized (e.g., developed new methodology), and training outcomes (e.g., graduate student success). Additionally, items involving outreach (e.g., forming partnerships with industry) and collaboration (e.g., started collaboration outside the project that will continue after the project is completed) were also used. **Tables 7a and 7b** list collaboration, knowledge transfer, and outcome measures.

The pilot survey was first field-tested by a senior principal investigator and three university professors. Based on their recommendations, the survey was modified and administered to interested team scientists at all four CTSA institutions in the state of Texas. Additionally, CTSA administrators at 56 additional funded CTSA sites were contacted and asked to distribute the pilot survey to known team science leaders, project managers, and team scientists.

<table>
<thead>
<tr>
<th>Collaboration Frequency</th>
<th>Knowledge Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication among team members</td>
<td>Coauthorship</td>
</tr>
<tr>
<td>Ability to capitalize on members’ strengths</td>
<td>Conferences</td>
</tr>
<tr>
<td>Resolution of conflicts</td>
<td>Presentations</td>
</tr>
<tr>
<td>Productivity in meetings</td>
<td>Outside speakers</td>
</tr>
<tr>
<td>Trust among members</td>
<td>Training</td>
</tr>
<tr>
<td>Respect among members</td>
<td>Multidisciplinary courses</td>
</tr>
<tr>
<td>Openness to criticism</td>
<td>Advising students</td>
</tr>
<tr>
<td>Productivity improvements</td>
<td>Student exchanges</td>
</tr>
<tr>
<td>Overall team productivity</td>
<td></td>
</tr>
</tbody>
</table>

**Table 7a:** Collaboration and Knowledge Management.
<table>
<thead>
<tr>
<th>Knowledge Transfer (Communications)</th>
<th>Knowledge and Transfer Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face-to-face meetings</td>
<td>Developed new area of research</td>
</tr>
<tr>
<td>Informal interactions</td>
<td>Developed new model</td>
</tr>
<tr>
<td>Email</td>
<td>New grant funding</td>
</tr>
<tr>
<td>Telephone</td>
<td>Patent application</td>
</tr>
<tr>
<td>Conference call</td>
<td>Presented at conference</td>
</tr>
<tr>
<td>Video conferencing</td>
<td>Published articles, books</td>
</tr>
<tr>
<td>Instant messaging</td>
<td>Recognized with awards</td>
</tr>
<tr>
<td>Online forum</td>
<td>Collaborations continued after project</td>
</tr>
<tr>
<td>Project website</td>
<td>Shared data outside project</td>
</tr>
</tbody>
</table>

*Table 7b: Collaboration and Knowledge Management.*
Results of Qualitative Study

As seen in Table 3, a number of themes emerged from the interviews, and it would be beyond the scope of this paper to discuss all 27 potentially critical factors for scientific team success. We selected three for discussion: collaboration, leadership, and implementation of project management processes.

Collaboration

All of the interviewees acknowledged the need for collaboration in order to obtain NIH funding and that it was essential to establish a culture of collaboration. Accordingly, the CTSAs are very much focused on team science and “pushing the envelope” to make investigators understand that “the single-investigator laboratory is not something that is going to get funded” anymore. “That’s not the future,” said one administrator; “[t]he future is how do you take some of that discovery work and complement it with these other pieces to get to an answer faster.”

Each of the four CTSAs’ ability in meeting that goal varied significantly. Some stated that they had made measurable progress while others admitted that they had a long way to go. Although younger scientists seemed to embrace the team concept, older, full professors and clinicians were less likely to participate in the team process. According to a PI:

In teams you are oftentimes dealing with people who have big egos. There are people who have had success and have had career advancement and all of that and have pretty strong ideas about what needs to happen. And so then you go into a multidisciplinary translational team, which organizationally is a very flat structure with distributed responsibility and distributed authority.

In addition, some of the teams had been in existence prior to the formation of the CTSA at their institutions, and were known as legacy teams. These teams had been very successful in their outcomes but they were also very hierarchical in structure. The challenge was to present these teams in a more horizontal team-based picture in order to create a more collaborative approach.

Scientists must now be focused on an end product to help patients and to change the epidemiology. Moreover, teams are comprised of a number of doctors—both researchers and clinicians—as well experts in core technologies, biostatistics, bioinformatics, and proteomics, the kind of basic science that spreads out across all areas. Team science evolves very differently compared with industry project teams. Often, an experienced researcher will form a team to investigate a particular area—for example, eye disease. Other researchers can volunteer to participate become a part of the team based on the availability. According to a PI of several scientific teams, much of the focus toward improving team work at his institution has been on both the scientific output and the group dynamic. All of the teams have placed a great deal of effort in improving that dynamic through outside interventions as well as through internally driven modifications.

Communication is one area of considerable concern. Because of the multidisciplinary nature of scientific teams, communication often hampers the process because various team members are looking at a problem from different perspectives and fields of expertise and using different language and terminology to describe
their ideas. To attempt to bridge this gap in communication, one CTSA established a series of discourses, which it called “method intuition,” in which each team member would describe at each level what he or she did, the methodologies used, the data, and other important aspects of the study. What that allowed the team to do, said the PI, was to “let us become truly interdisciplinary as opposed to multidisciplinary . . . and pointing to the next iteration as transdisciplinary.” Further, the process of method intuition seemed to have the greatest value when the level of heterogeneity was the greatest.

CTSA institutes have facilitated collaboration in several administrative ways. First, they are the central point of administering all the funding received from the NIH for translational scientific research. To stimulate new ideas and the formation of teams to investigate these ideas, the CTSA provides pilot funding, generally US $50,000 to US $75,000, to allow the researcher to jump-start the project. Generally, the pilot funds are awarded to junior investigators. All of these pilot grants are competitive and peer reviewed. Scientific merit determines whether or not they get funded. Joint pilot grants are awarded to encourage multidisciplinary people to work together.

The CTSAs also created formal conferences designed to encourage scientists who have identified an idea to present it to both basic and clinical scientists; the CTSA then helps nurture that idea in a way that will stimulate interdisciplinary science. It also sets up guidelines that allow people who aren’t familiar with informatics and infrastructure and how they could help facilitate research. The CTSAs raised the level of awareness and provided an opportunity or method by which a scientist could gain access to either patient or laboratory material. As one interviewee stated, the informatics stimulated basic scientists to work more closely with clinicians or clinical investigators.

In terms of collaborations, the CTSAs also helped investigators understand the regulatory function as a key resource; if a scientist wants to submit an investigational new drug application, the CTSA provides resources and expertise to help submit the application, as “it is a fairly daunting process.” CTSA administrators are also critical when it comes to obtaining the necessary internal approvals for conducting studies that involve human subjects.

At one institution, interventions were successfully used, particularly at the time when teams were initially formed. MD teams at all locations typically fell into one of two categories: those that had already been in existence at the time the awards were granted and had experienced a fair degree of success, and those that were created specifically to initiate projects and receive start-up funding under the grant. In the latter cases, projects were almost always initiated by an investigator who handpicked the team members. In addition to providing monetary support, this university furnished team coaches, workshops, and monthly team training, as well as peer-review processes and evaluation metrics that looked at both scientific accomplishments and team skills. After three years, a respondent reported significant improvement in productivity among some of the teams, but not as much in others. The teams that were successful were building synergies and adhering to the idea of translation. “These teams really bought into the idea of team science in sort of an authentic way where it seemed to be very equal dialogue among the different members from different disciplines,” noted one administrator.

In addition, a key focus of the grant process is to encourage teams to be more innovative. To this end, CTSA institutions have explored ways to improve social integration in teams. This involved developing a shared vision and integrating the different worldviews of team members into the project. There are often changes in the MD group because of transfers, promotions, and terminations, all of which force the group to rethink the project and derive new directions. The CTSAs recognized that in order to transform knowledge into innovation, increases in integrative capacity are both critical and difficult given the diversity among team members. We posit that this should be the main focus of team and collaboration development in the future.
Internally, teams recognized the need to maintain collegiality in order to move forward and took steps to resolve conflict among members. One example of the latter is a co-PI who commented that if “we saw that something was not working we would have to rethink this and come up with a new direction and get everyone involved with that again.” However, although some team members were receptive to this process, others were resistant to change and reacted either through denial or by exiting the team.

**Leadership**

Prior to the CTSA structure, scientific research was autonomous. In an academic lab, an experienced researcher led a team of dedicated associates who explored a specific area of scientific research. The NIH mandate for collaboration led to the increased importance of teamwork and the need for leadership within the academic research process. According to one interviewee, the biggest factor explaining the difference in degrees of success among scientific teams was team leadership. "Nobody in academic medicine has ever been taught how to be a team leader," he commented. "Despite numerous workshops and interventions, it is difficult to train PIs to become transformational leaders." The question, therefore, became what skills and behaviors were needed to lead these very different project teams.

Initial recognition by administrative leaders that there were gaps in the teams’ leadership alerted CTSA that this was an area that needed their attention and was just as important as the formation of the teams themselves. This was a critical change from the previous assumption that someone was automatically the leader even though that person may not have had the time or the skills necessary to lead or to make sure that other team members were comfortable and that communication was happening. Creating a team involved more than staffing. It required members to let go of their past successes and focus on how they could contribute to the team’s success and well-being. According to several of the interviewees, team formation was more than just bringing some successful people together.

A good deal of time and resources have been dedicated to leadership development within several CTSA teams. For example, at one institute, the principal investigator observed that in team formation, an attempt was made to identify a natural leader. Sometimes, a physician was identified as the best leader because the physician knew some basic science and knew clinical science. Often, a basic scientist who has both the research skills and the time and also knows clinical science would emerge as a natural leader. In either case, it takes a fair amount of energy to get people together, so typically there were one or even two people at the core of team who provided the energy and many of the ideas.

However, in some teams, it was not as clear whether the PI or a more seasoned scientist would fit the leadership role or would even be willing to take over that responsibility. As noted by one administrator, if the natural leader is a postdoc or assistant faculty member, and someone on the team is a full professor who has been at the university for 15 or 20 years and has been funded, how does the leader take control? “Or do you assume that because this is the professor who is well funded, that he is your leader? But suppose the full professor has always worked alone and he doesn’t know how to now manage a team—this can pose a problem with teamwork and collaboration.”

Changing behaviors has been a very difficult problem at all the institutes interviewed. Accordingly, most institutes have scheduled just as much leadership and team training as science into the process of bringing researchers together. At one institute, a formal academy of mentors was established, with 30 different senior faculty members available to work with any translational researcher who needed mentoring. With this
mentoring process, the institute is working to improve the quality of team leadership and is evaluating its mentoring process to determine what works and what needs to be changed.

Alternatively, instead of letting a leader emerge within a team, some institutes have actually put people in roles and taught them about roles and responsibilities and made that just as much a critical part of the team formation as looking at the different disciplines that need to be part of the team. In forming the team, the institute identifies the different roles and responsibilities and holds people accountable for them, making sure that communication continues to happen and that the team continues to grow. However, there is also a recognition that the team is not constant: Science evolves, and the team needs to adapt. Some team members are core resources and need to remain constant, while others will have a more temporary role, depending on where they fall in the continuum. Each time there are changes, the roles and responsibilities need to be redefined.

Identifying resources to help team members was a common concern among interviewees. One of the major responsibilities in the CTSA and many other scientific undertakings is workforce development—giving people at multiple levels the skills they need to be able to work successfully in the current and future environment of science and clinical research. For example, providing a biostatistical consultation to young investigators and giving them the additional skills needed to be successful is an example of effective leadership. Thus, the leader needs to be adept at identifying resources and the ability to deploy those resources in value-generating activities that support team effectiveness. If a team leader “is an outstanding leader, he or she will be as interested or more interested in the success of their trainees as they are in their own personal success, because if their trainees are successful, if their people are successful, they will be successful,” according to one PI who was interviewed.

Another area of concern among CTSA administrators is how leadership can promote innovation. One of the objectives of the CTSA grants is to stimulate innovation; the PIs need to think about how they can work with teams in terms of better teaching and rewarding transformative leadership to get teams to be more innovative. Further, innovation will not work if the team leader is too rigid. Creativity often stems from the bottom up, and if junior researchers are being discouraged from suggesting new ideas, the team is depriving itself of an important resource. If any team member has a novel observation or there is something that is truly innovative, team leadership must be able to accommodate these new ideas.

Other interviewees identified more managerial functions as essential to leadership. For example, the team needs someone to establish a time frame and specific deadlines and get people to actually stick to that time frame. Day-to-day operations were also identified as needing strong leadership. Even within operations, however, leadership was often demonstrated in the team. For instance, an interviewee reported a situation when the principal investigator of a team abruptly left and there was a lot of tension among team members. According to the interviewee, a new leader emerged who was able to resolve the conflict and establish new relationships with many of the outside contacts with whom the departing investigator had worked. This resulted in a smooth transition of leadership and maintaining the effectiveness of the team.

Project Management

Although project management has been recognized as useful to scientific teams (Gist & Langley, 2007), we note that according to our interviews, project management did not appear to be a concept that was incorporated into the MD teams at the four research sites we studied. As one respondent noted, “I don’t remember hearing anything [about] project management tools.” Another respondent, a PI and instrumental member of the CTSA implementation effort, commented: “[P]hysicians and scientists generally do not have management skills. It is
not part of our training at any time." Yet another commented: "It is hard to use formalized project management. I think one of the issues we run into is that although business is very good at doing project management following metrics, academics have not embraced that very much. We get a lot of pushback for a lot of our tracking and evaluations. . . . It distracts from [team members'] major goal." Another administrator and PI observed that at his institution, "to try to apply business practices to the management of science is still viewed by many as being an anathema."

One researcher defined the problem very succinctly. In industry, there are defined protocols and rules for sticking to them. Failure is acceptable if it leads to a quick decision to abandon a project. With scientific research, there are no articulated protocols that prevent deviation from an established plan or require that the research team terminate the study. As noted by an interviewee, if a researcher sees something novel, he or she can go down that "rabbit hole" and investigate further: "Scientists don’t see failure as a bad thing. It gives them an answer so they can know how to go differently." In addition, scientists view themselves as having much longer time horizons. The business model is typically based on short-term time horizons with clearly defined deliverables. The academic approach has a longer time horizon, limited accountability, and less emphasis on return on investment.

However, the CTSAs have evolved, and several had adopted processes typically utilized by project managers to improve workflow and outcomes. For example, an interviewee reported that his team had experimented with naming two project managers and concluded that was not ideal. However, the project manager was often a more junior member of the team, "who doesn’t know how to interact with people or who is intimidated by a senior person or who has no sense of logical flow of conversation." In fact, the team leader was often reluctant to burden a junior team member with administrative responsibilities that could detract from the important research that needed to be done to be successful in academics. In such cases, an outside consultant was brought in to help with meeting management, agendas, and encouraging participation. In addition, when a new project manager was brought on to the team, a briefing session was held to describe "what is the project, what are the outcomes, what are we trying to accomplish, where are we, what have been the hurdles so far, what is active, what do I need to take on right now, what direction are we moving, what are the deliverables that we have to get out, what is the time frame on those things, and so on." Otherwise, project managers—even fairly junior persons—were given broad discretion to manage their teams.

In terms of standardization, the scientific teams have implemented some shared processes. These typically encompass preapproval of experimentation (internal review board, or IRB approval), compliance protocols, and grant writing. At one institution, an administrative office was established to essentially be a “one-stop shop,” where approvals and regulatory formalities can not only be submitted, processed, and approved, but research, publications, and grants can also be tracked. Eventually, this institution hopes to create an infrastructure that can collect and sort educational information for use by other researchers. Having findings and research somewhat standardized can allow them to be propagated to another study with similar characteristics. However, not all CTSAs were as systematized in their administration; as one interviewee described the process, it is "more like a brute-force way, where we basically track applications, grants, subsequent grants funded, submitted grants funded, and patents generated" without standardized software or procedures. The following paragraphs more fully describe the implementation of project management concepts at each stage of the scientific project.

**Conceptualization Stage**

Using the traditional project management life-cycle approach, the interviews revealed that few project management techniques were being used in the conceptualization stage. PIs were given broad discretion to
formulate their ideas and choose their teams. According to one PI, “I basically go out and search for common interests and try to advertise it somehow so people can join your team.” Scientific inquiry is not conducive to the typical feasibility studies or strategic needs analyses seen in industry. By definition, the goals of providing care or a cure for patients seems to fit the meaning of a strategic need. As noted by an administrator at another institution, preplanning and thinking through the possible pathways and alternatives is what academics do not do: “We just do it. . . . Therein may be one area where some components of project management could help the resource allocation in terms of knowing when to fund more and when to pull the plug.” A PI at a third institution observed that in examining the feasibility of a research project, though it is expected that the proposal will explain the application of the project and where the team is going with the next step, the evaluation does not look at that carefully or at whether the team is sustainable.

Planning Stage
At this stage, project management concepts seemed to be applied to the planning stage of MD teams where team-building activities have been incorporated into the process. Respondents from three of the four institutions reported the frequency of team meetings as sometimes once per month and some with external observers who viewed the teams in terms of both scientific success and team development. Outside facilitators were often used to set agendas and handle meeting management and “the organizational things.” Direct statements from the interviews revealed the following:

Need for planning

■ “We get the money and we just start doing it rather than waiting until we are ready to do it because of many dynamics.”
■ “They are not good on the time aspect. That is a difficulty. And so I do encourage everybody to do time lines. . . . Most grants require some kind of time line, you know. But people need a time line also to get the proposal written in order to get the planning done, which they don’t really think about for the most part.”
■ “Most scientists are not trained to do the administrative aspect of that. I think it is just by pure chance that some of them are able to do it. It is a difficulty.”

Reporting

■ “Getting people to think about reporting out for more deliverables, which means at the start of the project, you have to have a very good (idea of) who is doing what, who is on second, roles and responsibilities, metrics to measure by, how do you judge success or failure in those interim windows.”

Execution Stage
At the execution stage, project management approaches are difficult to incorporate because the projected and intended result of the project is often difficult to quantify. Whereas industry project management sets definite due dates and milestones to attain, scientific discovery is not amenable to such specificity. Often, the principal investigator establishes the milestones and has a time frame, and it is up to that individual to get people to actually stick to the time frame. Scientists are not trained in the administrative aspects of managing projects, noted one respondent. Attempts to introduce structure, such as tracking software, are often opposed, even when researchers acknowledge their usefulness. Comments such as the
following reveal how implementation of project management has been incorporated into the work of the multidisciplinary team:

- “They are unstructured and loosely defined, but we have very well-developed evaluation processes for our teams.”
- “We work with the project manager to identify appropriate metrics that would indicate whether they are moving along and making progress in their individual projects.”
- “We have a quarterly evaluation where we sort of have an online data management, where project managers report their progress along these metrics.”
- “One aspect that I like is risk-based monitoring. We are building that into the system.”

Termination/Transition Stage

Because the success of a scientific project is not necessarily measured by obtaining specified goals, a project may not be abandoned if the hypothesized outcome does not result. There is also less likelihood that a scientific research project will be terminated if deadlines are not met. One interviewee commented that at his institution research teams are not terminated; team members simply “sort of choose to dissolve.” Another principal investigator observed: “There are even greater consequences for pulling the plug on things in academia as compared to industry. . . . [I]t’s more of an emotional investment [and] some components of project management could help the resource allocation . . . in terms of knowing when to maybe fund more and when to pull the plug.” Similarly, another interviewee commented: “One thing that successful businesses do very well that academic centers don’t do well is to know when to throw in the towel.”
Results of Survey

In total, we received 39 usable surveys from scientific team respondents. Because we relied on administrators at several CTSAs around the country to disseminate the survey to their colleagues, we cannot ascertain how many surveys were actually distributed to team members or the actual response rate. However, although the number of surveys returned was lower than expected, we were still able to identify trends in the four areas surveyed in the questionnaires. Demographic data revealed that 80% of the respondents were female, and the average age was between 45 and 55. Seventy percent of the respondents were PhDs, 25% were MDs, and 5% held a master’s degree. Seventy-seven percent were assistant professors, associate professors, or full professors, with the rest either graduate students, postdoctoral students, or fellows.

Of the 39 respondents, 83% were on the team for more than one year, 75% were on at least one other team, and 75% of the teams had between three and nine members. Forty-two percent of the respondents were either the principal or co–principal investigator, 17% identified themselves as a project manager, and the rest were team members.

Critical Success Factors and Management Knowledge

Of the 23 critical success factors listed in the survey, virtually every factor was identified as important and 15 were identified as essential in one or more stages of project management. Table 8 reports the results of the survey, showing the factors identified at each stage by at least one-third of the respondents. Management knowledge areas of particular importance were human resource management, time management, quality management, and communication management, especially at the execution stage, as shown in Table 9.

Interestingly, the need for clear objectives and adequate resources was identified as critical in all four stages of project management. Other factors were more specific to the conceptualization/planning stages or to the execution or transition stages.

Leadership Qualities

Seven leadership qualities were identified as most essential by 50% of the respondents, with six of them relating to the intellectual competencies and the seventh relating to the managerial competency of communication. In addition, except with respect to the competency of “the ability to see the impact of implementation and changes to a project,” which related to the execution stage, all seven factors were most important in the conceptual and planning stages. Fewer respondents selected competencies relating to the emotional style of leadership, although a fair number reported that participative, inclusiveness, and sensitivity qualities were important in the execution and transition stages (see Table 10).
Factors | Conceptual | Planning | Execution | Transition |
---|---|---|---|---|
Clear Objectives | X | X | X | X |
Support from Sr. Mgt. | X | X | |
Adequate Resources | X | X | X | X |
Realistic Scheduling | X | X | | |
Effective Team Building | X | X | | |
Recognizing Complexity | | | X | |
Effective Leadership/Conflict Management | | | X | |
Monitoring and Feedback | | | X | X |
Flexibility to Change | | | X | X |
Talented People | | | X | |
Accounting for Past Experience | | | | X |
Conceptual Awareness | | | X | |
Clear Communication | | | X | |
Clear Project Boundary | | | | X |
Considers Multiple Views of Project | | | | X |

Table 8: Fifteen Critical Success Factors Identified for Scientific Project Teams.

**Project Management Tools**

Though interviews with principal investigators and administrative leaders did not reveal that scientific teams used project management tools to a large extent, the survey data suggested otherwise. Figure 2 reports the results of the survey, showing that many project teams used several project management tools and that those tools differed depending on the stage of the project.

**Collaboration and Knowledge Transfer**

Measures of collaboration frequency reveal that 81.25% of the respondents said that communication among team members took place frequently or always, while 62.5% said that the overall productivity of their collaborations occurred frequently or always. All of the respondents reported that their teams could capitalize
<table>
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<th>Conceptual</th>
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Table 9: Management Knowledge Factors Identified for Scientific Project Teams.

- Keeps up with innovations and new breakthroughs
- Gathers information from a wide range of sources
- Balances long- and short-term considerations
- Identifies opportunities and threats
- Develops new ways of looking at complex problems and ideas
- Is able to see the impact of implementation and changes to a project
- Communicates a clear and positive vision for the future

Table 10: Leadership Qualities Identified as Essential for Scientific Project Teams.
Figure 2: Project Management Tools.
on one another’s strengths at least some of the time. However, the resolution of conflicts and the productively of meetings occurred less frequently. Trust and respect among team members was rated very high, with 93.34% of the respondents agreeing or strongly agreeing that they trust and respect their fellow team members. Further, 60% of the respondents reported that their collaboration had improved their research productivity.

Knowledge transfer most typically occurred through coauthorship, conferences, workshops and seminars, presentations, invited speakers, and co-advising students, with greater than 50% of respondents reporting activities in these areas. All modes of communication frequently occurred among teams, with the exception of online forums and project websites.

Regarding outcomes, the survey results revealed the following as the most typical success indicators of collaboration and knowledge transfer experienced by the scientific teams: started a new area of research, developed new models, received grant funding, published in recognized journals, and made conference presentations. Fewer respondents reported submitting patent applications or being recognized with an award for their contributions. Finally, 87.5% of respondents reported that collaborations that started within or outside the project will continue after its completion, while only 46.67% of the respondents said they shared data with other research projects.

![Figure 2: Project Management Tools. (continued)](image-url)
Discussion

Since project management emerged in the 1950s as a distinct research discipline, studies have generally focused on how processes can be refined and improved, leading to more efficient methods and better outcomes. Traditional project management assumptions contemplate a linear process, a cumulative sequence of phases or events. Cicmil et al. (2006) observed that a key expectation of project reality is the project life cycle (PLC), which presents a linear model with specified milestones or deadlines on which documentation, budgets, and information controls are based. Winter et al. (2006) characterized the standard as a “hard systems model,” emphasizing the importance of planning and control and chronological scheduling. Related to project management and team science, these observations are made more salient given the recent report by Wooten, Calhoun, Bhavnani, Rose, Ameredes, and Brasier (2015), who found that of all longitudinal change criteria for scientific teams, the most resistant to development were leadership behavior and practices. Further, project management assumes that the PLC model leads to a specified outcome, a final result defined and quantified at the beginning of the project. More relevant to project management research is the view that studies should produce universal best practices, contained in mainstream manuals and procedures (Cicmil et al., 2006).

During the early 21st century, however, management researchers began to rethink the goals of project management and to re-conceptualize projects as social processes of complex and nonlinear events. Recent discourses on project management have suggested that traditional ways of visioning projects should be explored and modified. As noted by Cicmil and Hodgson (2006), “research into project and project management remains heavily reliant on a functionalist, instrumental view of projects and organizations, where the function of project management is taken to be the accomplishment of some finite piece of work in a specified period of time, within a certain budget, and to agreed specifications” (p. 111). Recounts of project management failures have called into question existing models of project models, calling for changes in the basic assumptions that underlie the planning, tasks, and outcomes of projects, as well as the objectives of project management research.

Conclusions stemming from a government-funded research project in the United Kingdom identified several areas for redirecting project management research. Among them were the development of new models and theories that recognize the complexity of projects, frameworks that focus on value creation as the net benefit of projects, and a broader approach to projects that is both multidisciplinary and loosely defined (Winter et al., 2006). Similarly, planning is a critical aspect of project management and is often viewed as essential to project success (Dvir & Lechler, 2004). Nevertheless, studies have found that traditional approaches to planning may be too rigid, which curtails the ability to make modifications when needed or to take into account opportunities that might enhance innovation (Bart, 1993). In their study of 448 projects, Dvir and Lechler (2004) identified two types of changes that mitigated the planning conducted in the initiation stages of projects. Plan changes involve events that prevent managers from following their initial plans because of factors such as delays, budget cuts, or resource deficits. Although these changes are unavoidable, it can be argued that better planning could have anticipated such hurdles. Conversely, goal changes result from decisions to alter the ultimate outcomes desired from the project and often change the basic scope and deliverable of the project. In either case, the authors found that goal changes and plan changes had a more profound effect on the success of projects than the initial planning process.

Despite calls for innovation in project management and new directions for research, studies appear to continue to follow the classical models embedded in project management theory, most notably life-cycle and mission
identification (Lenfle & Loch, 2009). A cursory review of recent studies confirms acceptance of the conventional wisdom that project management performance is dependent on adhering to the well-accepted functions of initiating, planning, execution, and control (Humaidi & Said, 2011; Nenonen, Kivistö-Rahnasto & Vasara, 2012; Sinha, 2014; Yani, 2014). Moreover, new theoretical models based on the recommendations stemming from task forces in the United States and Europe remain to be developed.

With this prescriptive in mind, we set out to examine the way scientific teams manage long-term projects funded with NIH grants that mandate both collaboration and an objective of discovering a medical breakthrough that will ultimately help patients. Because multidisciplinary teams had been formed and in existence for several years, we expected that some management techniques would have been adopted and used to manage the diverse makeup and functions of the teams. Our interviews with the principal investigators and senior administrative personnel revealed that although they recognized the need for formal management processes and procedures, in many cases teams were still in the development phases, especially during the conceptual and transition stages of the project. Survey data, however, revealed that more sophisticated techniques were being used at all stages of project management. We also learned that certain success factors were deemed critical, with clear variations at different stages of the teams’ projects. This is an important finding because project managers need to be aware of the needs of their team members and must communicate effectively in order to ensure that those needs are met. Even more interesting are the survey results regarding leadership qualities. From the answers received, we learned that leadership in the areas of strategic vision, keeping current with new developments, innovation, and communication are essential, especially in the conceptual and planning stages. However, several respondents reported that the softer emotional skills, including participative leadership and sensitivity, were also important.

Implications for Managers

Multidisciplinary scientific teams, though somewhat unique in their makeup and project goals, nevertheless share features with other types of project teams. Thus, our findings have general application for project managers. From our interviews with senior administrators, we learned that seniority and prior successes were essential in forming teams for research projects. Team members will place a great deal of emphasis on the credibility of the principal investigator and his or her ability to attract other talented team members. However, after the initial conceptual and planning stages, other factors became more important, such as flexibility to change, inclusiveness, feedback and monitoring, communication, clarity, boundary setting, and managing resources. Similarly, quality, time, human resources, and communication management skills were reported to be most important during the execution stage. Thus, although charismatic and transformational leadership qualities may be best suited for the initial stages of the project, basic management and organizational skills are needed once the project is under way.

There are several clear applied implications from our findings that have relevance for the future use of project management in the academic research context. First, though there was some concern among the PIs and more senior university administration that project management tools were not being used, our limited pilot data suggested otherwise. This, coupled with the different types of project management tools repeatedly used across the life cycle of scientific projects, suggests that a “community of practice” has emerged, impacting what is useful and utilitarian but not necessarily what is prescribed or suggested by the project management literature and developed techniques. This further reinforces the situation-specific and cyclical nature of project management in science. Further, this suggests that scientific leaders must not only be taught the most useful techniques, but must also feel comfortable using them as needed. Thus, scientific leaders using project management tools must develop more refined diagnostic skills.
Second, data indicating different resource configurations and leadership style application in relation to different stages of the life cycle suggest that leaders not only need to display stage-specific behavior, but also must manage the continually changing human resources assigned to their team. In this case, the scientists who are not core (permanent) or those trainees assigned for workforce development will require leadership that is not only specific to the stage of the overall project, but to different and changing personnel configurations as well. This suggests a very high level of leadership sophistication, and is clearly beyond the training of most inexperienced scientific leaders. Thus, additional tools need to be developed relative to training future leaders to both manage the overall project transformation and to simultaneously manage project members contextually, based on team member needs and maturity. Therefore, a hybrid form of project management and project leadership is necessitated. This is crucial for the application of project management in science. Recent evidence (Wooten, Calhoun, Bhavnani, Rose, Ameredes, & Brassier, 2015) suggests that scientific leadership in a sample of MD teams was the most resistant to change among all evaluative criteria.

Our third managerial implication for academic researchers implores CTSA program managers to develop partnerships with local PMI chapters. From an academic perspective, CTSA research managers need training in order to understand the power of and how to effectively use project management methodologies, frameworks, and tools. For many academic researchers, project management is an innovation that disrupts their existing way of managing research projects. Project management training and interaction with certified project management practitioners will help managers understand the value of project management. From a practice-based perspective, the adoption of project management in an academic environment is an opportunity to expand project management knowledge because existing methodologies might need to be adapted to fit a nonprofit environment that seeks to harness academic creativity in order to solve public health problems.

The findings of our reported analyses can be extended beyond the academic environment to suggest more broad-based managerial implications. First, project managers must not only use project management tools and methodologies to enhance the research process but also simultaneously to improve the research product. Specifically, processes that are designed to improve inter-project communication and the transfer of knowledge also foster creativity and innovation. The following discussion highlights this managerial implication further.

Current project management methodologies involve a horizontal, cross-disciplinary approach to managing projects to achieve better control, customer satisfaction, and value generation (Lee-Kelley & Leong, 2003). Interdisciplinary science teams might benefit by employing project management techniques to maintain order, support coordination, and facilitate communication by “providing templates for completion during the course of the project to ensure timely and accurate recording of data, they organize team meetings and keep records, and they organize team training” (Curry, 2008, p. 7). We contend that project management methodologies not only introduce a new language to academic research projects in the form of discipline, coordination, and standardization, but also that similar phenomena occur in the nonacademic environment.

A new language is necessary because university scientists as well as other technical specialists possess tacit knowledge or "know-how" that relates to a specific scholarly, scientific, or mechanical area (Kachra & White, 2008) and accumulate latent knowledge that provides valuable intuition about the inner workings of a technical system (Agrawal, 2006). They participate in scientific or industrial communities with others who share the same domain expertise (Gittleman & Kogut, 2003). By doing this, researchers increase their domain expertise but also tend to become locked in their own thought world (Dougherty, 2001). Locked in their thought worlds in such a way, scientists are unable to communicate and share their knowledge. However, project management tools can provide a standard language that can reduce silo barriers and improve communication and knowledge sharing.
Project templates, frequent status meetings, and training all improve the research process but also offer team members from different projects a new language that they can use to interact, develop trust, share knowledge, and innovate. By making research processes more effective and efficient, project methodologies provide the tools to bring together different stocks of domain knowledge to create knowledge and to innovate. Knowledge is created when individuals interact with one another across functional, organizational, or hierarchical boundaries (Nonaka & Toyama, 2005). Innovation can only occur when there are processes that enable project team members with different functional expertise to communicate. To unleash the power of project management tools, research managers understand the inextricable link between the research process and research product. Innovation can only occur once there are standardization, coordination, and communication processes in place to bring together disparate knowledge sources across project and departmental domains.

**Implications for Research**

This study should be viewed as a preliminary look at the antecedents and consequences of collaboration within scientific teams after an external directive forced new directions for research at medical schools. From our interviews, 27 common themes emerged as relevant to the success of the CTSAs at the four universities and to the scientific teams sponsored by those institutes. This paper focused on three of those areas: collaboration, leadership, and project management. However, each of these important dimensions was studied independently; relationships between effective leadership and successful collaborations or implementation of project management tools need to be further examined to make a more meaningful contribution to research and project managers. Similarly, we have just begun to look at some other factors, including change, communication, processes, and transformation and their interactions with leadership and collaboration. One of the biggest challenges facing the CTSAs was establishing a culture of collaboration among scientific teams, especially when older researchers, many of whom were set in the ways of a hierarchical structure, were asked to forego their presumed leadership role in favor of a more participatory approach. We learn from organizational behavior literature that change management requires transformational leadership that focuses on developing and disseminating a shared vision (Bass & Riggio, 2006). In the realm of change leadership activities within project management, shared goals, together with defined roles, leader guidance, training, and, above all, multilayered communications, have been identified as critical success factors (Griffith-Cooper & King, 2007). Further existing interviews alerted us to problems among interdisciplinary teams because the same words may be used by different fields in different ways (Lund, Coleman, Gunnarsson, Appleby, & Karkinen, 2006). The role of the leader of a multidisciplinary team is to broker the coordination and exchange of information both within the team and with external actors (Gray, 2008). More research is needed to identify the activities that will enhance communication among scientists and produce increased collaboration leading to medical discovery. A framework to examine the role of leadership in collaborative settings was developed by Vangen and Huxham (2003) in situations where hierarchical relationships centering around a formal senior business head did not figure into the process. Instead, their model focused on the mechanisms that “make things happen in collaboration” (p. S62). The teachings from that model appear to be relevant for enhancing collaborative activities among scientific teams.

The survey data also revealed that respondents viewed strategic leadership abilities, such as keeping up with innovations, gathering information, balancing long- and short-term considerations, and so forth (see Table 10), as the most important for multidisciplinary teams. These form the same list of leadership qualities identified for project management (Gray, 2008). However, day-to-day managing activities, such as scheduling meetings, sending emails, preparing reports, and ensuring that the project is progressing in a timely manner, are also
important tasks for project managers. In scientific teams, we learned that the appointed project manager is often not the de facto team leader and is very often a more junior person who may not have the respect or authority to command more senior team members’ actions. The relationship among these management activities and the leader’s delegation of his or her authority will be further studied based on the information from interviews as well as additional survey responses.

We consider this study and the resulting findings to be merely the beginning of a more in-depth study of scientific teams. With the knowledge gained from this research, we plan to modify and streamline our survey and administer it to a wider population of scientists. We also plan additional interviews to enhance our understanding of the success factors and leadership qualities needed for productive scientific research. We will also pose questions that more closely examine how project management furthers collaboration and knowledge transfer. With additional data, we will then analyze whether the presence of these factors, tools, and qualities have a positive relationship with outcomes of success.
References

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Exhibit 1. PMI Grant

Potential Interview Questions—Principal Investigators and Research Administration

Introductory Questions

■ What year was your CTSA first awarded? What would you say has been the major focus (scientific research focus) for your institution’s CTSA award?

■ Describe the overall goals and strategy for your institution’s CTSA. How would you judge the success of this so far? What have been the biggest hurdles or obstacles? What has been most surprising?

■ After CTSA funding, have the cross-disciplinary/interorganizational collaborations changed? If so, how? Is your institution’s CTSA organized to facilitate collaborative translational research? How is this measured/tracked? How effective, in your opinion, has this been?

a) What factors at your institution have helped facilitate or support productive cross-disciplinary/interorganizational collaborations—for example, leadership, infrastructure, communications, or institutional policies?

b) What mechanisms are in place to facilitate data sharing among collaborators?

c) What challenges have emerged related to engaging in or supporting productive cross-disciplinary/interorganizational collaborations?

d) How have your interorganizational collaborations adapted to a virtual environment?

■ How is your institution’s CTSA organized to facilitate innovation? How is this measured/tracked? How effective, in your opinion, has this been?

■ How is your institution’s CTSA organized to facilitate community/industry engagement? How effective, in your opinion, has this been?

■ Since your CTSA funding, have decision-making responsibilities regarding research, funding, and prioritization changed? Is your CTSA structured in a more centralized or decentralized manner? Are decisions more likely to be made by individuals (if so, by whom?) or committees? Are decisions now made by persons other than administrative personnel?
Administrative Questions

■ How has the CTSA award changed research at your institution generally?

a) Level/amount of research?

b) Focus or area/target of research?

c) Participation/who conducts research?

d) Significance/impact of research?

■ How has the CTSA award changed the management of science or research administration of your institution generally?

a) What has changed about your institution’s management information systems and controls since the CTSA award?

b) What research policies have changed since the award (e.g., pilot funding, research support, promotion, and tenure)?

c) How have research administration processes changed since the award (planning, budgeting, performance evaluation, resource allocation, management information systems/intelligence, reporting structure)?

1) Before the creation of the CTSA, describe your tenure process. What behaviors were rewarded and how were they rewarded?

2) After the creation of the CTSA, have you changed your tenure process to include different metrics to evaluate tenure and promotion decisions (e.g., collaborative-based assessments, publications with outside coauthors, grants with outside institutions, etc.)?

3) Have you encountered resistance to changing the tenure policy or support?

d) What specific changes have you noticed in your institution’s culture since the CTSA award (e.g., norms, expectations, reward structure, values, rituals, etc.)?

e) How has the leadership of research enterprise been changed by the CTSA award?

1) Before the creation of the CTSA, who assumed leadership in research?

2) After the creation of the CTSA, how has leadership changed? How has the role of the leader changed?

3) How has the role of the leader influenced and been influenced by institutional goals and objectives?
Project Management Questions

- How are CTSA-funded science projects organized at your institution (structure, leadership)? Is there a preferred model or archetype? How has this worked out?

- How are CTSA-funded science projects coordinated at your institution? Is there a preferred system of coordination? How has this worked out?

- How has the CTSA award changed the way scientific projects are organized and coordinated at your institution? What has really changed (if it has changed at all) about how projects are managed and facilitated?

- How have the changes (since the CTSA award) in your institution’s research policies, promotion, culture, and leadership influenced the way scientific projects are organized, coordinated, and managed?

- Who is generally selected to be the project manager? Are science project leaders or members given any training in project management? If so, describe it.

- Are there scientific project management tools (e.g., planning, tracking, meeting management, information systems) that are (a) required, or (b) used by your CTSA-funded projects?

- Since the CTSA award, what would you say have been the biggest changes in methods, process, or tools in the management of scientific projects at the project level?

- How have the above-mentioned changes at the project level influenced the overall research administration at your institution?

  a) Information systems for research?

  b) Research policies?

  c) Research administration practices?

  d) Institutional research culture?

  e) Institutional research leadership?
Questions for PIs

- Collaboration: Prior to CTSA, describe the extent to which your institution engaged in research collaborations with other medical schools, universities, or commercial firms.

- How has the creation of the CTSA changed your institution’s participation in interinstitutional research collaborations? If there has been a change, can you describe factors that contributed to it?

- Has the type of research collaboration changed after the development of the CTSA?
  a) What mode of collaboration was popular before the creation of the CTSA?
  b) What mode of research collaboration was popular after the creation of the CTSA?
  c) To what do you contribute the change in research collaboration modes?

- Were there any other influences/outcomes at your academic institution, such as the influences of or changes to institutional culture, administrative routines, or institutional policies?

- Training: What training programs have been implemented to facilitate CTSA? Who are the scholars and trainees? How frequently does training occur each year? Does training cover both team training and cross-training in research and clinical science? Where does training take place?

- What are the specific objectives of the training? Have they been successful? How is success measured?

- What changes in training could be made to make it more effective?

- Have any formal mentoring and/or coaching programs been implemented? If so, please describe them.
Appendix

Appendix 1. Summary of Proposal Objectives and Research Accomplishments

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Appendix 2. Biographies of Principal Investigators

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