Research Management Review, Volume 18, Number 2
Fall/Winter 2011

Managing Risk and Uncertainty in Large-Scale University Research Projects

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ABSTRACT

Both publicly and privately funded research projects managed by universities are growing in size and scope. Complex, large-scale projects (over $50 million) pose new management challenges and risks for universities. This paper explores the relationship between project success and a variety of factors in large-scale university projects. First, we characterize the challenge of large-scale university research project management, synthesize findings from the literature, and identify research gaps. Second, we offer a profile of large-scale U.S. university-run projects based on a survey conducted by us. The projects address a range of research from large-scale clinical trials to the construction of complex scientific instruments. While NIH is the largest overall government funder of university research, NASA is the largest funder of these large-scale university projects. Third, we share some preliminary results from our survey. While universities often meet their technical performance goals, cost and schedule overruns are common and can be significant. Qualitative data confirmed that research project managers face anti-management challenges in the university setting and challenges with project management techniques not tailored to the university.

INTRODUCTION

The number of large, complex research projects managed by universities is growing in size and scope. Additionally, industries are shifting more research projects to universities (Hall, Link, & Scott, 2003). At Arizona State University (ASU), for example, the amount of annual funding for sponsored projects over $5 million has risen from $10 million to $40 million over the past twenty years (Raudenbush, 2011). Large-scale research projects (over $50 million) pose management challenges and risks because they are often complex and unpredictable, involve new technologies, involve a large number of stakeholders and institutions, and extend over a long time scale (Bonnal, Jonghe & Ferguson, 2006). The traditional project management (PM) literature offers a number of methodologies for managing risk and uncertainty in large-scale projects, with a focus on minimizing cost and schedule overruns. However, universities are not known for the implementation of sophisticated project management systems and the management methodologies may fall by the wayside of 'getting the science right.' The relatively new field of research project management (RPM) is still developing its professional identity and gaining legitimacy, and scientists have resisted managers' attempts to engage in research project management (Sapienza, 2004; Schuetzenmeister, 2010).

As the scope and size of research projects expand, universities have become major players, and sometimes leaders, in multi-million dollar research and development (R&D) projects. For example, in 2009, the National Science Foundation (NSF) awarded over $200 million to the University of Wisconsin-Madison to construct a deep-ice neutrino detector, called IceCube, in Antarctica. In 2007, the National Institutes of Health (NIH) awarded over $63 million over three years to George Washington University to develop a Diabetes Prevention Program. Over the past decade, NASA has granted several dozen awards over $100 million to universities for first-of-a-kind spacecraft research and development, including Genesis, Deep Impact, and Galex. These research projects are often: (1) extremely complex; and (2) decentralized, with work occurring at multiple institutions and across disciplines; and (3) may change dramatically in scope. All of these risk factors contribute to cost and schedule overruns in large-scale projects.

". . . large-scale research project management techniques should be improved in order to increase project success."

This paper explores the current population of completed or nearly completed large-scale university-run research projects and then examines the relationship between university management techniques and project success. We demonstrate that a significant amount of funding is spent on university-led projects larger than $50 million and argue that large-scale research project management techniques should be improved in order to increase project success. We begin by discussing how large-scale projects are defined and characterized in the literature and how we apply these characteristics to large-scale university-run research projects. Next, we discuss a number of challenges facing university research project managers. We then offer an overview of project outcome measures, primarily cost, schedule, and technical performance, and discuss how these apply specifically to R&D. Next, we describe our methodology for developing a sample of large-scale university-run projects, which we believe is the total population minus U.S. Department of Defense projects. We describe the attributes of this population, finding a median university total project cost expenditure of $93,586,025 and an average project timescale of seven years. Finally, we share some preliminary findings from our survey of managers of these projects. While many university projects meet their overall technical objectives, many do so by overrunning the original cost and by slipping the initial schedule.

WHAT IS A LARGE-SCALE RESEARCH PROJECT?

The large-scale project and its even larger counterpart, the megaproject, are often defined based on cost ranges, though these cost ranges vary throughout the literature. For example, Flyvbjerg (2007) defined large-scale projects as those that cost between $100 million and several billion dollars. He defined megaprojects as projects over $1 billion with a lifetime of 50 years or more (Flyvbjerg, 2005). Merrow (1988) defined large-scale projects as those over $500 million, and he defined projects over $1 billion as “very large projects.” Large-scale research projects, however, are generally lower in cost than the large-scale infrastructure projects on which much of the literature on large-scale projects focuses. Further, projects on which the university is the lead manager are typically on the lower end of the large-scale research project cost range.

For the purposes of this study, we used a cost threshold of over $50 million in total project costs to characterize large-scale research[1] projects, of which there are roughly 58 U.S. university-led projects in the United States (as of 2010).[2] This choice was empirically driven. If we had used the $100 million cut-off from the literature described above, the sample would have been limited to 21 projects and skewed toward National Aeronautics and Space Administration (NASA) and U.S. Department of Energy (DOE) projects led by California Institute of Technology (Caltech) and Stanford University. Types of scientific and technical research projects over $50 million include the construction of complex scientific instrumentation; the construction of first-of-a-kind spacecraft; the design of innovative weapons systems; the construction of large-scale, first-of-a-kind computing infrastructure; longitudinal clinical trials; and bioscience research projects with a singular objective. Due to our focus on university management, we did not address scientific megaprojects, which are typically over $1 billion and international in scope, and extend over decades (Cross, 2009). Scientific megaprojects are often managed by one or more government agencies rather than universities. Examples of megaprojects include the International Space Station, the Human Genome Project ($3 billion), and the Superconducting Super Collider (expected cost of $8 billion, but cancelled in 1993). While these "Big Science" projects garner much attention, guidance and program evaluation are also needed on middle-range university-led projects, which also represent significant research expenditure.

We defined a project as having a clear objective and timescale and a definable outcome. In contrast, many large-budget scientific operations are research programs with components at multiple universities, across scientific domains, and sometimes representing several countries. Basic research at this funding scale tends to be conducted at dozens of universities working to fulfill a research center's typically broad mission. NIH funds a number of research programs distributed across multiple universities, such as the Center for AIDS research, national/regional primate research centers, and the general clinical research center. These did not fall under our definition of a project.

Basing the definition on a range of total project costs is likely not the only, and perhaps not the most useful, metric for characterizing these large-scale research projects in a way that facilitates understanding of the management challenges they pose. Large-scale research projects are also often highly complex and uncertain, extend over long time scales, and involve a large number of stakeholders and researchers. Bonnal et al. (2006) characterized large-scale projects based upon the following factors: number of contributors to the project; number of activities the project seeks to perform and the relative complexity of these activities; number of intermediate deliverables that are produced throughout the project's execution; number of activities outsourced to external contractors; and project duration that can span over a decade, making it difficult to define the long-term objectives of the project at the project's conception. In fact, these characteristics are more relevant to research projects, which may have smaller budgets than construction projects but be extremely complex in terms of the number of involved actors and institutions; the number of experiments and activities; the long time periods, particularly until the science is translated into a societal benefit; and the number of stakeholders ranging from human subjects to the policymakers and taxpayers funding the research. In summary, large-scale research projects, for the purposes of this study, have a clear and achievable research goal, are very complex, often involving uncertain technologies, typically involve a large number of actors and institutions, often involve relatively long time scales, and cost over $50 million in total project costs.

THE CHALLENGES OF MANAGING LARGE PROJECTS AT UNIVERSITIES: MANAGEMENT KNOWLEDGE AND THE RESEARCH MANAGEMENT PROFESSION

Universities are being called upon to manage increasingly large research and technology development projects, but there has been a surprisingly small subsequent gain in the systematic knowledge of the challenges and risks involved with university research project management (RPM). Universities face challenges in each stage of managing large-scale projects: winning the project, defining the project, and managing the project. Universities face two key conceptual issues when managing large-scale projects. First, universities are not designed as project management organizations and therefore are not necessarily equipped to manage these behemoth projects in an efficient manner. Second, research does not progress in a linear fashion in the way that construction projects often do. Research project managers face the discovery paradox, meaning that discovery occurs in serendipitous ways,[3] but existing management techniques are typically linear and prescribed.

To address these challenges, 1) knowledge of university project management is needed, and 2) experienced research project managers are needed. We will address the need for RPM knowledge first. The traditional project management profession has developed a set of project management tools based initially on experience with construction and infrastructure projects. These tools have been refined for large-scale weapons systems, environmental clean-up and restoration projects, and large-scale information technology projects. This experience and research have even been synthesized in a number of publications, including the *Project Management Body of Knowledge* published by the Project Management Institute. However, higher education institutions are often the slowest adopters of project management (Kralevich, 2008). While there is some synergy with traditional project management techniques and research project management, PM techniques designed specifically for university are lacking (Austin, 2002; Erno-Kjolhede, Husted, Monsted, & Wenneberg, 2001; Powers & Kerr, 2009). This is a gap in need of further research.

As mentioned above, these research project managers face the scientific discovery paradox. Geles et al. (2000) argued that most project management strategies were designed for business, not science; further, this literature is not

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rigorous. Geles et al. outlined some of the project management strategies they believe would be suitable for use in the laboratory, including using a work breakdown structure for planning, charting the overall resource inputs required for the project, planning for risks and contingency, scheduling using Gantt Charts and project milestones, and using a costing scheme that converts resources into a common unit, e.g., U.S. dollars. Others feel more strongly that a completely new set of methods should be developed. Austin (2002) argued that the project management literature is too uniform and is not adaptive enough to be applied to science where there is "genuine discovery" that cannot be anticipated and planned for. Conventional project management strategies are better suited for construction because it is more predictable. Instead of spending a lot of time planning, research projects will require some learning-by-doing. Therefore, Austin argued, dynamic research project management methods with adaptive approaches are needed for innovative projects. This discovery paradox is a key challenge facing research project managers moving forward.

Also needed are experienced research project managers. A National Research Council report argued that Ph.D. scientists have not been trained in management, so large-scale research projects will require a research project manager who should be hired based on management skills, not scientific credentials (Nass & Stillman, 2003). These research project managers fulfill an important role in managing a growing amount of external funding for the university and their level of experience is thought to contribute to keeping projects on schedule and budget. This unique profession interweaves academic, managerial, and public service training and skills (Schuetzenmeister, 2010). It works at the boundary between science and society, managing and negotiating with multiple stakeholders both in and outside of the academy (ibid.).

". . . most project management strategies were designed for business, not science . . . ."

However, the research management profession is still forming its professional identity, struggling to delineate itself from university administration (ibid.). It is also working to prove that it possesses legitimate expertise and a credible identity in laboratories that have traditionally seen themselves as self-governing. There is a stigma that managing science is not as good as doing science, and large-scale research project managers must work to develop an interactional form of expertise even though they are often not trained in the particular field of study and are often less eminent than the scientists they are managing (Collins & Sanders, 2007). Research project managers face the following challenges in the lab: forces that pull research teams apart, anti-management (i.e., resistance to being managed), goal conflict between scientists and managers, difficulty with performance evaluation, and anti-organization because following the scientific method is viewed as providing sufficient organization (Smith & Tuttle, 1988). Further, large-scale research projects often require management across multiple disciplines and communications barriers may increase the project risk (Sapienza, 2004).

> **"There is a stigma that managing science is not as good as doing science . . . ."**

MANAGING COST, SCHEDULE, AND TECHNICAL RISKS IN LARGE-SCALE RESEARCH PROJECTS

All large-scale projects entail a unique set of management challenges. These include the following: the technology involved is often not standard, the decision-making process includes multiple actors with conflicting interests, the project scope and ambition level change over time, contingency estimates are usually inadequate despite statistical forecasts, and misinformation about costs and benefits is the norm (Flyvbjerg, 2005). These factors may result in cost overruns and performance shortfalls in a majority of projects (ibid.). Project management is geared toward increasing planning to reduce project uncertainty and risk. Project risk is a function of complexity, innovativeness, project definition, management experience, regulatory environment, budget certainty, and error (Cash, McFarlan, & McKenney, 1992; Merrow, 1988; Myers et al., 1986; Weil, 1992).

Schedule Slip

Changing project scope and poor project definition are key contributors to schedule slippage. Defining the project includes mapping out the project tasks, task relationships, project environment, and outcomes. Poor project definition has been shown to be a key contributing factor to cost and schedule overruns (Myers et al., 1986). Myers et al. (1986) also found that slippage in the project's total startup time could be explained by the number of process steps that were not commercially proven and by dispersed project responsibility. It is also widely acknowledged in the literature that project scope change is a major contributor to risk and uncertainty and drives schedule slippage. For instance, Samid (1994) found that one of the biggest challenges in R&D projects is that there are so many late-planned changes that the project bears little resemblance to the original plan (a reflection of the discovery paradox).

Managing Cost Uncertainty and Overruns

Cost growth, or cost escalation, is the difference between the estimated cost and the actual cost of the project (Merrow, 1988). In large-scale projects, technical goals usually take priority over time and cost goals (Grun, 2004). Therefore, cost growth in large government-funded construction and infrastructure projects has been a major focus in the PM literature. Unsurprisingly, cost escalation is identified as a major problem in these larger projects, with overruns of 50–100% being common (Skamris & Flyvbjerg, 1997). It seems that cost overruns are determined early in a project's lifespan; Christensen (1993) found that defense contracts are highly unlikely to recover from cost overruns incurred in the first 15% of the project.

Cost overruns are also often blamed on mis-estimation. In one study of infrastructure projects, underestimation was found to occur in nine out of ten cases (Flyvbjerg, Bruzelius, & Rothengatter, 2003). Priemus et al. (2008) analyzed cost estimates in megaprojects and found that they have not improved in the past 70 years, and Ramachandran (1989) found that while cost-estimating methodology has become much more sophisticated, the level of accuracy has not improved. There is disagreement in the literature about the reasons for mis-estimation. Sometimes it is attributed to appraisal optimism. Samid (1994) found that in construction projects contingency is often just used to pad cost estimates, rather than being thoroughly analyzed. Bruzelius et al. (2002) found that in megaprojects of $1 billion or more, the difference between the cost forecast and actual costs could not be attributed to inability to predict the future alone. They concluded that project proponents are intentionally biasing the forecasts, leading to poor decision-making by policymakers who are unable to rigorously evaluate the costs and benefits of a project because of these biased forecasts. They assert that technical error is actually a minor part of the cost overrun. Flyvbjerg (2007) recommended subjecting project forecasts for publicly funded projects to rigorous peer review.

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R&D and Risk

One of the main risk factors addressed in the literature is technological complexity, also referred to as the level of innovation in the project or the use of 'unproven technologies' (Parker, Benson, & Trainor, 1988; Sadeh, Dvir, & Shenhard, 2000; Shenhard & Dvir, 1996). The level of technological innovation in the project contributes to uncertainty and can result in cost escalation (Melamed, Skokan, Zenkowich, & Kocher, 2008; Merrow, 1988). The three measures of the level of innovation are whether 1) the project used a first-of-a-kind technology, 2) it employed new materials or methods, and 3) it was the largest project of its kind when it was constructed.

R&D brings with it uncertainty that is difficult to quantify. Pinto and Covin (1989) drew distinctions between R&D projects and construction projects due in part to overt risk. Rigorous, yet flexible, techniques are needed (Samid, 1994). Previous knowledge is required for effective statistical analysis, yet in R&D projects the assumption that previous knowledge can be used to predict outcomes often fails (ibid.). Austin (2002) argued that risk management for highly uncertain R&D projects might need to be different from the risk and uncertainty methodology that has been well developed in the construction industry. In a survey about the usefulness of risk management strategies, Galway (2004) found that construction managers are wedded to risk management, but high technology practitioners are ambivalent toward it.

LARGE-SCALE UNIVERSITY RESEARCH PROJECT MANAGEMENT SURVEY RESULTS

Methodology

We developed a sample of recently completed or nearly complete research projects over $50 million in which a U.S. university was the primary leader. Our sample size was 58, which we believe is the total population minus U.S. Department of Defense (DoD) projects. We faced several challenges developing this sample. First, there was little freely available information on the number and manager of large-scale research projects funded in the United States. Secondf, grant money was often distributed over multiple years or even through multiple grants and thus difficult to aggregate. We obtained project lists from the NIH, Centers for Disease Control (CDC), NSF, DOE, and NASA. Only NSF hosts a publicly available online database that may be searched by project cost. NASA and DOE staff provided us with information from internal databases. DOE maintains an online research and development database, but it is not searchable by cost. The NIH hosts a publicly available database with grant information, but it also cannot be searched by project cost. NIH and CDC required us to submit Freedom of Information Act (FOIA) requests in order to obtain the data. We were unable to obtain data from the DoD; the DoD officials we contacted were unaware of any DoD-funded university-run projects over $50 million. We also contacted the sponsored projects office at major universities, but most were unable to provide us with a list of their large-scale projects.

We designed a 28-page survey instrument that addressed the characteristics of the project, information about the project manager and project team, whether the project experienced cost overruns or schedule slip, what factors contributed to a successful project, the management and planning techniques used, and demographics. We asked the respondents to report on their initial cost and schedule estimates and their final cost and schedule outcomes to correlate these outcomes with a variety of risk factors. The development of the questions was theory-driven, drawing on factors in the literature thought to contribute to project success.

The survey was administered to project managers online through SurveyMonkey. If the project did not have an RPM or the RPM could not be reached, the survey was sent to the project's Principal Investigator. We sent an alert letter to both the university's office of research and to the head of the project prior to sending the survey invitation. We also sent multiple email requests and made follow-up calls aimed at boosting the response rate.

Characteristics of the Project Sample

Our development of the sample offers a unique overview of the characteristics of university-run large-scale research projects. The median university total project cost expenditure for the sample was $93,586,025. The average timescale for these projects was roughly seven years (or a median of 6).[4] The federal government is the main funder of projects of this magnitude. There was no systematic method for searching for state-funded projects, and only one was uncovered through internet and database searches. The sample consisted of three CDC projects, 11 DOE projects, 24 NASA projects, 15 NIH projects, six NSF projects, and one Ohio Department of Transportation project (see Figure 1).

Even though NIH is the largest overall government funder of university research (AAAS, 2012), it does not fund the greatest number of large-scale university-run projects. This is because much of NIH's research funding is dispersed across universities and is not project-based. For instance, much of NIH's expenditures are spent on basic research that is expected to one day translate into societal outcomes. NASA is the biggest funder of university-run large-scale research projects. Government funding for large-scale research projects consists of large NASA space contracts, complex large-scale scientific instrumentation and research using this instrumentation funded by DOE and NSF, and longitudinal clinical trials and other project-based biomedical research funded by NIH.

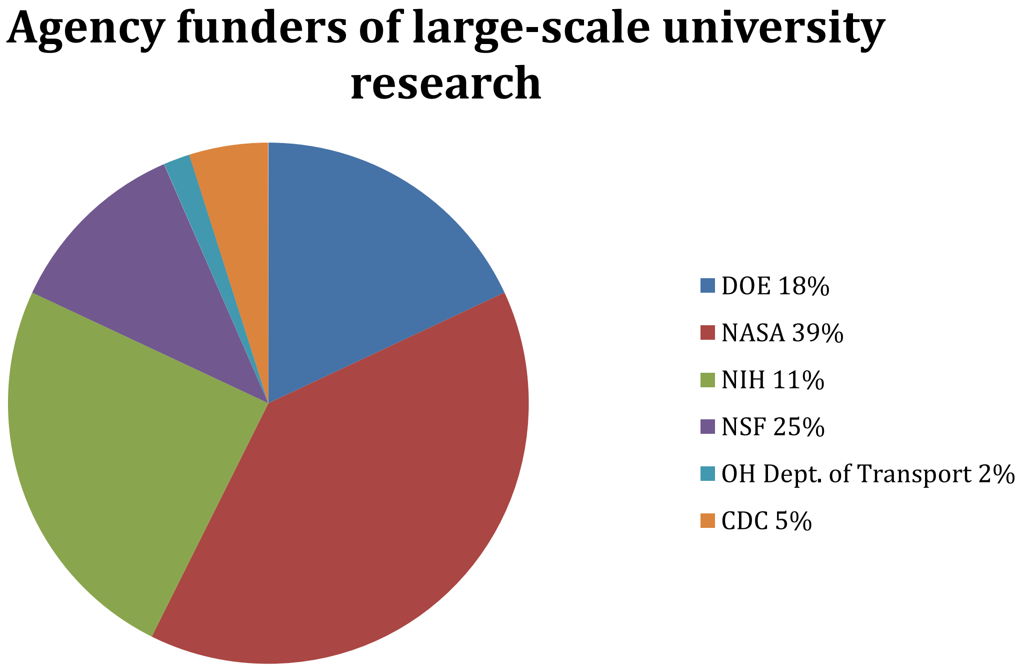

Figure 1. Funding Agencies for Large-Scale University-Run Projects Based on the Number of Recently Completed or Almost Completed Projects (through 2010). Note that this describes the survey sample, not survey respondents.

Four universities stand out as leaders in winning large-scale project contracts: California Institute of Technology (six projects plus one in partnership with Colorado State University, one in partnership with Hampton University, two in partnership with the Southwest Research Institute, and two in partnership with the University of California, Los Angeles), MIT (three projects), Stanford University (five projects), and the University of California, Berkeley (three projects).

As illustrated by Crow and Bozeman (2001), national laboratories provide leverage for universities to win large-scale projects. For example, Caltech's leadership may be attributed to its close partnership with JPL and its history of leadership in space projects. Many of the universities in the sample have partnerships with national laboratories, including Fermi National Laboratory (University of Chicago), Princeton Plasma Physics Laboratory (Princeton University), Jet Propulsion Laboratory (JPL) (California Institute of

Technology), and Lawrence Berkeley National Laboratory (University of California, Berkeley). Further, NASA provides an experienced project manager through one of its labs—e.g., NASA JPL, NASA Goddard, or NASA Langley—for all projects on which the university is the Principal Investigator. In other cases, a novel university hybrid organization managed the projects. For example, the construction of the High-Performance Airborne Platform for Environmental Research (HIAPER) was managed by a university research consortium, the University Corporation for Atmospheric Research. The project took five-years and was completed in 2006 for a total project cost of $80 million. It was funded by NSF.

> **" . . . national laboratories provide leverage for universities to win large-scale projects."**

These projects were diverse, including construction of complex scientific instrumentation, construction of first-of-a-kind spacecraft, fundamental research, and clinical trials (see Figure 2). Twenty-four of the projects involved first-of-a-kind space missions. For example, Deep Impact was a mission to impact and take samples of a comet. It was headed by University of Maryland (providing the Principal Investigator and scientific team) with the JPL (providing the project management) and Ball Aerospace & Technologies Corporation (providing the flight hardware). The construction and mission took six years at a total project cost of $330 million, $66 million of which went to the university. In another example, the NASA Wide-Field Infrared Survey Explorer (WISE) mission mapped the sky at four different infrared wavelengths with greater sensitivity than past maps. It was a $320 million mission in total project costs—with $220 million going to Caltech—over 11 years. The Principal Investigator was provided through the University of California, Los Angeles; NASA's JPL provided the project manager.

The NIH-funded biomedical projects ranged from clinical trials to genetic sequencing. One example is the $156 million Health and Retirement Study by the University of Michigan—a longitudinal in-depth interview study of senior citizens living in the United States. The researchers are interviewing 22,000 Americans over age 50 every two years. Another example is the sequence of the yeast genome by Stanford University at a total project cost of $97.5 million. A third is the BARI II trial at the University of Pittsburgh, which was a multi-country clinical trial on type II diabetes and coronary artery disease funded at a total project cost of $55 million.

NSF and DOE funded a number of complex scientific instrumentation construction projects. For example, the Ice

Cube project, run by the University of Wisconsin-Madison and funded by NSF, entailed the construction of a deep ice neutrino detector at the South Pole. The project required drilling 86 holes and installing 5,160 sensors for a total expenditure of $200 million. Another example is the Earthscope project funded by NSF and managed by Stanford University. It consists of 400 portable seismometers covering the entire United States, global positioning instruments positioned to observe fault zones in North America, and strainmeter instruments for observing and studying plate boundary processes and volcanic events. Other projects in the sample were large-scale research projects conducted on recently constructed complex scientific instrumentation such as the Alcator C-Mod Fusion Research Program funded by the DOE, the National Compact Stellarator Experiment, and the Stanford Linear Collider Research and Development.

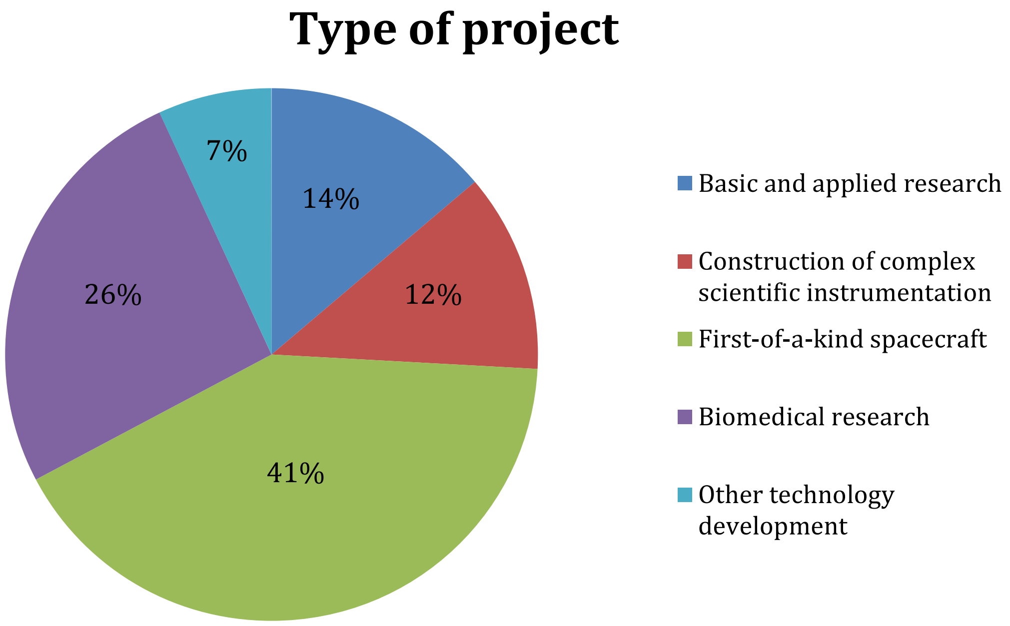

Figure 2. Type of Project Based on the Number of Recently Completed or Almost Completed Projects (through 2010). As categorized by the authors.

Survey Results

We received 18 partial responses and 12 complete responses from a sample of 58. Unfortunately, this was not a high enough response rate for statistical significance, but we were able to make some observations, outlined below. The dependent variable was project success, defined by whether the project met technical performance, cost, and schedule goals. Independent variables included key factors that the literature suggested would drive cost and schedule overruns, such as years of experience of the project manager; adequacy of project planning, particularly cost and risk estimation methods; changes in the scope of the project; inadequate project definition; sufficiency of the cost estimate; and interdisciplinary communication barriers.

Project success, defined as meeting technical performance, schedule, and cost goals, was mixed. The response rate for the cost and schedule slippage questions was low. Only project managers who met their technical performance goals responded to these questions, biasing the results toward successful projects. The response rate for the project cost estimate and actual expenditure was particularly low (*n*=5), perhaps due to the sensitivity of the question. Only one project manager reported meeting the project budget, while two experienced moderate overruns (5–10% of the estimate) and one experienced a significant overrun (15% of the estimate, or $15 million). Forty-two percent of projects came in on time or ahead, 29% were somewhat behind (i.e., 25–50% over schedule), and 29% were very behind (i.e., 25–50% over schedule) (*n*=8). Therefore, while all of the projects delivered on their technical promises, many did so well over schedule. Figure 3 outlines project success, which we defined based upon the significance of the cost overrun, the significance of the schedule overrun, and whether technical performance goals were met. Sixty-seven percent of projects were somewhat successful, 11% were successful, and 22% were very successful.[5] Surprisingly, only half of the projects (*n*=18) conducted a project risk assessment in the planning phases, suggesting planning for risk and contingency was insufficient.

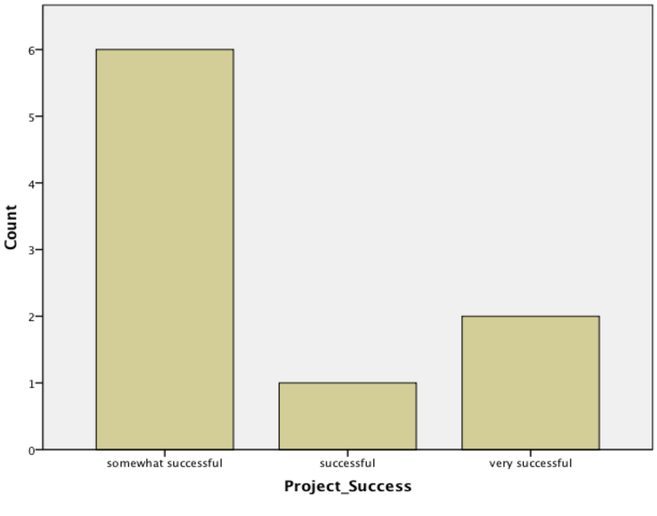

Figure 3. Project Success, as Defined by Cost, Schedule, and Technical Performance Goals. Source: PASW

Based on findings from the literature, the project manager's experience level was expected to affect project success. The majority of all managers who responded were highly experienced, with about 85% having five or more years of experience on projects over $50 million. Sixty-four percent had master's degrees in science, technology, or medicine, and 22% had Ph.D.s. (see Figure 4). Additionally, 61% had training in the scientific sub-discipline related to the project. In 77.8% of cases, project managers reported that the experience of the project staff was also critical to meeting technical performance goals.

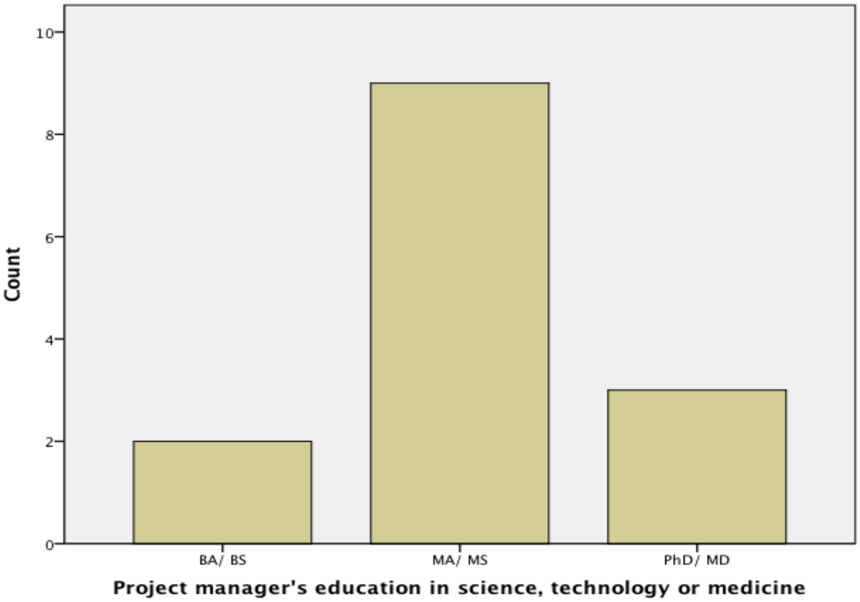

Figure 4. Project Managers' Education in Science, Technology, or Medicine
Source: PASW

Fifty-seven percent of the projects experienced turnover in the lead project manager during the project. While we expected to find that turnover in the lead project manager negatively affected the project, two managers stated that the change was positive because the initial project manager was either inexperienced in large-scale project management or was inexperienced in the scientific domain. Several others stated that there was a negative impact at the time of the change, but overall the change turned out to be positive, or even very positive, because they gained a more experienced manager.

The project managers' qualitative responses revealed challenges with anti-management and university-specific management techniques, reinforcing the findings from the literature on research management outlined above. One of the project managers reported that many of the

PM techniques NASA suggested they use were irrelevant to a university setting. Another pointed out that university clocks operate on different schedules than those of the aerospace contractors. Several managers reported that 'managing by walking around and speaking informally with people' was the most important technique. S/he stated, "people working on the mission need to know that you know them and that their contribution is important." In summary, project communication is important to success.

Five shared frank comments about their experiences with anti-management, with one stating:

> . . . many of the individuals assigned to work on the project were unfamiliar with, and resistant to, the implementation of formal project management processes. This resistance often led to a hesitance (and in some cases a refusal) to work with me and others on the project team to perform appropriate cost, schedule, and status reporting.

This finding reinforces the findings from the literature that research project managers face significant anti-management challenges and adds to it the possibility that these challenges may lead to cost and schedule overruns. One RPM reported significant staff turnover in the project due to anti-management.

Other RPMs reported struggling with scientists who believed management and science were mutually contradictory, with one stating that:

> Some scientists within the organization firmly believed that management of the project was contrary to scientific discovery; that managing to a budget, schedule, and scope were 'anti-science.'

This experience reflects the scientific discovery paradox.

DISCUSSION AND CONCLUSIONS

These preliminary findings suggest that there is much more to be learned about managing university projects. Research managers will continue to face challenges with anti-management, the discovery paradox, and university design. Developing project management methods that are tailored to the university setting and to risk factors specific to large-scale research projects is necessary for moving universities toward even greater success in completing research projects on time and on budget.

We discovered throughout the research process that federal agencies and universities lack data and data transparency about their large-scale projects. This makes it difficult to systematically develop a profile of the large-scale university-run research funded by the U.S. government. It also suggests a lack of coordination in this research profile. Additionally, most major research universities were unable to provide us with data, with one sponsored projects office lamenting that such data were very difficult to collect in their decentralized institution. The NSF has taken an excellent first step with its online database of projects searchable by cost. Other agencies may consider developing such databases, adding cost parameters to their existing databases, or making data available through databases like data.gov.

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While rigorous project evaluation may improve future project success rates, it is difficult to execute. Barriers to effective project evaluation include: difficulty tracking evolving projects; concern over disclosure of proprietary information; and a lack of incentive for managers to participate, particularly if the project was unsuccessful (Galway, 2004). While the key objective of our survey was to determine the significance of cost and schedule overruns in these projects, the response rate in that section of the survey was particularly low. Further, several project managers reported to us that they were not allowed to participate in such a survey. The length of the survey also contributed to the low response rate, particularly since there are few incentives for extremely busy managers to devote time to program evaluation. The research management profession and funders should consider counteracting these barriers, perhaps with incentives offered for participating in program evaluation. As management methodologies improve, research project managers will likely benefit from focusing on and improving project definition and structuring projects to reduce their complexity. Conducting a project risk assessment at the initiation of the project is also likely to aid in success. Universities may also consider opening a project management office to aid in winning these projects and successfully managing them.

ENDNOTES

1. In this study, 'research' describes the spectrum of fundamental and applied scientific research as well as innovative technology projects.

2. This excludes the U.S. Department of Defense projects, for which data were unavailable.
3. For a discussion of scientific research and serendipity, see Hackett, Parker, Conz, Rhoten, and Parker (2006).
4. Project duration data and total university expenditures were available for 48 of 58 projects. The data gaps for cost were for NASA projects; the agency told us that the university contract was above $50 million for the list of projects they provided, but they did not provide us with the exact amount. We were unable to locate this information in the public domain for 10 projects. If data were available for the missing 10 projects, it would likely increase the median cost because NASA total project costs were generally higher. Note that cost expenditure and project duration data, where available, were provided by agency databases, except for NASA. NASA cost/duration data were obtained from *govbudgets.com NASA edition* or from project websites.
5. These data were only available for nine projects.

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