

Project Management in e-Science

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Executive Summary

This report is one of two, six month deliverables from the ‘Embedding E-Science Applications: Design and Managing for Usability’ project. In this report we identify and explore some of the challenges with project management in e-Science projects.

Section 1 introduces the report and describes e-Science projects as being extremely complex due to the size of the collaborations, the distributed nature of the collaborations and the unique knowledge, experiences and vocabularies of the collaborators. Therefore, we argue that it is essential that such collaborations be carefully managed, mitigating the challenges potentially inhibiting successful collaboration on large-scale, distributed and multi-disciplinary projects. However, current project management methods have not been developed with e-Science projects in mind, which has led to the emergence of a number of challenges. The aim of this report is to describe these challenges. We conclude section 1 by describing the structure for the rest of the report.

Section 2 describes two current well-known project management methods: Prince 2 and Project Management Bodies of Knowledge (PMBOK). We describe their processes, as well as their strengths and weaknesses. Furthermore, we describe the features, strengths and weaknesses of several software development models which are used in conjunction with project management methods: the waterfall model, evolutionary development, throw-away prototyping, formal systems development, re-use based development, incremental development, the spiral model, rapid application development (RAD), quality design and development (QUAD), the star lifecycle model and agile methods. However, these project management methods and software development models have also not been developed with e-Science projects in mind. Consequently when e-Science projects have attempted to utilise and implement traditional project management and software development approaches, a number of challenges managing e-Science project have emerged.

Section 3 provides an overview of the methodology used to identify the challenges managing e-Science project. In order identify challenges we have started to conduct interviews with project managers and project participants of major e-Science projects in the UK, and drawn upon a series of ongoing workshops initiated at Oxford, but also workshops at NeSC, AHM and with the EPSRC.

Section 4 reports the challenges we have identified and explored which include:

1. **The research bid:** the challenge of defining a detailed research bid from an ambiguous research project.
2. **From proposal to project:** the challenge of making the project a reality from the project vision.
3. **The legal framework:** the challenge of defining a legal framework when project partners often have conflicting legal requirements.
4. **Managing intellectual property rights (IPR):** the challenge of establishing IPR when several project partners are involved in producing a deliverable.
5. **Roles and responsibilities:** the challenge of identifying whether a project participant will actively or passively contribute to a project, and the work packages they will engage in or ‘own’.
6. **Critical path vs. research:** the challenge of identifying and assigning critical path and research activities to project participants.

7. **Planning releases:** the challenge of managing the completion of deliverables from several project partners.
8. **Managing requirements:** the challenge of effectively communicating requirements between project participants.
9. **Managing collaborative work:** the challenge of coordinating collaborative activities between large-scale, distributed and multi-disciplinary teams.
10. **Managing resources:** the challenge of managing resources that the project manager has little control over.
11. **Managing press releases (PR):** the challenge of releasing accurate, clear and consistent PR from all project partners.

Section 5 concludes the report summarising what has been discussed. Building upon the challenges identified we present a number of recommendations to be utilised by current and future e-Science projects:

1. **Feasibility studies:** small scale studies conducted before a research project is funded aimed at reducing the ambiguity and risk of research projects, whilst at the same time not requiring them to be fully specified. Furthermore, such studies will allow new research collaborations to be explored before a full commitment is given to delivery of a large-scale infrastructure.
2. **Project start-up questionnaires:** questionnaire administered to project participants can be used to elicit the opinions of project participants at project start-up, thus making explicit what the aims, objectives and innovation of the project may be. Such questionnaires ask project participants: what they think the objectives of the project are; what the critical success factors for the project are; what they would like to get out of the project; and what they will contribute to the project. This information allows the project manager to understand the project participants expectations and drivers, which in turn can help the project manager, assign roles and responsibilities.
3. **Alphabetical authorship:** ordering the authorship of project participants on publications alphabetically in order to reduce conflicts between project participants. However, such a recommendation requires a restructuring in the academic merit system.
4. **Code ownership:** basing the ownership of software on a line-by-line of code basis in order to reduce conflicts over who owns the software.
5. **Research Days:** dedicated days to research to achieve a balance between critical path and research activities.
6. **Blueprint documents:** a document used to capture research ideas that cannot be addressed within the lifetime of a project or are outside the scope of the project.
7. **Debriefing meetings:** daily meetings held at the end of a working day designing for project participants involved in critical path activities to inform others what they have done, what went well and what did not go well. Such meetings may be either face-to-face or conducted via tele- or video- conferencing.
8. **Dissemination meetings:** meetings conducted weekly, quarterly or in between, designed for project participants involved in research activities to inform others what they have been researching and the results of their research. Such meetings may be either face-to-face or conducted via tele- or video- conferencing.
9. **Project showcases:** an event designed for project participants to exhibit their work to other project stakeholders. This form of dissemination allows project participants to see how their work fitted into the project and provides an

opportunity to discuss future research. In addition, such events help the project progress as project objectives have to be met by given deadlines.

10. **Transition workshops:** workshops designed to help one project partner pass their outputs to other project partners, thereby supporting the transfer of tacit knowledge. Such workshops can help avoid misunderstanding from occurring on multi-disciplinary teams.
11. **Lessons learned exercises:** activities designed to getting project participants to talk about what went well in the previous phases of a project and what did not go so well.
12. **PR Board and Policies:** a centralised PR board for the project with a clearly defined policy to ensure a clear and consistent message.

In order to build upon these recommendations we have identified a number of potential future studies. These studies include:

1. A continuation of our interviews and workshops with project managers and project participants, which will be further complemented by a set of ethnographic studies to obtain a deeper understanding of the challenges managing e-Science projects.
2. Ethnographic studies to assess the effectiveness of our recommendations when implemented in e-Science projects.
3. Ethnographic studies aimed at trying to understand how project managers execute project management activities during large-scale, distributed and multi-disciplinary e-Science projects and understanding emerging tensions.
4. A study into the use of collaborative tools such as Basecamp, Wikis and other data repositories, understanding their strengths and weakness supporting collaboration across large-scale and distributed projects.

Overall, our research aims to understand how we can best support project management activities in e-Science projects.

1 Introduction

E-Science, or cyber-infrastructure as it is known in the US, promotes a vision of large-scale, collaborative and multi-disciplinary research (Hey & Trefethen, 2002). Such research is extremely complex for a number of reasons: the size of the collaborations, the distributed nature of the collaborations and the unique knowledge, experiences and vocabularies of the collaborators. The size and distributed nature of e-Science collaborations can make it difficult for stakeholders to communicate with each other, as it is not always possible to meet face-to-face. Difficulties in communication can impact the coordination of stakeholders' activities. Furthermore, the unique knowledge, experiences and vocabularies of the stakeholders can further impact collaboration. It can be hard for a stakeholder from one discipline to understand stakeholders from another discipline (e.g. Fischer, 1999), for example, difficulties between end-users and developers has been well documented (e.g. O'Neill, 2000). Such differences are exacerbated in e-Science due to the number of multi-disciplinary stakeholders involved in these projects. Therefore, in these projects it is essential that such collaborations be managed, mitigating the challenges potentially inhibiting successful collaboration on large-scale, distributed and multi-disciplinary projects.

The management of day-to-day collaborative activities between project stakeholders on these large-scale, distributed and multi-disciplinary projects primarily lies with the project manager. However, project managers face a number of challenges when managing such large-scale, distributed and multi-disciplinary projects. The main cause of these challenges is that neither project management methods nor software development approaches utilised by project managers have been developed with e-Science projects in mind. Consequently when e-Science projects attempt to utilise and implement traditional project management and software development approaches, a number of challenges managing e-Science project emerge.

In this report we first set the scene by presenting an overview of project management methods and software engineering approaches, and hence argue their lack of fit with e-Science projects. Having described our methodology, we present eleven challenges with project management in e-Science that have emerged when existing project management methods and software engineering approaches are used. We introduce and discuss each challenge providing supportive examples from various e-Science projects. Finally, we draw our conclusions and highlight directions for future research.

2 Project Management

In this section we describe the key features of several project management methods that are utilised in practice on e-Science projects. In order to understand how these project management methods can assist in the coordination of e-Science projects we describe the strengths and weaknesses of these features as they have emerged throughout the course of various case studies.

Various authors have identified the key objectives of project management. For example, Lock (1996) stated that project management 'is to foresee or predict as many of the dangers and problems as possible and to plan, organise and control activities so that the project is completed as successfully as possible.' To achieve this goal a project manager will usually define project activities with known purposes that have discrete start and end

dates, and identify the dependencies between project activities. Various project management methods have been developed to guide the project manager in this endeavour.

For example, a major project management method, *Prince 2*^{1,2}, was developed by the Central Computer and Telecommunications Agency³ (CCTA) in the 1980s as a UK Government standard for IT project management. Since its establishment in the 1980s, it has become the *de facto* of project management methods, with many organisations recruiting project managers who have backgrounds or qualifications in Prince 2.

Typically, Prince 2 covers the organisation, management and control of projects, describing sets of processes, each with inputs and outputs, as illustrated in figure 1.

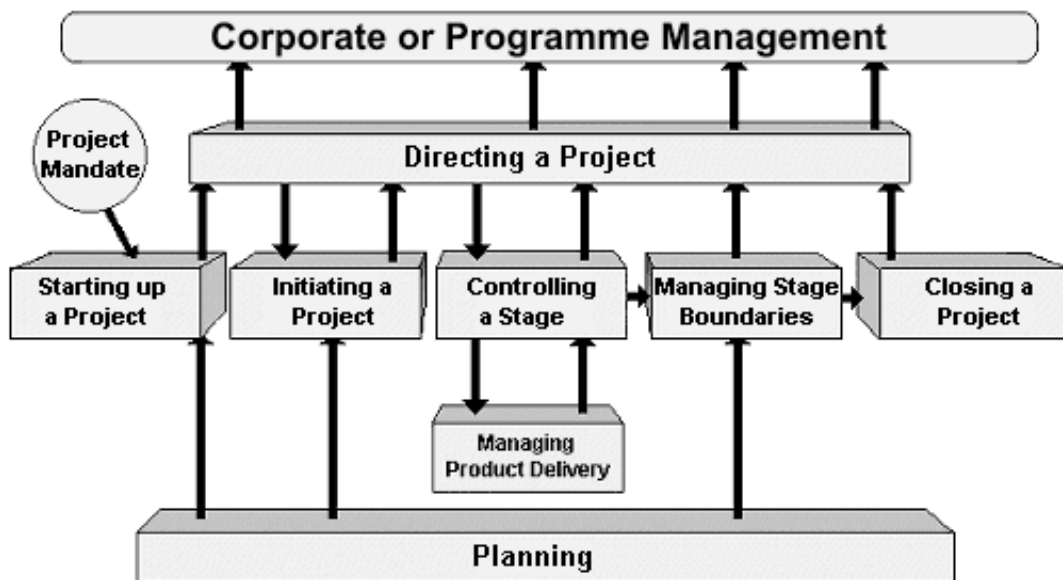


Figure 1. The Prince2 Process Model

The following discusses each of the sets of processes in a little more detail:

- **Directing a project** runs from the project start up till its closure. The process is aimed at the project board that manage by exception, monitor via reports and controls through a number of board meetings.
- **Starting up a project** is a pre-project process, designed to ensure that the pre-requisites for initiating the project are in place. Furthermore, the process is built around the production of three elements: the information required for the project team is available; the appointment of a Project Management Team; and the creation of a Project Mandate.
- **Initiating a project** has a number of objectives: to agree or not whether there is sufficient justification to proceed with the project; to establish a stable management basis; confirm acceptable business cases exist for the project; agree to the commitment of resources; enable and encourage the Project Board to take ownership of the project; specify a process for decision making; and define the

¹ http://www.ogc.gov.uk/prince/about_p2/about_intro.htm

² <http://www.princetwo.com/index.htm>

³ The CCTA is an executive agency with the UK government's cabinet office providing help and guidance to government departments, other executive agencies and various public bodies on the efficient and effective use of IT to deliver business objectives

time and effort required to be invested by project participants, and take into account risks.

- **Managing stage boundaries** has a number of objectives: to assure the Project Board that all stage deliverables have been completed as specified in the Project Mandate; provide information needed by the Project Board to assess the continuing viability of the project; to provide the Project Board with information needed to approve the current stage's completion and authorise the start of the next stage; and record any measurements or lessons which can help later stages of the project and/or other projects.
- **Controlling the stages of a project** is a process that describes the monitoring and control activities of the Project Manager, ensuring that a stage stays on course and copes with unexpected events. The process forms the core of the Project Manager's effort on the project, being the process that handles the day-to-day management of the project. The management activities a Project Manager may engage in are: authorising work to be done, gathering progress information on work, watching for changes that may effect the project, reviewing the project, reporting and taking corrective actions.
- **Managing project deliverables** has the objective of ensuring that planned products are created and delivered on time by: making sure that the work allocated to a team is authorised and agreed upon; ensuring the work meets the requirements specified by its work package; ensuring the work is done; assessing work progress and forecasts regularly; ensuring the completed products meet quality criteria; and obtain approval for completed products.
- **Closing a project** involves wrapping up a project either at its end or premature close. The objective of closing a product are to: check the extent to which project objectives or aims were met; check the customers satisfaction with the deliverables; obtain formal acceptance of deliverables; assess to what extent the project deliverables have been handed over to the customer; confirm the maintenance and operation arrangements in place where appropriate; make recommendations for follow-up actions; capture lessons resulting from the project and complete a Lessons Learned Report; prepare the end project report; and notify the customer of the intention to disband the project organisation and resources.
- **Planning** is a repeatable process, and plays an important role in other processes, main ones being: planning an initial stage, planning a project, planning a stage and producing an exception plan. Furthermore, Prince2 provides a product-based planning framework to be applied to a project involving: establishing what products are needed; determining the sequence in which each product should be produced; defining the form and content of each product; and resolving what activities are necessary for their creation and delivery.

It can be seen that Prince 2 deals with the standard activities from initiating to closing a project, however, it should be noted that it does not specify pre- and post- project management activities, such as setting up contracts and legal agreements, for example. These activities were found to be a key feature of the e-Science projects, especially where industrial or clinical collaborators were involved.

A related project management method, *PMBOK*, was developed by the Project Management Institute⁴ (PMI) and also details the process and lifecycle options for typical

⁴The PMI is the world's foremost advocate for the project management profession. PMI is governed by a volunteer board of directors comprised of 15 directors-at large elected to serve a three-year term

project types but, in addition provides useful training information for project managers (Duncan, 1996) and provides requirements for good leadership and management.

PMBOK organises project management activities into five groups of processes as illustrated in figure 2.

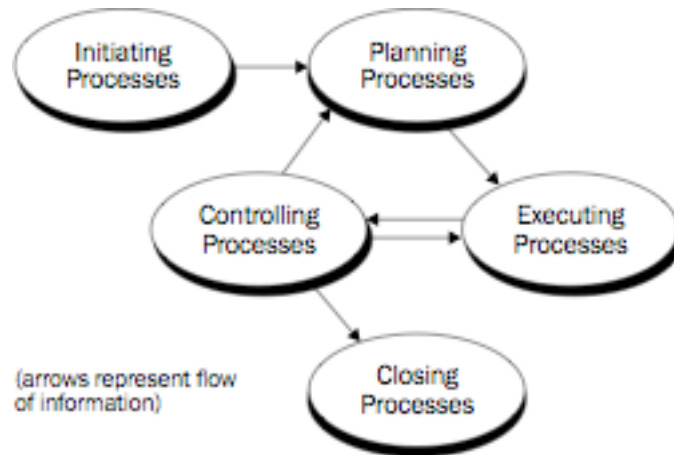


Figure 2. The PMBOK process model

- **Initiating processes** recognises that a project or activity should begin and commit to doing so. This includes a single process:
 - *Initiation* – committing the organisation to begin the next phase of the project.
- **Planning processes** devise and maintain a scheme to accommodate the project or project’s activities. The core planning processes which may be iterated over several times during a phase of the project are:
 - *Scope Planning* – developing a written scope statement as the basis for future project decisions;
 - *Scope Definition* – sub-dividing the major project deliverables into smaller, more manageable components;
 - *Activity Definition* – identifying the specific activities that must be performed to produce the various project deliverables;
 - *Activity Sequencing* – identifying and documenting interactivity dependencies;
 - *Activity Duration Estimating* – estimating the number of working periods which will be needed to complete individual activities;
 - *Schedule Development* – analysing activity sequences, activity durations, and resource requirements to create the project schedule;
 - *Resource Planning* – determining what resources (people, equipment, materials) and what quantities of each should be used to perform project activities;
 - *Cost Estimating* – developing an approximation of the costs of the resources needed to complete project activities;
 - *Cost Budgeting* – allocating the cost estimate to individual work items;
 - *Project Plan Development* – taking the results of other planning processes and putting them into a consistent, coherent document.

Furthermore, there are a number of facilitation processes that are performed intermittently during the project-planning phase:

 - *Quality Planning* – identifying which quality standards are relevant to the project and determining how to satisfy them;

- *Organisational Planning* – identifying, documenting and assigning project roles, responsibilities and relationships;
- *Staff Acquisition* – assigning human resources to work packages on the project;
- *Communications Planning* – determining the information and communication needs of the stakeholders: who needs what information, when will they need it, and how will it be given to them;
- *Risk Identification* – determining which are likely to affect the project and documenting the characteristics of each;
- *Risk Quantification* – evaluating risks and risk interactions to assess the range of possible project outcomes;
- *Risk Response Development* – defining enhancement steps for opportunities and responses to threats;
- *Procurement Planning* – determining what to procure and when;
- *Solicitation Planning* – documenting product requirements and identifying potential sources.
- **Executing processes** coordinate people and other resources in order to carry out the work plan. The core and facilitating processes are:
 - *Project Planning Execution* – carrying out the project plan by performing the activities included therein;
 - *Scope Verification* – formalising acceptance of the project scope;
 - *Quality Assurance* – evaluating overall project performance on a regular basis to provide confidence that the project will satisfy the project’s objectives to the specified quality standards;
 - *Team Development* – developing individual and group skills to enhance project performance;
 - *Information Distribution* – making needed information available to the project stakeholders in a timely manner;
 - *Solicitation* – obtaining quotations, bids, offers, or proposals as appropriate;
 - *Source Selection* – choosing from potential vendors;
 - *Contract Administration* – managing the relationship with the vendors.
- **Controlling processes** ensure the project objectives are met by monitoring and measuring progress, and taking corrective action when necessary. The core and facilitating processes are:
 - *Overall Change Control* – coordinating changes across the entire project;
 - *Scope Change Control* – controlling changes to the project scope;
 - *Schedule Control* – controlling changes in the project schedule;
 - *Cost Control* – controlling changes in the project budget;
 - *Quality Control* – monitoring specific project results to determine if they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance;
 - *Performance Reporting* – collecting and disseminating performance information. This includes status reporting, progress measurement and forecasting;
 - *Risk Response Control* – responding to changes in risk over the course of the project.
- **Closing processes** formalise the acceptance of the project or activity and bring it to an orderly end. Includes the following processes:
 - *Administrative Closure* – generating, gathering, and disseminating information to formalise phase or project completion;

- *Contract Close-out* – completion and settlement of the contract, including resolution of any open items.

In order to deal with the complexity of all kinds of large, distributed projects, not solely software development projects, various differences have emerged between the Prince 2 and PMBOK project management methods (e.g. Wideman, 2002). Fundamentally, Prince 2 is seen to be prescriptive and management and business case driven, whereas PMBOK is descriptive and user requirements driven. Prince 2 and PMBOK both provide useful support for project managers, however the added dimension and complexity of software development also is a critical factor of e-Science projects.

In order to deal with the complexities of software development, various models have been developed, to varying degrees of success, in order to abstract the activities of the software development lifecycle (Sommerville, 2001). Project management has to interact with and engage with these approaches in order to be part of the process of managing the software development lifecycle, as well as the other features of e-Science projects described previously. Some common software process models as described by Sommerville (2001) and Preece *et al* (2002) are:

- **The waterfall model** takes the fundamental process activities of requirements engineering, design, implementation, testing and maintenance and represents them as cascading from one activity to another in a sequential manner.
- **Evolutionary development** is where the software development team works with users to explore their requirements and deliver a final system. The development starts with part of the system that is well understood and evolves adding new features proposed by the users.
- **Throw-away prototyping** also requires the software development team to work with users to explore their requirements and deliver a final system. The development starts with the parts of a system that are not well understood, thereby allowing requirements for the final system to be better defined.
- **Formal systems development** aims to produce a formal mathematical specification for a system, which can then be transformed using mathematical methods to construct a program. The system is verified by making mathematical arguments. This process is similar to that of the waterfall model.
- **Reuse-based development** focuses on the existence of reusable components. The development process focuses on integrating existing components together, rather than developing them from scratch.

For the most part, the above software development models are linear, whereas many projects describe the need to support iteration during the software development process as new user needs and requirements are identified. Hence, several software process models have been developed to support iteration:

- **Incremental development** combines features of the waterfall and evolutionary development models. During the incremental development process users first outline the functionality of the system. These functionalities are then grouped into a number of increments. Requirements for increments are then defined and developed. As each increment is developed it is delivered to the users. Each time an increment is completed it is integrated with the existing increments.
- **The spiral model** rather than representing the software development process as a sequence of activities, presents them as a spiral. Each loop of the spiral

represents a phase of the software development process, where each loop is split into four segments: objective setting, risk assessment and reduction, development and validation and planning.

- **RAD** takes a user-centred approach and tries to reduce the risk of changing requirements in software development projects. To encourage a user-centred approach and reduce risk the RAD lifecycle consists of five phases: project set-up, Joint Application Development (JAD) workshops, iterative design and build, engineer and test final prototype and implementation and review.
- **QUADD** is a highly disciplined, integrated methodology that involves active end-user participation and is designed to rapidly deliver business applications that improve processes and performance. The QUADD process consists of four stages: Rapid Implementation Plan (RIP) workshop, design, implementation and production. The RIP workshop is designed to rapidly identify the client's needs and develop a strategy and action plan to meet those needs. The design workshop focuses on outlining the proposed process changes and required information technology solutions. The implementation stage primarily involves the development and testing of the new solution or enhancements to existing solution. The Production stage primarily involves the maintenance, enhancement and support of the solution after it is operational. While the QUADD process is designed as an integrated approach, each stage represents a separate contractual commitment and concludes with the delivery of a discrete value-added deliverable. Clients are able to elect at each stage whether to proceed to the next stage of the process.
- **The star lifecycle model** consists of activities of task analysis/formal analysis, requirements specification, conceptual design/formal design representation, prototyping and evaluation. Unlike other models it does not specify any ordering of activities. Activities are highly interconnected going through a central evaluation activity. Evaluation is an essential activity of this model, as the outcome from any activity must be evaluated.
- **Agile methods** deliver small releases through an iterative process. The core elements of this process are: small releases (1 – 2 weeks), simplicity in design, testing, paired development, re-factoring and a user-centred process.

Together these software development models and the project management methods provide a toolkit for project managers to draw upon. The choice of the project management method in conjunction with the software development lifecycle are choices that are made in the context of the type of project at hand. Project managers use the project management methods and software development models, together with their experience to best manage the project. In the following subsection we shall discuss the application of these project management methods and software development models when applied e-Science projects.

2.1 Traditional Methods and Models Applied to e-Science Projects

E-Science projects have brought a new research field to academia. These e-Science projects involved large, distributed, multi-disciplinary teams, from academia and industry, both working on critical path and research activities. The complexity and dependencies of the activities are beyond those seen by many academic projects before. Therefore, to

manage such complexities, many flagship e-Science projects (e.g. eDiaMoND⁵) employed project managers. The majority of project managers employed had industrial backgrounds and were very familiar with various project management methods and software development models, such as the methods and models described in this paper. Furthermore, many of these project managers had a wealth of experience managing complex commercial projects. It was believed that by including project managers in these e-Science projects, the complexities that potentially threatened these projects would be alleviated.

However, neither project management methods nor software development approaches had been developed with these types of projects in mind and where typically in industry these project managers had been faced with the delivery of concrete 'products' or systems, these multidisciplinary e-science projects posed the challenge of balancing the delivery of prototypes/systems and maintaining the innovation and research. Rather than focussing on the development of a product *per se*, e-Science projects are also concerned with the production of research papers and building communities of e-Scientists. This means that traditional project management methods and software development models are not directly applicable to e-Science projects without tailoring these approaches or supplementing these with additional techniques. For example, on the CancerGrid project⁶, the project manager adopted the Prince 2 method. The execution of the Prince 2 method meant that the CancerGrid project processes were highly structured and productive. However, the Prince2 method was only used for the first year of the project. While the project produced many white papers, due to the priorities of Prince 2 other aspects of the project were underdeveloped. For example, due to the time and effort required to produce the white papers and follow various reporting structures, there was less time to devote to the research component of the project was lacking. This was very noticeable by the project participants, who coming from research backgrounds did not perceive the benefits of the project management activities. To reduce the burdens created by the Prince 2 method, the reporting mechanisms were relaxed. Rather than a piece of documentation having to be created from each task, only major components of the project were documented in technical reports, which could then feed into journal papers, conference papers and presentations. However, this relaxing of the project reporting structure also meant that it was harder for the project manager to keep track of the completion of tasks and monitor the overall progress of the project. Thus, it is clear to see from this example that elements of traditional project management methods may not be directly applicable to e-Science projects, whilst other features may need enhancing to deal with the contingencies of such e-Science collaborations. Furthermore, in addition to the inapplicability of traditional project management methods and software development models, a number of challenges have emerged during e-Science projects that are unlike any others faced by the project managers before.

To identify and investigate the challenges of project management in e-Science, we draw upon interviews with project managers and other project participants, project management workshops and focus groups, and ethnographic fieldwork. We describe in this report the results of our preliminary analysis.

⁵ The eDiaMoND project was a research project which had the ambitious aim of proving the benefits of grid technology to e-Health, in the case of Breast Imaging in the UK: <http://www.ediamond.ox.ac.uk/>

⁶ The CancerGrid project is a consortium of UK researchers formed to develop open standards based solutions for clinical cancer informatics: <http://www.cancergrid.org/>

3 Methodology

Project management as an activity is a relatively new aspect of academic research, though of course previous large-scale computing programs in the UK, such as Alvey (Guy *et al*, 1991), also generated challenges and commitments to project management. Building on Kalawsky *et al*'s JISC Human Factors Audit (2006), and the SUPER report (Newhouse *et al*, 2007) we have tried to get a more detailed understanding of the issues, activities and challenges faced by project managers on e-Science projects. In this ongoing work, we have started to conduct interviews with project managers and project participants of major e-Science projects in the UK. We have also drawn upon a series of ongoing workshops initiated at Oxford, but also workshops at NeSC, AHM and with the EPSRC.

The interview framework was based upon a review of various publications and presentations project managers interviewed have accumulated over the years and initially have focussed on the difficulties faced by project managers (see appendix). The framework is also based upon a list of these challenges identified in Lloyd & Simpson (2005) is as follows:

1. **The research bid:** the challenge of defining a detailed research bid from an ambiguous research project.
2. **From proposal to project:** the challenge of making the project a reality from the project vision.
3. **The legal framework:** the challenge of defining a legal framework when project partners often have conflicting legal requirements.
4. **Managing intellectual property rights (IPR):** the challenge of establishing IPR when several project partners are involved in producing a deliverable.
5. **Roles and responsibilities:** the challenge of identifying whether a project participant will actively or passively contribute to a project, and the work packages they will engage in or 'own'.
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11. **Managing press releases (PR):** the challenge of releasing accurate, clear and consistent PR from all project partners.

In the next section we introduce and discuss key findings from our analysis. These preliminary issues will be unpacked and developed in the next phases of our research.

4 Preliminary Findings

In the following sub-sections we shall introduce and discuss each of the challenges faced by e-Science project managers with illustrative examples from various e-Science projects.

4.1 The Research Bid

Even before projects begin, experience has found that it is particularly difficult to specify bids for e-Science projects. This has been accounted for in terms of the complexity of detailing both the research issues and what is to be built, in a setting where potential project collaborators may not necessarily know each other. Nonetheless, in the face of such ambiguity, funding bodies still require finite resources such as people, equipment and other financial expenses to be specified. In cases where there is going to be a high degree of innovation, it can be particularly difficult to define resources needed when it is less clear what is going to be built. For example, the Integrative Biology (IB)⁷ project was given the finances to develop technologies to support a community of users. However, at the start of the IB project, while the investigators knew there was a community who needed support, they did not know who their users were nor what their users' needs were. Ultimately, this meant there was a poor understanding at the start of the project as to the equipment that was needed to support the project's user community. As the project progressed the project's users and their needs were determined, and requirements for the equipment needed were specified. Although, as the project progressed the project's user's evolved, their needs changed and the user base increased. This is one of the challenges of developing technologies to support a community of users.

In contrast, in commercial settings, projects are normally better defined before being costed. Where companies develop commercial applications for example, the decision by a company about what to develop is usually based on an exploration of the market and a decision based on an analysis of risk for that company on what to deliver as a base product. Where a company is developing a solution for its own needs, for example, a new finance system or intranet, the process usually requires signoff of on expenditure or expected expenditure. In these cases most commonly, the development team works closely with users and those affected by the delivery of such a system. Where a company is developing a solution for another company, a scoping document and a requirements document are produced, which are signed off by a customer ready to be costed by the company. Changes that evolve over the life of the project often have cost implications that are managed through formal change management processes. In some cases, a client also pays for the scope and requirements exercise with this initial activity costed through pre-sales engagement. Where a company bids for a contract, a more detailed analysis of work and its associated costs usually has to be produced, thus exposing the deliverer to a higher level of risk.

Thus it can be seen that there is a clear distinction between research and commercial projects. A commercial project will typically describe in some detail what is to be done and then fully specify and cost the project. In contrast, research projects provide a high-level overview of what the project intends to do and costs these activities. Only when the project is funded, do participants begin the process of determining and detailing what is to be done. Overall, this inherently makes research projects high risk and requires careful planning on the part of the project manager and principle investigators, on, for example, amongst other things, how to spend the funds wisely. For example, on the IB project the project manager was hired for the lifetime of the project. However, the

⁷ The IB project brings together an international consortium of leading biomedical and computing researchers to address two of the most important problems in clinical medicine today: understanding what causes heart failure and how cancer tumours develop and grow: <http://www.integrativebiology.ox.ac.uk/>

project manager's time on the project was reduced to make funds available for other resources, such as the purchase of equipment. It is common for research projects to shift funds to accommodate unforeseen changes in the project.

One way to reduce the risks of research projects could lie in the staged release of funds, making them easier to specify and cost. However, due to the innovative nature of research it is important that such a process is not too constraining. For example, some research councils, such as JISC and the DTI, require projects to be highly specified. A project has to describe what it is going to do in terms of objectives, tasks and deliverables, as well as specifying target dates, dependencies and exploitation plans. These projects are reviewed on a regular basis, for example, every three months. Reports are produced indicating what a project intended to do and what it has achieved. These reports are accompanied by a financial report of project spending. One example is the Generic Infrastructure for Medical Informatics (GIMI) project⁸ that has a quarterly meeting with a representative from the DTI. At this meeting they have to present what they intended to do and what they have achieved. Furthermore, the project must provide supporting documentation, including a financial report. Only if the research council representative is satisfied is the funding approved for the project to continue. Administratively this is a high overhead for a research project, but encourages more openness of work with partnering organisations and continual development of collaborative plans and potential exploitation.

Feasibility studies could be run to reduce the ambiguity and risk of research projects whilst at the same time not requiring them to be fully specified, thereby easing the path to innovation. On the project consortium side, this would also enable new research collaborations to be explored before a full commitment is given to delivery of a large-scale infrastructure. Upon the research council approving a project, a given amount of funds could be made available to the project team to further assess the feasibility of the project. Such a feasibility study could ensure that the domain of interest is worthy of study and also can allow the project to explore their collaborative working arrangements. Furthermore, a feasibility study could allow the project to be more accurately specified and costed. If the study for a project is successful, the funds for a project could be approved and released. If it indicates that a research project may not be successful, valuable research money would be saved. The findings from a feasibility study could then be used to re-specify the project in question. However, feasibility studies could introduce their own set of challenges. For example, it may be difficult to recruit research staff for a small scale feasibility study that has no guarantee of being funded.

Thus, it can be seen that there is a trade-off between the specificity of a project and the potential for innovation. This is reflected in the difficulties encountered by a project manager when specifying a research bid where well-defined projects are easier to specify and cost compared with open-end projects. Feasibility studies could be one solution to reducing the risk of highly innovative research projects, making the difficulty of bid management easier for project managers and principle investigators alike.

⁸ The GIMI project is a large-scale collaborative research project which is concerned with the development of a secure IT infrastructure to support medical research: <http://www.gimi.ox.ac.uk/>

4.2 From Proposal to Project

The start-up of an e-Science project is very expensive in terms of the time and effort required by the project manager. If the project manager is employed on a project without having had prior input to the proposal, considerable effort is spent in reading and analysing the project proposal and any associated press releases (PR), and discussions with stakeholders to determine the perceived scope of the project. During this time the project manager will evaluate what activities are achievable with the resources available and highlight any anomalies in the proposal that may lead to issues arising from stakeholder expectations. On gaining a clearer idea of the project, the project stakeholders must be brought together to re-iterate the objectives and critical success factors of the project and to eliminate misunderstandings. This can be a very time consuming exercise as very often stakeholders may have different expectations of and goals for the project (Lloyd & Simpson, 2005). For example, on eDiaMoND participants spent a considerable amount of time debating whether the project would deliver a proof-of-concept, a prototype or a production-level system. In this example, it took six weeks for the project partners to reach some kind of consensus. This consensus formed part of a high-level requirements and critical success factors document. It is interesting to compare this situation with projects funded by the European Commission where extensive work is put into the definition of the proposal and each partner provides detailed input to the costings, workpackage definitions and resources. Such an approach provides clear benefits in that the collaborating groups seem to understand what is required of them in more detail before a proposal is submitted.

Furthermore, it is the difficult job of the project manager to also highlight what is new in the project and to ascertain what is realistic to achieve with the resources available. The more project partners involved in e-Science projects the greater the challenge for the project manager to ensure all project partners are satisfied. In order to address this issue, questionnaires have been used on subsequent projects to review the opinions of investigators at project start-up, thus making explicit what the aims, objectives and innovation of the project may be. Such questionnaires ask project participants: what they think the objectives of the project are; what the critical success factors for the project are; what they would like to get out of the project; and what they will contribute to the project. This activity has been performed on the NeuroGrid project⁹, for example, to determine the stakeholders understanding of the project and their contribution to the project. The project manager used the information to negotiate a direction for the project and assign roles and responsibilities to project participants. In addition to using this questionnaire once a project has started, it may also be possible to perform this same activity at the time of proposal initiation in order to prevent a situation where partners are signing up to projects where they have little or no understanding of what the project will do for them. This stage of the project is crucial in order to set a firm foundation on which to build upon.

⁹ The NeuroGrid project is a research project aimed at enhancing collaboration between clinical, imaging and e-scientists to create a Grid-based network of neuro-imaging centres and a neuro-imaging tool-kit: <http://www.neurogrid.ac.uk/>

4.3 The Legal Framework

It is not only the type of collaborations that are put in place for e-Science projects, but also the ways in which these collaborations may be protected by law. Legal frameworks are very complex on e-Science projects, yet they are essential for this type of collaboration. The aim of a legal framework is to protect project partners and to put in place a contract that explains the legal obligations of all of the partners concerned. This contract typically details what is to be kept confidential, what should be done with intellectual property (IP), what may be published, and what elements of the project must adhere to UK law. The legal framework will specify what project partners may do with deliverables. Usually during a project, deliverables can be used for research purposes with the rules for commercialisation clearly stated or procedures for follow-on activity defined. This legal framework prevents project partners from taking deliverables and creating spin-off companies or obtaining commercial gain from other peoples work. It also prevents project partners from releasing potentially damaging press about other project partners and puts in place the rules for confidentiality. One positive aspect of the legal framework is the development of enhanced trust knowing that the law may protect them if required.

Producing such a legal framework requires extensive negotiation between project partners. Usually the lead partner will specify a base contract for the project partners to work from. A process of negotiation will then ensue. The contract will evolve as it is passed between project partners. Only once all the project partners agree with the contract is it signed. This process is very difficult and time consuming. For example, on the eDiaMoND project one of the lawyers was quoted saying, “it [putting a legal framework together for the e-Science project partners] was a research project in its own right”. For a detailed discussion of the ownership rights on eDiaMoND, please see d’Agostino *et al* (forthcoming)¹⁰. On the eDiaMoND project it took 16 months to agree on the legal framework for the project. In contrast, NeuroGrid took 3 months to establish their legal framework, whilst it took the Integrative Biology (IB) project 38 months. Until the legal framework is established, project partners are potentially at risk and the trust necessary for collaboration can be hampered during this period.

In most cases specialist legal teams are responsible for setting up the legal framework between project partners. However, during this very sensitive period the project manager will act as a liaison, not only between the project partners, but also between the lawyers. It is also during such times that the project manager is vital to maintaining successful collaboration between project partners, ensuring trust relationships hold in place.

4.4 Managing Intellectual Property Rights (IPR)

With many project partners contributing towards the development of e-Science it is crucial to determine who owns the IP. During e-Science projects it is often the responsibility of the coordinating legal entity to work with the partners’ legal teams to coordinate the ownership of IPR. Project partners must be able to protect their IPR that existed before the projects and those that are established during the project. If someone

¹⁰ The IMaGE project investigated in some detail the ownership models for collaborative medical databases

contributes to a project, what rights of ownership do they have to the resultant deliverable if it is commercialised? For example, on the eDiaMoND project the clinicians who contributed towards the requirements that informed the design of eDiaMoND grid technologies and applications, questioned whether they had any IPR if the system were commercialised. Taking another example from the eDiaMoND project, one of the project partners invested heavily in digitising and storing mammography images. However, when questions were asked as to the ownership of the data, the project partners who owned the original mammography images believed they did, whereas the project partner who digitised the mammography images believed they owned the data. These issues are very complex and UK laws need to be revised to provide legal clarity into these matters. For a detailed discussion of different modes of ownership, please see d'Agostino *et al* (forthcoming). Many of the questions raised in this sub-section are open to debate and require effective and careful management. One such research project that investigated some of these questions was the IMAgE project (d'Agostino *et al*, forthcoming).

In addition to establishing who owns the IP, there is also the question of ownership. For example, many of the outputs from e-Science projects are disseminated through publications, which include project reports, journal papers and conference papers. As e-Science projects involve a large number of project participants who have all contributed towards an e-Science project, issues can exist with the ordering of authorship. The physics community has combated this problem by alphabetically listing the authors on a paper. However, the issue of ownership is more complex for the software developed by a project, where many stakeholders have contributed towards the design and development of the finished system. For example, on the eDiaMoND project, both Oxford University and IBM developed code. Issues existed over who owned the software developed or which parts of the software. In such cases, rather than the software being owned *per se*, the lines of code that were developed are owned by the person who wrote them. This solution can lead to complexities if the software were to be commercialised, as permission would have to be obtained by all the developers of the software and royalties would have to be assigned to each developer.

4.5 Roles and Responsibilities

On an e-Science project proposal there are a number of investigators. Previous papers have described a basic differentiation between investigators (Lloyd & Simpson, 2005). A *contributor* is someone who is passively involved in the project. They may wish to be involved in project meetings and follow the progress of the project, but not be involved in its day-to-day activities or take ownership over a particular part of the project. A *doer* is someone who is actively involved in the project. They will participate in the day-to-day activities of the project and perhaps 'own' a particular activity or work package. It is the responsibility of the project manager to identify the roles and responsibilities for each project participant. Often at the early stages of the project those who will become contributors and those who will be doers emerge through the detailing of the project objective and goals.

One of the project managers' responsibilities is to elicit from each of the stakeholders what they are going to contribute to the project; and what they wish to achieve from it. Based on information from the project proposal and the questionnaires obtained from project participants as to their understanding of the project and their contribution, the project manager will produce a project structure document. This document specifies the

project's structure in terms of the project board, the steering committee and research staff. Furthermore, it specifies the project's work packages and which participants are involved with them, including information on their objectives, responsibilities and deliverables.

In essence, it is the project manager's aim to ensure that roles are clearly defined and project stakeholders know what is expected of them. Delegating tasks gives stakeholders ownership over various aspects of the project, thereby easing the project management process. Although, as the project progresses the project manager will monitor the progress of the project and project participants roles and responsibilities may evolve.

4.6 Critical Path vs. Research

The goal of most e-Science projects is to deliver tools and technologies to support the scientific endeavour. In producing these tools, projects tend to comprise of a critical path that ideally leads to the deliverable being produced on time. However, e-Science projects are also concerned with innovation and thus, there is also a strong component of fundamental research. *Critical path activities* are those that are aimed towards the development of some deliverable. Such activities are well defined and often have a number of dependencies. *Research activities* are more open-ended and tend not to have many dependencies. For example, a critical path activity for the eDiaMoND project was to deliver a working demonstrator at an All Hands Meeting (AHM). In addition to this critical path activity some project participants were also engaging in research activities, such as researching security mechanisms to enable secure access to e-Science applications.

There is often a tension played out in such projects between these two activities. Critical path activities can be particularly problematic in a research environment. When a research institute employs people, they are often employed as research assistants. Quite reasonably then, these participants perceive that their roles will involve a high degree of research. However, many of these participants will find themselves working on a critical path activity where the need to produce deliverables takes precedence over research activities. This can be a difficult situation for the research staff and in turn for the project manager. Therefore, the project manager needs to balance the research and critical path activities that can be achieved by giving research staff a range of both. It is a constant challenge to achieve the correct balance and in this respect dedicated research time may help to focus the research activity. For example, the GIMI and NeuroGrid projects have dedicated research days, although these research days may have to be postponed or abandoned when critical path deliverables are due. In such cases, so that valuable research potential is not lost, the use of a Blueprint document enables the project teams to document information that is out of scope yet useful for future projects or reference. Due to the highly exploratory nature of eDiaMoND, the Blueprint was used extensively both to deal with participants growing research expectations in the context of the limited resources of the project.

In addition, the critical path activities themselves also require intense project management. Typically critical path activities often depend on other deliverables. The project manager must ensure that research staff meets their deliverable dates, not only to fulfil their own obligations, but also to avoid a situation where others project members work is compromised. Of course, there is a degree of risk in any project, for example, research members may become sick, equipment may stop working or participants may

leave. It is precisely for such cases that the project manager will also have defined contingency plans, which will specify a back-up plan that is tried, tested and can stand alone.

In essence, due to the fundamental differences in critical path and research activities, the project management approaches adopted should fit the context of the activity in question. For example, some project members working on critical path activities may prefer explicit directions about what they are to deliver, often on a daily basis. This may be made possible though a debriefing activity at the end of every day during periods of high critical path activity. For example, on the CancerGrid project, project participants have work package meeting everyday, which review what they said they would do, what they have done and what they are going to do. These work package meetings are complemented by an additionally weekly meeting, which gives the entire project team an overview of the teams' activities. However, such debriefing activities involve huge amounts of administrative work on the part of the project manager. Furthermore, such activities are made more difficult due to the flexible working hours model adopted by many universities. Of course, such debriefing activities may not work for all members, who consider such administrative activities unnecessary.

Managing research activities may require very different styles of management. Due to the exploratory and uncertain nature of research it may be that less frequent meetings are more suitable for these kinds of activities. For example, on the NeuroGrid project, participants will meet via quarterly AccessGrid meetings to inform their colleagues what progress they have made and inform them of their intentions for the future. In addition, many e-Science projects have bi-annual face-to-face meeting to inform others of their work.

The challenge for the project manager is to tailor their management style to the individual, the activities individuals are engaged in and the context of the overall project. This requires a high volume of administrative work by the project manager.

4.7 Planning Releases

Phased delivery is required for critical path and research activities during e-Science projects, as with commercial projects. For example, critical path activities may take the form of the delivery of system functionality or the development of a demonstrator. Whereas, phased delivery for research activities may take the form of disseminating research findings through publications and reports.

Phased delivery or milestones are a powerful tool providing a focus for development. Milestones are typically events or reports where progress is particularly visible to the outside world. The project manager will set project milestones to ensure the delivery and completion of project objectives. This allows the project manager to have some control over the progress of the project. This is especially important when dependencies are involved. Visibility of work through demonstrations or target dates for the release of deliverables enables the whole team to be aware of the status of various aspects of the work and by discussing collaboratively the progress made, reduces the risk of dependencies being missed or partners progressing too slowly. They also focus the team on the incremental steps towards achieving the overall project objectives. For example, the project manager on the IB project arranged a showcase for the project. The showcase allowed the various work package teams to present their work to the other

project members. This form of dissemination allowed project participants to see how their work fitted into the project and provided an opportunity to discuss future research.

4.8 Managing Requirements

A first major activity on the critical path of many e-Science projects tends to be the requirements gathering process. The project manager's responsibility during this activity is to ensure the effective communication of requirements between project participants. Requirements engineers need to gather requirements from a whole host of stakeholders who have differing and sometimes conflicting goals and objectives for the system to be developed. The process is further complicated by the different technical backgrounds and expertise of the various stakeholders and therefore the ways in which the requirements are expressed is of critical importance.

Much depends on the model selected for system development. In a typical waterfall model requirements engineers produce requirements documents, use-cases and scenarios, and these documents may then be passed onto the developers. In this case the project manager may facilitate the necessary interactions between the requirements engineers and developers, and coordinate their activities.

However, due to the limitations of the conventional waterfall model other approaches have emerged (see section 2) and are now being explored within the e-Science community, for example, the Chaste project¹¹ is investigating the use of Agile method approaches in e-Science.

In addition, there is a growing recognition that for the long term success of e-Science tools and technologies, we must not only include end-users in the development, but must also engender a growing community of e-Scientists (Warr *et al*, 2007). Thus on many e-Science projects, requirements engineers are also required to interact at quite a deep level with that potential community of users, be they health practitioners, bio-chemists or classicists. Including users at such a deep level demands a model of requirements gathering that allows understandings of users in their working environment to be developed. This approach also has to fit in with the expectations of developers and the overall software development model selected.

For example, on the eDiaMoND project, a great amount of the requirements activity was spent understanding the radiologists work practices and working environment. The requirements engineers had expected to interact with developers in producing the requirements. The developers expected a requirements specification of the right level of granularity that would tell them what to build. This scenario required the project manager to facilitate communication between the requirements engineers and the developers. In order to do this the project manager produced seven scenarios that specified the actions of the system in enough detail to be developed. However, this was a far from ideal solution and more detailed research needs to be undertaken in order to understand how project management and software development can facilitate and support an ongoing commitment of embedding e-Science applications in their working context.

¹¹ The Chaste project is aimed at developing the next generation of modelling software to allow in silico modelling of the whole heart to move on to a new level of sophistication and applicability

In the eDiaMoND case study requirements documentation was noted as being a static procedure for communicating requirements and requires *bridging work*, to communicate user requirements, on the part of requirements engineers and *translation work*, to translate understandings of document descriptions into technical design, on the part of developers. This example demonstrated that translating requirements documentation into technical design solutions is not easy. And that other methods for communicating requirements need to be explored.

Thus, in some cases the project manager may have to act as a requirements engineer taking the needs and expectations of the end-users and communicating them to the project partners. Fundamentally, this role is enacted in order to remove blockages, overcome difficulties and facilitate the process.

It has been suggested that the requirements engineering and the project management roles should be undertaken by different people (Sommerville, 2001). However, in some cases, as in the eDiaMoND example, the project manager may temporarily take on requirements activities in order to facilitate the development process. Overall, it is the responsibility of the project manager to support the management and communication of requirements between project partners. This requires the project manager to be sensitive to the needs of all project partners in order to facilitate effective collaboration.

The project management structure can also facilitate collaboration between requirements engineers and developers by facilitating workshops in which they can exchange information about user requirements and technical capabilities. These workshops can also include users as is done in participatory design and agile methods. Developer contact with users and requirements engineers reduces complications that may exist when developers interpret written specifications. This activity does however rely on users being available more frequently than eDiaMoND could expect from its busy clinical partners.

4.9 Managing Collaborative Work

Managing collaboration between project partners on e-Science projects is complex due to the sheer number of project participants. Large numbers of project partners may make it difficult to get consensus. It is the responsibility of the project manager to get consensus between project partners so the project may progress. In order to reach consensus, the project manager often needs to remind the participants of the implications of not reaching an agreement – moving the focus from their differences to a common goal. For example, as previously mentioned it took the IB project 38 months to reach an agreement over their legal framework. The implication of losing 16% of their funding if a consensus was not reached, motivated the project partners to reach an agreement. However, as e-Science projects increase the number of partners collaborating on a project, further work is necessary to understand what challenges will emerge and how to improve large-scale collaboration. Such a consideration needs to be taken into account by research councils at the project proposal stage. As mentioned previously, feasibility studies could be one way of determining whether such collaboration might be successful. However, it may also be fruitful to consider how a project may be structured by key partners (creators of the vision), contractors (developers of the vision) and trust relationships (users of the vision). The needs of each of these must be considered as currently project decision reside with only the key partners and limits the spheres of influence of developers and users

Successful collaboration is further complicated by the distributed nature of e-Science projects. In order for this distributed collaboration to be successful, communication is essential and it is the responsibility of the project manager to facilitate regular communication between collaborating project partners. To enable this communication the project manager may organise (AccessGrid) meetings or teleconferencing meetings at varying intervals. For example, the CancerGrid project staff has daily work package meetings and weekly project meetings via a videoconferencing tool. Typically, a project will meet less frequently for face-to-face meetings – every six months. However, workshops, project boards or integration fests are deemed critical forms of face-to-face meetings, maintaining the levels of engagement required to hold a project together. During such meetings, project partners will communicate what they have been working on; what they are working on; and what they are going to work on. This communication, often facilitated by the project manager, allows all the project partners to hear the progress of others and see how their work fits into the overall project. If this type of communication did not occur there is a risk that participants may feel isolated and consequently act more independently of the team (Galegher *et al*, 1990). This could be potentially disastrous to a project where the deliverables of various project partners make up and contribute to the success of the overall project.

In order to ensure the success of a project, it is also the responsibility of the project manager is to identify and manage conflicts of interest between collaborating project partners. For example, project partners may be trying to file competing patent applications. In a worse case scenario, such conflicts of interest could be damaging to collaborations between project partners. This would be detrimental to the project if there were deliverables with dependencies between the conflicting project partners. In such cases, the project manager coordinates between the project partners and research services to resolve any conflict. The project manager tries to get all project partners to be open about potential conflicts that might arise during the project so such worst case scenarios can be avoided.

In order to facilitate effective collaboration between project partners, the project manager will need to encourage the sharing of information between project participants. This has proved to be a key challenge on many of the e-Science projects. In some cases this can be achieved by asking project partners to talk about their successes, an activity that can be very rewarding. However, there are cases when participants are not willing to share information. For example, a participant may wish not to share their information until they have published the results of their work. Whilst working collaboratively, some may feel a sense of competition with and/or from their collaborators. The sharing of information is very much based on trust relationships. Lessons learned exercises have been a powerful tool in getting partners to talk about what went well in a previous phases and what did not go so well. For example, the eDiaMoND project participants engaged in a lessons learned activity to discuss the successes and failures of the phase 1 release. The lessons learned from this activity were then fed into phase 2. However, such openness is not rewarded in an academic setting and publishing lessons learned will not benefit the Research Assessment Exercise. The challenges relating to academic and organisational work practices have been documented elsewhere (see Welsh *et al*, 2005).

4.10 Managing Resources

Project managers often have very little control over resources on e-Science projects. This often means that the project manager has to put a positive “spin” on things, to get things done.

While the project manager is involved in the day-to-day activities, the project board is utilised to refer difficult or cross institute decisions to ensure buy in from the partners on actions like budget cuts, scope changes or taking on additional staff. The level of autonomy varies from project to project and particularly the level of engagement of the Principal Investigator.

However, a lack of control over resources means the project manager has to also convince the research staff of a particular course of action. For example, in an academic setting, the project manager is unable to take away resources from research staff or reduce their pay. Nor should they, as while such a forceful approach may get things done in the short-term, it could have long-term implications. However, nor is it possible for the project manager to give financial incentives to encourage project participants to complete a desired deliverable. Rather, the project manager must convince the research staff of the benefits they would receive from a particular course of action – implicit rather than explicit motivation. For example, the showcase event organised by the project manager for the IB project was designed to encourage the project participants to meet their deliverables. The project manager informed the project participants of the potential for future funding resulting from this event, which encouraged the project participants to make the event a success.

While such management is difficult in an academic setting, it is far more complex with commercial partners. If a commercial partner is involved in an e-Science project, which is often the case, the loyalties of commercial employees are torn between the project and the company. For example, if the project manager requests a project deliverable be completed by a given date and the employee’s company requests a company deliverable for the same date, the company deliverable will take priority. The consequences for not meeting a company deadline could be far more severe than not meeting a project deadline. In these situations the project manager has very little control and has to make the best of the resources they have available.

4.11 Managing Press Releases (PR)

Public relations offices write press releases as a useful resource to get projects known. However, they can also be a dangerous tool. For example, the eDiaMoND project received a huge amount of media attention, which increased the popularity of the project. However, ambitious statements in PR created false expectations about the project. It is important that PR is consistent from all project partners, thereby giving a clear and accurate message about a project. Centralising PR through a PR board with a clearly defined PR policy is one way of achieving a clear and consistent message. The project manager is a key person involved in this process, as they have an overview of the day-to-day activities of the entire project. However, this can be quite burdensome, as PR is very time consuming and often not costed into a project, but can reward project partners with benefits including follow on funding, project prestige and enhanced career prospects.

5 Conclusions and Future Work

In this report we have identified and explored some of the challenges of project management in e-Science. We set the scene by providing an overview of project management. This overview included a description of two project management methodologies, Prince 2 and PMBOK; and described a number of software development process models that the two project management methodologies may be applied to. However, we argued that these project management methodologies and software development process models were not developed with e-Science projects in mind. Therefore, e-Science projects and their project managers face a number of challenges. To identify these challenges we conducted interviews with project managers and project participants of major e-Science projects in the UK. We have also drawn upon a series of ongoing workshops initiated at Oxford, but also workshops at NeSC, AHM and with the EPSRC. From our data 11 challenges faced by e-Science projects and their project managers were identified. Each of these challenges were introduced and discussed, and various examples from e-Science projects were presented where appropriate.

Based on the exploration of these 11 challenges and building upon our interviewees' experiences, below we suggest a number of recommendations for e-Science projects to consider in order to facilitate project management in e-Science.

1. **Feasibility studies:** small scale studies conducted before a research project is funded, aimed at reducing the ambiguity and risk of research projects, whilst at the same time not requiring them to be fully specified. Furthermore, such studies will allow new research collaborations to be explored before a full commitment is given to delivery of a large-scale infrastructure.
2. **Questionnaires for project participants:** questionnaire administered to project participants can be used to elicit the opinions of project participants at project start-up, thus making explicit what the aims, objectives and innovation of the project may be. Such questionnaires ask project participants: what they think the objectives of the project are; what the critical success factors for the project are; what they would like to get out of the project; and what they will contribute to the project. This information allows the project manager to understand the project participants expectations and drivers, which in turn can help the project manager, assign roles and responsibilities.
3. **Alphabetical authorship:** ordering the authorship of project participants on publications alphabetically in order to reduce conflicts between project participants.
4. **Code ownership:** basing the ownership of software on a line-by-line of code basis in order to reduce conflicts over who owns the software.
5. **Research days:** dedicated days to research to achieve a balance between critical path and research activities.
6. **Blueprint documents:** a document used to capture research ideas that cannot be addressed within the lifetime of a project or are outside the scope of the project.
7. **Debriefing meetings:** daily meetings held at the end of a working day designing for project participants involved in critical path activities to inform others what they have done, what went well and what did not go well. Such meetings may be either face-to-face or conducted via tele- or video- conferencing.
8. **Dissemination meetings:** meetings conducted weekly, quarterly or in between, designed for project participants involved in research activities to inform others

what they have been researching and the results of their research. Such meetings may be either face-to-face or conducted via tele- or video- conferencing.

9. **Project showcases:** an event designed for project participants to exhibit their work to other project stakeholders. This form of dissemination allows project participants to see how their work fitted into the project and provided an opportunity to discuss future research. In addition, such event help the project progress as project objectives have to be met by a given deadline.
10. **Transition workshops:** workshops designed to help one project partner pass their outputs to another project partners, thereby supporting the transfer of tacit knowledge. Such workshops can help avoid misunderstanding from occurring on multi-disciplinary teams.
11. **Lessons learned exercises:** activities designed to getting project participants to talk about what went well in the previous phases of a project and what did not go so well.
12. **PR board and policies:** a centralised PR board for the project with a clearly defined policy to ensure a clear and consistent message.

In order to build upon these recommendations we have identified a number of potential future studies. These should not be viewed as a finite list of studies, but rather a list of possibilities that shall evolve to meet the needs of the e-Science community and our research findings. These studies include:

1. A continuation of our interviews and workshops with project managers and project participants, which will be further complemented by a set of ethnographic studies to obtain a deeper understanding of the challenges managing e-Science projects.
2. Ethnographic studies to assess the effectiveness of our recommendations when implemented in e-Science projects.
3. Ethnographic studies aimed at trying to understand how project managers execute project management activities during large-scale, distributed and multi-disciplinary e-Science projects and understanding emerging tensions.
4. A study into the use of collaborative tools such as Basecamp, Wikis and other data repositories, understanding their strengths and weakness supporting collaboration across large-scale and distributed projects.

Through these and similar studies we aim to understand how we can best support project management activities in e-Science.

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Appendix

The semi-structure interview framework was as follows:

1. Describe the process and challenges of bid management on e-Science projects
2. Describe the process and challenges of moving from the proposal to the project on e-Science projects
3. Describe the process and challenges of establishing a legal framework between project partners
4. Describe the process and challenges of managing IPR on e-Science projects
5. Describe the process and challenges of assigning roles and responsibilities to project participants on e-Science projects
6. Describe the process and challenges of managing critical path and research activities on e-Science projects
7. Describe the process and challenges of planning releases on e-Science projects
8. Describe the process and challenges of managing requirements on e-Science projects
9. Describe the process and challenges of managing collaborative work between project participants on e-Science projects
10. Describe the process and challenges of managing resources on e-Science projects
11. Describe the process and challenge of managing PR on e-Science projects

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Andrew Warr is a researcher with interests in Human-Computer Interaction (HCI), Computer Support Cooperative Work (CSCW), Design and Creativity. Andrew is currently a Usability Researcher Fellow at the Oxford e-Research Centre (OeRC), University of Oxford. He is working with Dr. Marina Jirotko (PI) on the EPSRC funded 'Embedding e-Science Applications - Designing and Managing for Usability' project. Prior to this project, Andrew studied for his PhD in the HCI Group at the University of Bath, supervised by Dr. Eamonn O'Neill. His PhD research focused on 'Understanding and Supporting Creativity in Design'. During this time Andrew was also a Visiting Researcher at the Centre for LifeLong Learning and Design (L3D) at the University of Colorado, Boulder working with Prof. Gerhard Fischer and his colleagues. In addition to these research activities, Andrew also has strong interests in designing, developing and evaluating mobile and pervasive technologies for social settings.

Sharon Lloyd is a project manager and research facilitator at Oxford University. Sharon was project manager for the 2-year £4 million eDiaMoND project led out of Oxford in collaboration with IBM and 10 partner sites. She is now project manager for both Integrative Biology and NeuroGrid projects, which are led from Oxford, working with over 120 people over 25 sites. Before joining the University in February 2003, she worked in industry for 17 years where she gained extensive experience in project management in a commercial environment as well as people management through her management of IT teams. She has experience of both scientific and commercial IT development projects both in the UK and overseas.

Marina Jirotko is Director of the Oxford Centre for Requirements and Foundations, Lecturer in Requirements Engineering at Oxford University Computing Laboratory and Fellow of St Cross, Associate Director of the Oxford e-Research Centre (OeRC), and James Martin Research Fellow at the e-Horizons Institute. She has degrees in Social Anthropology and Psychology and Computer Science and Artificial Intelligence. She received her DPhil in Context Driven Requirements Capture from the University of Oxford Computing Laboratory in 2000. Her main areas of research have been developing novel methods and techniques for requirements capture drawn from the social sciences, focussing on workplace studies, practice driven requirements and design elicitation. Her research interests have long been concerned with developing systems that support everyday work and interaction, primarily to bring a richer comprehension of socially-organised work practice into the process of engineering technological systems. She developed the Requirements Engineering module that forms part of the MSc in Software Engineering and the MSc in Computer Science at Oxford University. In recent years her research has focussed on requirements for e-Science applications, particularly e-Health and she has worked on various industrially funded research projects, DTI, ESRC and EPSRC projects. She has been the requirements analyst on flagship e-Science projects such as eDiaMoND and is advisor on requirements methods and techniques for e-Science projects such as Integrative Biology and Virtual Research Environments for Humanities. She is a member of the UK e-Science Usability Task Force, Co-Director of the Oxford e-Social Science node that is investigating the Ethical, Legal and Institutional Dynamics of Grid Enabled e-Sciences and is Principal Investigator of the EPSRC project Embedding e-Science Applications: Designing and Managing for Usability.

Grace de la Flor is currently a DPhil student at the Oxford University Computing Laboratory studying the ways in which e-Science can change and improve the working practices of researchers and scientists. Her current research will assess how best to design and evaluate e-Science systems in support of the complex ways in which science happens; from 'in silico' experimentation, data sharing and visualization to new knowledge generation.

Ralph Schroeder is a James Martin Research Fellow at the Oxford Internet Institute (OII). Before coming to the OII, Ralph Schroeder was Professor in the School of Technology Management and Economics at Chalmers University in Gothenburg. He completed his PhD at the LSE in 1988. He has written extensively about virtual environments and recently completed a book manuscript 'Rethinking Science, Technology and Social Change'. At the OII he is continuing his research about how people interact in shared virtual environments. He is writing a book on this topic that will link virtual reality technology to other types of computer-mediated communication and new media.

Mustafizur Rahman interests focus on Information and Communications Technologies (ICT), particularly in translating and realising non-technical social aspects of Requirements Engineering into technical realities, for applications in advanced collaborative technologies in distributed computing and Grid technologies. Working closely with the Oxford e-Research Centre and the Centre for Requirements and Foundations (CRF), he has worked on several multidisciplinary projects, including CyberSEM (remote microscopy) and IMaGE (Law/IPR and e-Health), and has been involved in the requirements aspect of the eDiaMoND breast cancer screening research project as a Principal Researcher at the CRF. As the ICT Programme Manager the Oxford University Begbroke Science Park, he is tasked with fostering collaborative university-industry applied R&D, training and education and technology transfer activities.

Mr Rahman received his MSc in Software Engineering at Oxford University (UK) after completing his BSc in Computer Systems Engineering at the University of Massachusetts at Amherst (USA). He has spent a number of years working on research projects at universities before working at multinational companies such as Digital, Compaq and IBM. He was also one of the core members at a start-up company specialising in distributed systems management. He worked for over two years on a DARPA sponsored research project on Quality of Service before joining Oxford University in March 2003.

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