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The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

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1 Introduction

1.1 Project Overview

The concept of *Provenance* is already well understood in the study of fine art where it refers to the trusted, documented history of some work of art. Given that documented history, the object attains an authority that allows scholars to understand and appreciate its importance and context relative to other works of art. Objects that do not have a trusted, proven history may be treated with some scepticism by those that study and view them. This same concept of *Provenance* may also be applied to data and information generated within a computer system; particularly when the information is subject to regulatory control over an extended period of time.

Today's grid architectures suffer from limitations, such as lack of mechanisms to trace results and infrastructures to build up trusted networks. *Provenance* enables users to trace how a particular result has been arrived at by identifying the individual and aggregated services that produced a particular output. The overarching aim of the *Provenance* project is to design, conceive and implement an industrial-strength open provenance architecture for grid systems, and to deploy and evaluate it in complex grid applications, namely aerospace engineering and organ transplant management. This support includes a scalable and secure architecture, an open proposal for standardising the protocols and data structures, a set of tools for configuring and using the provenance architecture, an open source reference implementation, and a deployment and validation in industrial context.

The purpose of this project is to provide mechanisms that allow information generated and managed within a grid infrastructure to be proven and trusted. By this we mean that the information's history, including the processes that created and modified it, are documented in a way that can be inspected, validated and reasoned about by authorised users that need to ensure information controls have not been altered, abused or tampered with.

All material generated by the project is available from the project website at http://www.gridprovenance.org

1.2 Project Objectives

The overarching aim of the Provenance project is:

> *To design, conceive and implement an industrial-strength open provenance architecture for Grid computing, and to deploy and evaluate it in complex grid applications (aerospace engineering and organ transplant management).*

Specifically, the objectives of the project are:

1. To specify the contents of provenance in relation to workflow enactment.

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2. To design and implement a scalable and secure distributed co-operation protocol to generate provenance data in workflow enactment.
3. To conceive and implement tools to navigate, harvest and reason over provenance data, also in a scalable and secure manner.
4. To design and engineer a scalable and secure software architecture to support provenance generation and reasoning.
5. To deploy and evaluate the provenance system in two different grid applications, namely aerospace engineering and organ transplant management.
6. To propose a draft provenance specification for input to an open standardisation process thereby contributing to the standardisation efforts in this area within the Grid and Web Services architecture domains.

1.3 Project Consortium

The project consortium consists of six partners.

1. **IBM United Kingdom Limited United Kingdom (IBM)** was responsible for:
    a. Management of the consortium
    b. Leadership of workpackage 4 (Security)
    c. Leadership of workpackage 5 (Scalability)
    d. Leadership of workpackage 9 (Implementation)
2. **University of Southampton United Kingdom (UoS)** was responsible for:
    a. Leadership of workpackage 3 (Architecture)
    b. Leadership of workpackage 10 (Collaboration)
3. **University of Wales, Cardiff United Kingdom (UWC)** was responsible for:
    a. Leadership of workpackage 6 (Tools)
4. **Deutsches Zentrum fur Luft- und Raumfahrt e.V. Germany (DLR)** was responsible for:
    a. Leadership of workpackage 7 (Aerospace application)
5. **Universitat Politecnica de Catalunya Spain (UPC)** was responsible for:
    a. Leadership of workpackage 8 (OTM application)
6. **Magyar Tudományos Akadémia Számítástechnikai és Automatizálási Kutató Intézet Hungary (STA)** was responsible for:
    a. Leadership of workpackage 2 (Requirements)

Within the consortium, partners contributed to all workpackages according to the working project plan and allocation of resources.

1.4 Project Structure

The project consisted of ten workpackages.

1.4.1 Work package 1: Management

Led by IBM, this workpackage devoted to the coordination, management, dissemination and exploitation of the project and its results. It provided the periodic management reports to the European Commission and managed the project plans which were developed in collaboration with all partners in the consortium Regular face to face meetings were held at each partner's location.

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1.4.2 Work package 2: Requirements

Led by STA, the purpose of this work package was to elicit best practices for provenance generation, access, navigation and use. Also a set of scenarios and usage options were identified from which were derived a set of technical requirements. The role of this work package was crucial, because it steered the development of the architecture for the rest of the project. It delivered requirements at an early stage of the project to allow sufficient time for design, development, deployment and evaluation. Therefore, all partners were involved and a tight schedule of deliverables was adopted. The workpackage reflected business and marketing requirements by using IBM's presence in other application areas; in particular Financial Services.

1.4.3 Work package 3: Architecture

Led by UoS, this workpackage developed a technology independent architecture that addressed the concerns of its multiple stakeholders, end-users, developers and system managers. Different views of the architecture were adopted to this end: a logical view addressing functional requirements, process and physical architectures taking into account non-functional requirements and physical deployment, and development architecture identifying modules and libraries at the level of software development. We adopted an iterative design process, deriving a first architecture definition (strawman) from the technical requirements, iterating it into a final architecture definition, using feedback from the different application specific studies, tool design, and security and scalability analyses. The architecture was ultimately defined as a set of open specifications. The workpackage also developed a methodology describing how developers can make their applications provenance-aware.

1.4.4 Work package 4: Security

Led by IBM, this workpackage acknowledged that that security is pervasive in complex distributed systems. However, this workpackage focused on making the provenance architecture secure. It drew upon existing standardisation efforts in the Grid and Web Services world such as OGSA Security, WS-Security and WS-Trust. The overall goal of this work package was to ensure secure provenance data generation and access based on the Globus GT4 toolkit

1.4.5 Work package 5: Scalability

Led by IBM, this work package focused on the scalability of provenance generation and access. Scalability, like security, of the provenance architecture is an essential criterion for its adoption, and like security, scalability is pervasive within a distributed system.

1.4.6 Work package 6: Tools

Led by UWC, the objectives of this workpackage were to design and implement a suite of portal based tools that allow easy access, navigation and reasoning over provenance data. A further objective was to design a protocol that allows all components of the architecture to be configured and used by an application.

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1.4.7 Work package 7: Aerospace Application

Led by DLR, the purpose of this workpackage was to deploy the provenance architecture in an industrial application so as to exhibit some of the key scenarios identified in workpackage 2 and to evaluate the system in real life applications. This work package focused on the aerospace engineering domain, and specifically the TENT distributed workflow management system designed by DLR

1.4.8 Work package 8: OTM Application

Led by UPC with support from STA, the purpose of this workpackage was to deploy the provenance architecture in a realistic application environment. The application domain targeted is the tracking of patient medical record information and (more specifically) decision-making; the precise application scenario was based on the process of organ and tissue transplant decision-making and the subsequent care regime.

1.4.9 Work package 9: Implementation and Integration

Led by IBM, the purpose of this workpackage was to develop a reference implementation of the provenance architecture. The implementation was written in Java using other open source components based on the Globus GT4 toolkit. The reference implementation was released to the research community via the project website under the Common Public License (CPL). The reference implementation was integrated with the two test applications developed under workpackages 7 and 8.

1.4.10 Work package 10: Collaboration

Led by UoS, this workpackage coordinated the collaboration between the Provenance project and other IST Grid-related projects.

2 A User's Perspective on the Open Provenance Architecture

The Provenance project has defined an open provenance architecture [16], an architecture for provenance systems, based on an open data model, allowing explicit documentation of past processes to be expressed, and a set of public interfaces allowing the creation, recording and querying of such process documentation [17]. The Provenance project also produced a software implementation [35] of this architecture, its integration with several Grid toolkits, as well as a series of tools [25] operating against its open interfaces and data models. Such an approach offers multiple benefits to the users who have interacted with a deployment of the provenance architecture: in this section, we specifically examine the benefits to medical users, users in the aerospace domain, IT practitioners and process regulators.

2.1 Medical Users

With an explicit representation of past processes, medical users are able to visualise and inspect such past processes, navigating information using visualisation tools according to their needs. This is an activity that they cannot realistically perform with today's technology, since it would require trawling paper archives to reconstruct cases

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from collections of reports. Furthermore, a complete computerisation of such paper archives would not directly address this problem either, since reports do not explicitly contain the necessary links to establish causal relationships between events, actions and decisions. It is the contribution of the Provenance project to make such causal links explicit within the execution context, hereby making them queryable and processable by user specific tools.

Heads of medical units also benefit from such explicit representation of processes, since they now have the possibility of making internal audits of processes, so as to improve them. External auditing by medical authorities can now also be undertaken, to review individual cases, but also to derive necessary statistics in a reliable manner; such statistics may be of use internally for process improvement, and externally for regulatory compliance. While families are not given direct access to the system in our case study, they can be informed that the process is monitored and can be audited by the appropriate authorities: while no new functionality is available to families, they can gain better confidence in the medical establishment.

Our application demonstrator, making use of the European Health Record standard to exchange data, provides an integrated view of the execution of treatment process across multiple institutions, potentially located in different countries, under national legislations. Such functionality becomes more and more important in Europe due to trans-national population mobility resulting in patient records distributed in multiple countries. The provenance architecture gives doctors a better view of the health profile of their patients, and can help them provide better care.

2.2 Aerospace Engineering

While existing workflow systems and engineering simulation tools offer good logging capabilities, they typically do not capture causal relations, as supported by our open process documentation. Hence, currently, it is difficult for engineers to understand, after the facts, which parameters influenced simulation results. Since causal relations also facilitate comparisons of two runs, a tool that highlights the difference between two executions was shown in our evaluation [27] to be of use to engineers. Provenance also helps reproducing results: it captures all the steps, parameters, configurations, inputs and workflow details that led to such results, all of which can then be used for replaying execution.

The distributed nature of the European aerospace industry is well illustrated by the Airbus consortium, which consists of a federation of autonomous institutions. To ensure the necessary quality control, audit is required to check that design and manufacturing processes are compliant with the relevant regulations: with process documentation, an explicit representation of processes that are distributed across multiple institutions can be captured and seamlessly analysed. Within a given institution such as DLR, individual units adopt their own "standards" or "best practice": explicit process representation allows management to know what has been done. Process documentation is shown to be particularly adapted to contexts where institutions adopt different IT infrastructures and subcontracting is used.

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2.3 IT Practitioner

For the IT practitioner, whether developer or system administrator, the provenance architecture was given an industrial-strength focus. Indeed, protocols and data models were conceived to be scalable and to allow for scalable deployment of provenance stores by systems administrators. Provenance stores also allow for scalable backend storage by making use of OGSA-DAI, and by permitting clustering of the web service itself. From a security point of view, the architecture allows for inter-operability with well-established industrial security standards, and in particular WS-Security. From the outset, the architecture was conceived to support multiple security domains so as to allow for federated scenarios in healthcare and aerospace applications.

The success of the open provenance approach can also be measured by the nature of the distributed development undertaken within the project itself. As all partners (whether consumers or providers of process documentation) worked against well-specified, open data models and interfaces, development was undertaken in a distributed manner, allowing application developers to program tools specific to their needs.

2.4 Process Regulator

Companies are subject to a wide range of rules and regulations that apply directly to their internal operations and the products and services they provide. Compliance to these regulations is essential for a company to operate transparently and ethically in their particular markets. They are required to prove compliance to the imposed regulations through internal and external auditing activities. These auditing activities are usually manual where the auditors sample and inspect the documentation generated by the company being audited. This is both time consuming and potentially subject to error. Applying the Provenance architecture and methodology to business processes as they execute has the potential to improve the quality of the auditing activities, streamline them, improve the transparency of a company's compliance to the regulations, and provide cost benefits which impact profitability. We have shown that process documentation is particularly adapted for describing processes in distributed environments, making use of different IT solutions, and involving multiple institutions, possibly relying on outsourcing.

3 Project Deliverables

In this section we provide a roadmap to the EU Provenance project's document output. This output is categorised according to the project's deliverables. By providing this document for reviewers of the project we aim to facilitate navigation through the output of the project and to help provide an appreciation of the project's overall contributions. The documents described below are split into eight categories as shown in Figure 1.

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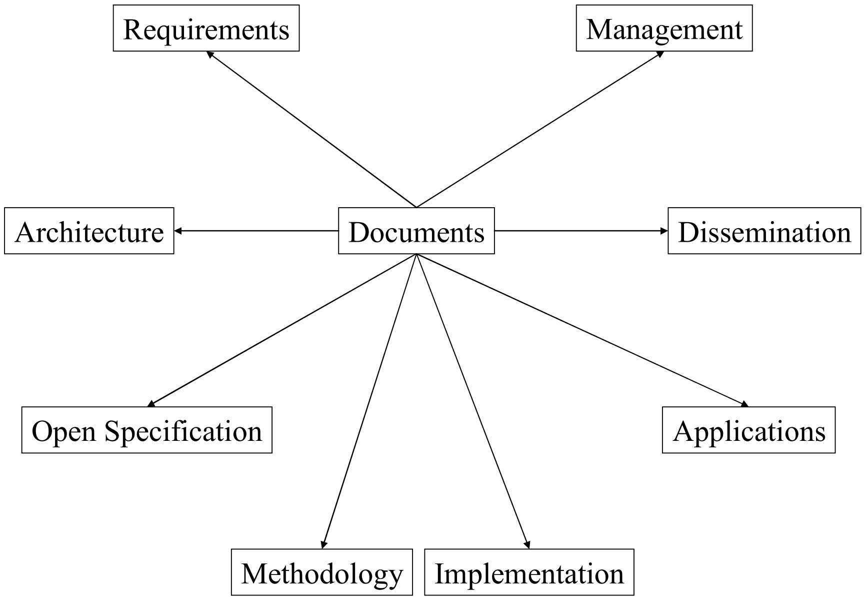

Figure 1: Documentation Roadmap

These categories describe the documents produced by the project as follows:

1. *Requirements* describes the set of documents produced as input to the other workpackages
2. *Architecture* describes the set of documents that relate to the project's architecture for provenance systems
3. *Open Specification* describes the set of documents that set out the open specification model of the provenance architecture
4. *Methodology* describes the project's best practice methodology for designing provenance aware applications
5. *Implementation* describes the documents leading to a scalable, secure implementation of the architecture
6. *Applications* describes the documents produced by the demonstration application partners
7. *Dissemination* describes the project's published papers in a variety of workshops, conferences and journals that contribute to the dissemination of the project's findings
8. *Management* describes the documents generated as part of the management of the project.

Following the sections covering these categories, we provide a section that contains an overview of all the contractual deliverable together with a complete bibliography of all the project publications.

3.1 The Provenance Requirements

Requirements were gathered by SZTAKI for the Provenance Architecture and subsequent implementation. These were gathered via an online questionnaire and

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were analysed to produce first a User Requirements document [14] from which was generated a Software Requirements document [15]. These then provided the input requirements to Southampton's Provenance Architecture activities. Documents produced later in the project justified design decisions based on these requirements.

3.2 The Provenance Architecture

A key deliverable of the EU Provenance project was the design of an architecture for provenance systems. Such an architecture was to be designed in a technology independent manner and would provide the framework for the design of a provenance store implementation (undertaken by IBM). In pursuit of this aim, Southampton researched and designed an architecture, whose development was captured by three key documents. First, the document entitled *A Proof of Concept Design for Provenance* [32] described a pre-prototype architecture that raised a number of important issues. Second, a document entitled *A Logical Architecture Strawman for Provenance Systems* [73] was delivered that described in much more detail a provenance architecture. Work on this architecture continued, resulting in many interim releases of the document describing the final architecture for the project (ten in total). This final document, entitled *An Architecture for Provenance Systems* [16] became the key reference in the development of the Provenance Store – a concrete architecture designed by IBM for the EU Provenance Project, of the Client Side Library developed at Southampton [36], and of the Provenance Tools developed by Cardiff University.

3.2.1 Papers describing the Provenance Architecture

Several papers have been authored that examine different aspects of the architecture. Of historical interest, the paper, *A proof of concept: Provenance in a Service Oriented Architecture* [54] presented a first look at the Provenance Architecture. In S*ecurity Issues in a SOA-based Provenance System* [86] the security considerations pertaining to a Service Oriented Architecture based provenance system are discussed and approaches to address them are presented.

Two investigations were carried out over the summer of 2006 that resulted in two technical reports being released. The first examined the visualisation of provenance information and is entitled *An Investigation into Provenance Visualisation (Summer Project Report)* [52], and the second, entitled *An Investigation on the Performance of Storing the Process Documentation in a Relational Database -Summer Project Report-*, examined the performance of a provenance store based on the architecture when tied to a relational database [62].

In addition to the above documents, Southampton has also released other documentation for partners to facilitate their use of the architecture. In Linking 101 [80], a tutorial on aspects of the architecture is given that enables distributed process documentation to be systematically stored. Finally, a document was written that provides answers to frequently asked questions about the architecture. The document can be accessed from the following link [61].

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At the International Provenance and Annotation Workshop held in Chicago, May 2006, the Southampton team presented a paper entitled, *Principles of High Quality Documentation for Provenance: A Philosophical Discussion* [58] in which several principles for documenting the past, grounded in work from philosophy and history are derived, which allow for provenance questions to be answered within a computational context. The paper provides a rationale for the adoption of certain key assumptions during the development of the Provenance Architecture. The publication entitled *Provenance and Annotation of Data—The International Provenance and Annotation Workshop (IPAW)* [74], presents all the papers presented at IPAW.

In the Provenance Challenge (see below for a description of this Southampton organised event), Southampton presented a paper entitled, *Extracting Causal Graphs from an Open Provenance Data Model* [69]. This paper describes Southampton's open provenance architecture (OPA), which is based on the Open Specification also developed by Southampton. A noticeable feature is that distinctions are made between the data recorded about what has occurred, *process documentation*, and the *provenance* of a data item, which is all that caused the data item to be as it is, and is obtained as the result of a query over process documentation. This distinction enables the tailoring of the system to separately address the requirements of recording and querying documentation.

3.3 Open Specification Documents

These documents introduce a framework for computational provenance; a set of nine technical specifications that define the normative description of the provenance framework in terms of a SOA model and related XML definitions. These technical specifications, summarised in Figure 2, define the means by which: a computational representation of process documentation can be realised, how process documentation can be recorded and queried, how the recording and querying of process documentation can be made secure, and how process documentation can be recorded in distributed systems.

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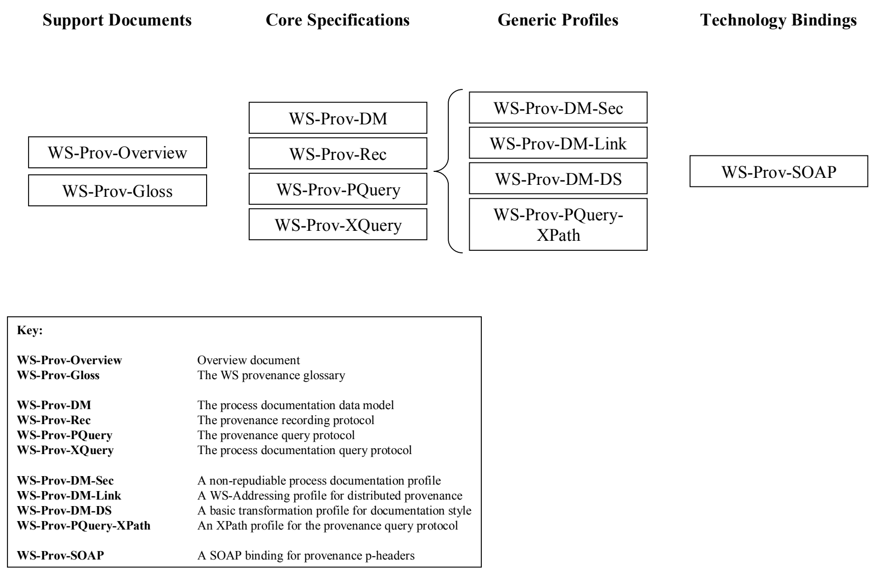

Figure 2: The Open Specification Documents

The family of documents comprise a set of two support documents [40, 50], four documents that introduce and specify the core framework [41, 42, 43, 44], four generic profiles that extend the basic framework [45, 46, 47, 48] and one example of a technology specific binding [49].

In support of the Open Specification the paper entitled, *Standardisation of Provenance Systems in Service Oriented Architectures—White Paper* [76] presents provenance in computer systems as a mechanism by which business and e-science can undertake compliance validation and analysis of their past processes. It describes how an open approach can bring benefits to application owners, IT providers, auditors and reviewers, and specific recommendations to move forward a standardisation activity in this domain are made.

3.3.1 Papers describing the Open Specification

In the *Report on the International Provenance and Annotation Workshop (IPAW'06)* [53] a descriptive account of the discussions that arose between participants during IPAW is given. These discussions centered on the differing uses of the term 'provenance' by the participants. These differences are captured in the paper entitled *Usage of 'provenance': A Tower of Babel. Towards a concept map* [72], in which a concept map that summarises key associated concepts and their relationships to provenance is described; importantly, such a concept map helps avoid ambiguities of current usages, which is key if the community is to be able to move towards a common standard.

In the *Special Issue on the First Provenance Challenge* [77] the *provenance*

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challenge is described: a special event organised by Southampton to further the development of an open standard for provenance systems. In particular, the challenge examines the following points:

1. The representations that systems use to document details of processes that have occurred.
2. The capabilities of each system in answering provenance-related queries.
3. What each system considers to be within scope of the topic of provenance (regardless of whether the system can yet achieve all problems in that scope).

In *The Provenance of Electronic Data* [75], a description of the provenance lifecycle is given as well as an argument for the need for an open approach to provenance. The paper also describes how a provenance system can be used in a medical domain application.

3.4 The Provenance Methodology

In addition to the development of the Provenance Architecture, Southampton developed a methodology to allow application developers to design provenance-aware applications. This methodology went through two major iterations resulting in *PrIMe: A Methodology for Developing Provenance-Aware Applications* [18], which greatly extended the original methodology.

3.4.1 Papers describing the Provenance Methodology

As well as developing the provenance methodology and authoring two documents that can be used by application developers to make their applications provenance aware, Southampton has also authored a paper entitled *PrIMe: A Software Engineering Methodology for Developing Provenance-Aware Applications* [79], that presents PrIMe from a software engineering methodology perspective. This paper was presented at the International Workshop on Software Engineering and Middleware in November, 2006.

In *Provenance in Agent-mediated Healthcare Systems* [66], three aspects of provenance in agent-mediated healthcare systems are examined, first provenance is defined and shown how it can be applied to agent-mediated healthcare applications; second, a method for independent and autonomous healthcare agents to document the processes they are involved in without directly interacting with each other is described; and third, it is shown how this method solves the privacy issues of provenance in agent-mediated healthcare systems. The paper provides insight how the Provenance Architecture can be applied to a domain using the provenance methodology.

3.5 The Provenance Implementation

The Provenance Implementation is a reference implementation of the Provenance Architecture including features to support the security and scalability requirements. The requirements were extracted from the software requirements document and addressed in two versions for each of the security [19 and 20] and scalability [21 and 22] requirements. Instead of a separate implementation for security and scalability,

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their final deliverables were included in the final implementation workpackage deliverable.

Three tools deliverables have resulted from the project. The first deliverable [23] described the overall Provenance Tool Suite – outlining interaction between the tools, and the criteria for selecting between different technologies to implement the tools. The two key selection criteria here involved choosing a suitable Portal technology, and choosing a suitable rule engine. The types of users most likely to utilize the tools was also outlined in this deliverable, along with assessment of requirements from the work undertaken in work packages 2 and 3. This assessment was subsequently discussed with colleagues from the application workpackages. Deliverable [24] describes the overall setup process, and various components that need to be configured during the setup process. A protocol is described in this document, along with particular states that need to be handled during this setup process. The setup involved in the Portal and the Analysis tool is also described – with suitable examples. Deliverable [25] describes the overall configuration process – outlining the types of configurations that would be needed within a provenance system in its entirety, and subsequently in the configuration of the tool suite. The deliverable also describes how the rule engine needs to be configured – with examples to demonstrate the process. The configuration of the Navigation and visualisation Tool is then described – again examples are provided to demonstrate the process. Performance results for uploading rules into the analysis engine, and for supporting provenance visualisation are also provided.

The implementation and integration workpackage first produced a proof of concept prototype based on existing technology [32]. It then produced a set of document deliverables to match the release of the reference implementation internally to the project [33] and later to the external community [34, 35 and 36]. The final deliverable includes details of the implemented security and scalability features.

3.5.1 Papers describing the Provenance Implementation

Cardiff has produced a number of publications and given demonstrations of the tool suite. All of the publications have been reviewed by international programme committees, and appear in the proceedings of the associated event. Cardiff have also given talks at various conferences to emphasise the importance of provenance in distributed systems.

Cardiff also participated at the IPAW event organised by the University of Southampton, and presented work on recording actor state – as reported in paper [89]. Three views on actor state are reported here:

1. when the actor records process documentation
2. when the actor uses the Client Side Library
3. when actor state needs to be inferred from the platform on which it is hosted.

Paper [88] demonstrates how actor state may be captured using the Ganglia monitoring tool. This is one of the most widely used monitoring engines within the Grid community, and also supported within the National Grid Service in the UK and

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the US TeraGrid project. Paper [83] demonstrates how actor state and interaction p-assertions can be used in a model to evaluate trust in a workflow.

A number of talks and demonstrations were also given by the Cardiff team. These included a demonstration at the UK eScience All Hands Meeting and at the Open Grid Forum [90, 92]. The demonstration was attended by a number of UK and European project participants, and has led to good subsequent interaction with these individuals. Another talk was given to participants who were not from the computer science area. This was delivered via the "Global Studio" site at Cambridge University, with participation from Keio University, Japan, Korean Information Society, and Korean Information Strategy Development Institute. The focus of this event was on the impact of "social networking" and "peer-2-peer" technologies on creativity in the arts. provenance mechanisms in Grid systems vs. those in the arts were compared and discussed. When comparing the proliferation of content creation by the "masses" – as witnessed in recent take up of "Blogs" and sites such as "YouTube" and "MySpace" – this talk focused on how one could assess the "provenance" of content that is provided via such media. Talk [91] was given at the UK Portals conference in Portmouth University, where the criteria for selecting the eXo Portal was outlined, along with discussion of features that were made available in the provenance portal. Talks [109, 110 and 111] were given in Asia – as part of GridAsia 2006 and a subsequent collaboration meeting in Thailand. Here, the importance of provenance themes were outlined – with reference to other work taking place in the South East Asian High Performance Computing community. Provenance Tools being developed in the project were also outlined.

3.6 The Provenance Applications

The Aerospace and Organ Transplant Management applications used the software developed in the project implementation workpackage. Each application builder prepared a specification which described how their application would make use of the provenance architecture and identified any domain specific issues that needed to be addressed [26 and 29]. Following the implementation and deployment of the application [27 and 30], they each produced a report [28 and 31] which evaluated the use of provenance and assessed their applications against the original requirements used to generate the Provenance Architecture.

3.6.1 Papers describing the Provenance Applications

DLR has produced one publication and given a number of talks covering provenance from the viewpoint of engineering applications. The paper [67], presented at the IPAW'06 conference, describes the implementation of provenance in a simulation environment for engineering applications.

Members of the DLR team have given a number of talks and presentations in a variety of internal and public meetings. Two presentations, given at a joint ESA-DLR workshop [95] and an internal DLR workshop on integration technology, focused on integration and simulation environments and covered the benefits of provenance

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information within this context. A seminar talk at DLR [94] covered provenance terminology and the EU Provenance project.

The paper [56] describes the use of the Navigation tool within the EHCR application. The paper first describes how electronic healthcare records may be fragmented across different hospitals that a particular patient visits, and subsequently describes how the Navigation tool and the Portal may be used to analyse p-assertions that have been submitted to rebuild the treatment history of a patient. This paper also demonstrates close collaboration between the tools and OTM application workpackages. Paper [81] describes how the Analysis Engine and Analysis Tool can be used to undertake trust assessment from a workflow. Essentially, the key idea here is to demonstrate the use of the analysis engine as a way to assess whether the result that has been produced from a workflow can be "trusted". A decision tree mechanism is used to make this evaluation.

3.7 Provenance Project Management

This section shows how the deliverables produced by workpackages 1 (Management) and 10 (Collaboration) are related. For the management periodic reporting, a series of reports were delivered at months 3 [1], 6 [2], 12 [3 and 4], 18 [5] and 27 [6 and 7]. These reports highlighted technical and management progress made during the reporting period. Exploitation of the project outcomes is a high priority objective of the project so a working exploitation strategy document was produced by the project with versions delivered at months 6 [9], 12 [10 and 11] and 18 [12]. At the end of the project in month 27, a final exploitation report was produced which provided an overview of the project [13]. This final documentation deliverable was also produced [8].

Workpackage 10 identified the collaboration of the project with others in the FP6 Framework. Its activities were reported periodically at months 4 [37], 12 [38] and 27 [39].

3.8 External references to the Provenance project

Southampton University generated a number of press releases throughout the project [123, 124 and 125] to advertise important activities. IBM through its Analyst Relations department arranged briefings for a number of IT Analysts about the project. These briefings resulted in references [119 and 128]. A further briefing has been arranged for December 2006 to report on the outcomes at the end of the project.

The project has also been identified in other news sites [120, 121, 126, 127 and 128].

4 Achievements versus Objectives

As specified by the technical annex, the Provenance project aimed to design, conceive and implement an industrial-strength open provenance architecture for grid systems, and to deploy and evaluate it in complex grid applications, namely aerospace

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engineering and organ transplant management. In this section, we discuss the projects achievements against its stated objectives.

1. **To specify the contents of provenance in relation to workflow enactment.**

   The project has proposed a novel definition of provenance for process-oriented computational environment, and has derived a data model for representing provenance that is technologically-independent. While still addressing workflow enactment, the Provenance project expanded its conception of provenance beyond workflow enactment to include a variety of programming and distributed systems styles. Concretely, this has allowed us and others to capture provenance in multiple workflow-based systems, such as Triana, Active BPEL [85], the Grid Virtual Data Toolkit [HPDC'05], Tent [67], but also in Java-based applications [69], and other distributed technologies such as RSS [68]. The generic nature of our approach, and its suitability for a variety of distributed styles, is also highlighted by our visualisation tools that can render enacted workflows graphically in multiple forms [56, 52]. Importantly, to help application designers extract the relevant process documentation to support their provenance query, the project has specified a methodology [18], which guides them step by step, to make their applications provenance aware. Such a methodology is the first of its kind.

2. **To design and implement a scalable and secure distributed co-operation protocol to generate provenance data in workflow enactment.**

   The project specified a recording protocol as the set of messages that application components cooperatively exchange in order to document their execution, whether workflow-based or not. Considerations of scalability and security influenced the design of the data model and protocol: the data model allows for autonomous creation of process documentation, whereas the protocol supports for their asynchronous recording, both promoting scalability [16]; cryptographic techniques such as signatures and digest in documentation style allow for preserving and verifying the authenticity of assertions [45].

3. **To conceive and implement tools to navigate, harvest and reason over provenance data, also in a scalable and secure manner.**

   Several tools have been designed and implemented, making use of the provenance store query interfaces [43, 44], and analysing process documentation, to provide added value to end-users, such as displaying past executions [56, 52], checking if past executions satisfy some constraints [25], finding inputs to an execution [69], identifying doctors involved in a case, or producing a textual narrative for an execution. As part of the implementation and design of the tool suite, scalability experiments have been undertaken on the analysis engine, and user access performance for the portal. By means of the Client Side Library [36], secure access to the provenance store [35] is ensured for tools in accordance to the overall security architecture. Tools themselves can help specify security configurations for the system [25].

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4. **To design and engineer a scalable and secure software architecture to support provenance generation and reasoning.**

   In its technology-independent form, the architecture [16] addresses both scalability and security: it specifies design patterns for alternative deployments of the architecture, it supports linking of multiple provenance stores, and it explains how multi-institutional deployments of the architecture can be achieved securely. Our open specification effort [18] addresses general security considerations in its various documents, in a similar manner to other standardisation proposals, but specifically focuses on a secure profile for the p-structure [45] and securing of messages and store [42]. In terms of software implementation, the provenance store deployed in the Globus Toolkit GT4 can make use of Grid security specification (such as WS-SecureConversation) [35], and allows for multiple store deployments for scalability or in the presence of multiple security domains. The Client Side Library [36] also built using the GT4 toolkit allows for secure communications with the provenance store.

5. **To deploy and evaluate the provenance system in two different grid applications, namely aerospace engineering and organ transplant management.**

   The reference implementation of the architecture was successfully deployed and integrated with the Aerospace [67, 28] and OTM applications [51, 31]. The evaluations involving users [27, 30] demonstrated how the architecture offered capabilities that were inexistent before. Furthermore, through the provenance challenge, another deployment of the architecture was successfully undertaken in the context of an FMRI (Functional Magnetic Resonance Imaging) workflow [69].

6. **To propose a draft provenance specification for input to an open standardisation process thereby contributing to the standardisation efforts in this area within the Grid and Web Services architecture domains.**

   The project has announced its open specification philosophy in a white paper [76] and provided an extensive open provenance specification [40] to [50]. It further contributed to the standardisation process by means of provenance scenarios in the OGSA Data Scenario document [55]. The reference implementation is a concrete realisation of this open specification, which was publicly released to the community under the Common Public License, an open source license. All our designs were based on a rigorous software engineering approach: we captured requirements from a dozen different projects; we formulated these as user [14] and technical [15] requirements; we designed an architecture, precisely and systematically identifying design decisions and the requirements they satisfied; we contacted the requirements providers and discussed our design with them, and iteratively improved our

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design; finally, deployments in concrete applications and the write-up of the open specification led us to specify a provenance FAQ [61] and clarify some architectural aspects. This allowed us to meet our contractual obligations, and produced the deliverables specified in the technical annex [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39]. Also, these substantial results allowed to disseminate the project outcomes and put exploitation strategy in place, as discussed in the next section..

5 Dissemination

In this section, we summarise the dissemination activities undertaken by partners (allocating papers to the first author's institution). Details can be found in the project documentation.

5.1 Refereed Papers

The project as a whole has published over 20 refereed publications in journals, conferences and workshops. Among them, we note two magazines IEEE Intelligent Systems [66] and Communications of the ACM [75], to ensure wide dissemination to IT professionals beyond the scientific research community.

STA PSACE'06 [63], JOATC'07 (in prep.), IS'06 [66]
UWC WI'06 [56], MGSJ'07 (in prep.), MACE'06 [81], SISS'06 [82], IPAW'06 [89], CCGrid'06 [88, 83]
UPC IPAW'06 [51]
DLR IPAW'06 [67]
UoS AHM'05 [54], SEM'06 [79], CACM'07 [75], IPAW'06 [58, 86], CCPE'07 [78, 69], software engineering journal (in prep. [18])

5.2 Proceedings

The project has taken the lead in organizing two international provenance-related events (IPAW'06 and the first Provenance Challenge) and has edited two proceedings respectively in the Springer series lecture notes [74] and in a special issue of the Wiley Computation and Concurrency: Practice and Experience journal [77].

UoS IPAW'06 [74, 53], Challenge'06 [77]

5.3 Position Papers

Two position papers on standardisation and terminology have also been made available to the community.

UoS Standardisation White paper [76], Tower of Babel [72]

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5.4 Tutorials

Provenance was mentioned or was the sole focus of several tutorials organised by the project members.

UWC Europar'05, CCGrid'06
UoS Provenance Architecture Tutorial 06 [115]

5.5 Teaching

At two institutions, provenance has been introduced in the curriculum, at the MSc level.

UWC CMP629, distributed multi-agent systems
UoS COMP6017, advanced topics on Web services

5.6 Talks

The project has given a vast number of presentations at conferences but also at multiple institutions in Europe and the US.

STA PSACE'06 [118]
IBM Internal company presentations (approximately 20)
UWC WI'06, MACE'06, SISS'06, IPAW'06, CCGrid 06 (2x), VRE'06 [91]
UPC AHC'06 [117], IPAW'06 [116]
DLR IPAW'06 [95], ESTEC-DLR [113], DLR [94]
UoS Harvard'06 ([104] 2x), Chicago'06 [104], ISI'06 [106], IBM'06 [105], Birmingham'05 [98], Kent'06 [103], IAM'06 [99], Rennes'06, AHM'05 [96], SEM'06 [108], IPAW'06 [93,114], Challenge'06 [97], HPC'06 [102], CT1 SC [107], GridAtWork'05 [101], ARW'05 [100]

5.7 Demonstrations

Besides internal demos to visitors, project partners have organised demonstrations at the UK All Hands Meeting (AHM'06), with well over 600 participants.

UWC AHM'06 [92]
UoS AHM'06

6 Exploitation

In this section, we discuss exploitation activities that project partners have initiated.

6.1 Standardisation Route

The Open Provenance Architecture is underpinned by the Open Provenance Specification [17], which promises the industry and the research community an open approach according to which new components can be developed, shared and reused, while providing inter-operable provenance related functionality. A substantial effort has therefore been made by partners to promote take-up of the approach. In particular, we note project presentations to IT analysts, who wrote about the project [119, 128].

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UoS Open Specification [40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50], AgentLink Roadmap [122], Press releases [124, 123, 127, 125, 121, 126, 120]
IBM IT Analysts [119, 128]

6.2 Web site

The Web Site is a major technique for disseminating all the public project outputs widely. In order to ensure the durability of Provenance legacy, we have acquired the domain name for ten years. Since October 1st, we have registered the site with Google analytics to perform an analysis of the site users. We see that twiki.gridprovenance.org is accessed from Europe, US, China, Japan and India.

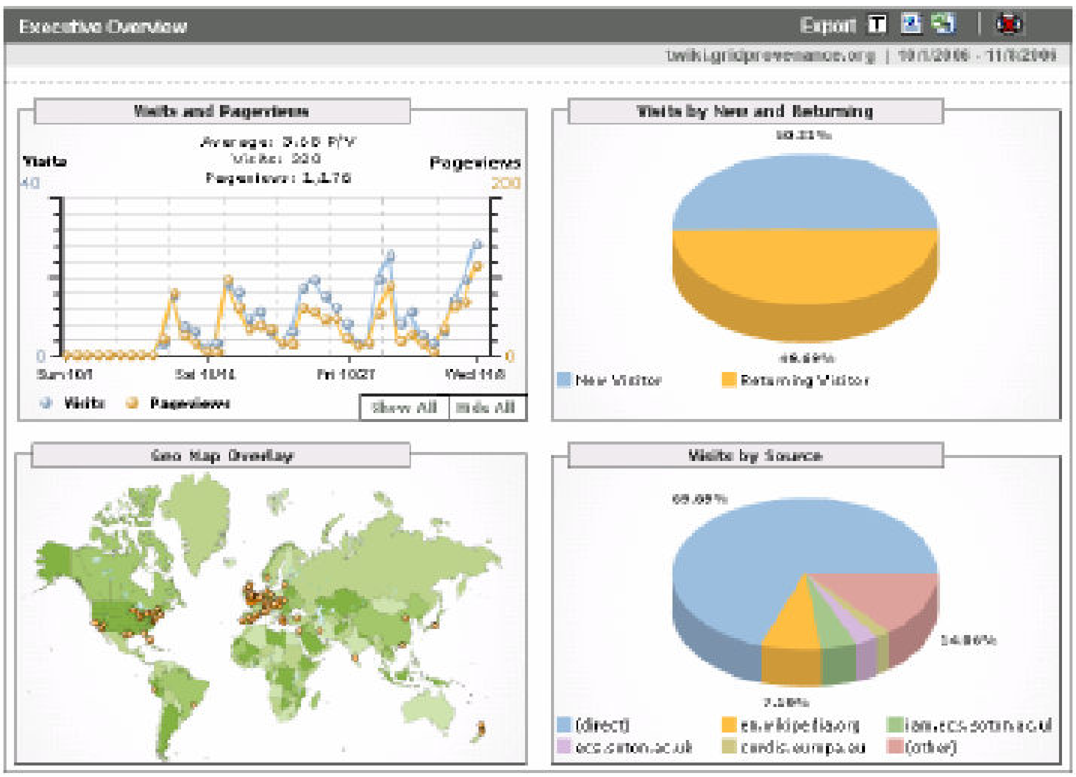

Figure 3: Google Analytics Report

6.3 Grid and workflow toolkits

To promote the wide use of the provenance architecture, we have integrated (or are in the process of integrating) the architecture with several grid toolkits, demonstrating the technology independence of the model, and the applicability of the architecture to multiple runtime environments. By making such work available to the community, we will facilitate take up of the provenance approach and its available tools.

UWC Triana Integration
UoS Active BPEL [85]

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Discussions with myGrid on integration of Taverna and Provenance [71]
Discussions with ISI on integration of Pegasus/VDT and Provenance

DLR DataFinder integration
Python binding for client-side library

IBM See confidential exploitation report

6.4 Other projects or applications

During the lifetime of the project, partners have applied the provenance architecture to other applications, are reusing it in the context of other projects, or have undertook case studies to other application domains.

STA The EHCR subsystem of the provenance-aware OTM Application is used in the K4Care project (http://www.k4care.net) EHCR case study [65]

UWC Astrophysics (Simulation of blackholes), using the Cactus toolkit [25]
Biodiversity case study [87]
Gravitational Waves case study [84]

UoS The Provenance Challenge's FMRI workflow [69]
Exploratory Provenance Visualisation [52]
Investigation of relational storage model for provenance [62]
Provenance-aware RSS feeds [68]
Quality of Result analysis [59]
myGrid case study [71]
MIAS case study [70]

IBM See confidential exploitation report
Provenance and compliance case study [60]

DLR Datafinder Integration
AeroGrid proposal

7 European Added Value

The political nature of Europe as a confederation of States presents technological challenges: these occur when trans-national organisations, whether virtual or not, must be compliant with the respective national and regional laws of the countries where some of their components are located, while still offering a coherent global behaviour. In particular, in applications where the analysis of past processes is of prime importance, we cannot expect a single execution technology to be used across all applications' services; hence, there is a need for a common model, independent of technology or institution, capable of describing previous executions, and making explicit the causal dependencies between events and data flows. Such a data model has been specified by the Provenance project in the form of process documentation.

We have successfully demonstrated that such data model allows multiple healthcare institutions, potentially distributed across countries (in the case of EHCR), to express their past processes, while still retaining their own autonomy, and in particular their choice of technology. We have also established that such a model would also be particularly well suited to capture and reason over design and manufacturing

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processes, across large-scale consortia such Airbus, where subcontracting of activities takes place frequently. In a smaller scale, the Provenance project has itself demonstrated how such a common data model allowed and facilitated the distributed development of complex, interoperable provenance-aware tools.

The activities of the project raised international awareness and brought provenance to the forefront of the research agenda; it allowed European researchers to be seen as undertaking leading provenance-related research in the academic and industrial community. We have created a new forum for discussion and publication, in the form of the IPAW workshop series, and we have initiated the Provenance challenge series, a community-driven activity to design inter-operable provenance-aware systems.

Finally, the Provenance project has interacted with a number of other European projects. Discussions with SIMDAT inspired us to specify a methodology to make applications provenance-aware; we captured requirements from a dozen of European projects; our Provenance tutorial was attended by members of NextGrid, OntoGrid and DataMiningGrid. The Provenance Challenge has also seen the participation of the Job Provenance team from EGEE. To promote awareness and support greater take up of Provenance with other European projects, we co-organised a meeting at Helsinki on KnowledgeGrid. This meeting was intended to demonstrate how provenance-related ideas could be used alongside approaches being adopted by the DataMiningGrid, OntoGrid, and InteliGrid projects.

8 Lessons Learned and Future Work

The Provenance project was completed on a very tight timetable, to capture requirements, conceive a new open architecture, specify it, implement it, deploy it in concrete applications and evaluate it, all this in just over two years, but as this final report indicates, the project has successfully met and exceeded its stated objectives.

It is recognised that new technologies take a longer time to mature and be adopted in a broad community. As a result, with the current provenance platform, the partners have identified further work to be undertaken:

1. Trust and confidence of information sources;
2. Provenance in a network of pervasive devices with limited resources;
3. Validation of processes in multiple domains (medical, etc.);
4. Design of development tools to assist users in following the methodology to build provenance-aware application;
5. Novel visualisation techniques (3D immersion, etc) for very large provenance stores;
6. Adaptation of provenance to governance in agent-Mediated Electronic Institutions;
7. Provenance-aware data management infrastructure (not only on automatically run workflows but also on manually-performed data and process management tasks);

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8. Rules language for Regulatory Compliance with checking against captured Provenance documentation.

The success of the approach is dependent on the existence of an open standard. IPAW and the Provenance Challenge have built a remarkable community momentum, which should be exploited in the future to lead to a single set of standards. Such momentum will be built upon by the definition of a second challenge (with a workshop likely to be co-located with HPDC'07) and IPAW'08 (likely to take place in early 2008). The user community can also grow by developing further tools, meeting the needs of their end users, and by developing provenance-aware applications in new domains.

In conclusion, the EU Provenance project has developed the infrastructure and vision for the further development of Provenance systems that will be crucial for European business and science going forward. It also has created an international activity involving both academia and industry and concerned with issues of interoperability between provenance systems.

9 Bibliography

This section includes a formal bibliography of all documents generated by the Provenance Project. It includes contracted deliverables together with other research publications, talks and external announcements.

9.1 Project Deliverables

[1] John Ibbotson. D1.1.0: Provenance 3 Month Interim Report. Technical report, IBM United Kingdom, January 2005. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-ThreeMonthReport-D110-Month3.pdf.

[2] John Ibbotson. D1.1.1: Provenance: 6 Month Interim Report. Technical report, IBM United Kingdom, February 2005. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-SixMonthReport-D111-Month6.pdf.

[3] John Ibbotson. D1.1.2: Provenance: 12 Month Interim Report. Technical report, IBM United Kingdom, September 2005. http://www.gridprovenance.org/deliverables/restricted/GRID-PROVENANCE-TwelveMonthReport-D112-Month12.pdf.

[4] John Ibbotson. D1.1.2a: Provenance: 12 Month Interim Report (Revised). Technical report, IBM United Kingdom, December 2005. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-RevisedTwelveMonthReport-D112-Month16.pdf.

[5] John Ibbotson. D1.1.3: Provenance: 18 Month Interim Report. Technical report, IBM United Kingdom, February 2006. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-EighteenMonthReport-D113-Month18.pdf

[6] John Ibbotson. D1.1.4: Provenance: Final Interim Report. Technical report, IBM United Kingdom, November 2006.

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-FinalMonthReport-D114-Month27.pdf
[7] Luc Moreau and John Ibbotson. D1.1.4a: Provenance: Final Project Report. Technical report, IBM United Kingdom, November 2006. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-FinalReport-D114a-Month27.pdf
[8] John Ibbotson. D1.2.1: Final Project Documentation. Technical report, IBM United Kingdom, November 2006. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-FinalProjectDocumentaiton-D121-Month27.pdf.
[9] John Ibbotson. D1.3.1: 6 Month Exploitation Plan. Technical report, IBM United Kingdom, February 2005. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-ExploitationPlan-D131-Month6.pdf
[10] John Ibbotson. D1.3.1: 12 Month Exploitation Plan. Technical report, IBM United Kingdom, September 2005. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-ExploitationPlan-D131-Month12.pdf
[11] John Ibbotson. D1.3.1: 12 Month Exploitation Plan (Revised). Technical report, IBM United Kingdom, December 2005. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-RevisedExploitationPlan-D131-Month16.pdf
[12] John Ibbotson. D1.3.1: 18 Month Exploitation Plan. Technical report, IBM United Kingdom, February 2006. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-ExploitationPlan-D131-Month18.pdf
[13] John Ibbotson and Steve Munroe. D1.3.1: Final Exploitation Report. Technical report, IBM United Kingdom, November 2006. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-ExploitationReport-D131-Month27
[14] Árpád Andics (ed.). D2.1.1: User Requirements Document. Technical report, MTA SZTAKI, February 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-UserRequirements-D211-Month6.pdf
[15] Árpád Andics (ed.). D2.2.1: Software Requirements Document. Technical report, MTA SZTAKI, February 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-SoftwareRequirements-D221-Month6.pdf
[16] Paul Groth, Sheng Jiang, Simon Miles, Steve Munroe, Victor Tan, Sofia Tsasakou, and Luc Moreau. D3.1.1: An Architecture for Provenance Systems. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13216/.
[17] Simon Miles, Steve Munroe, Paul Groth, Sheng Jiang, Victor Tan, John Ibbotson, and Luc Moreau. D3.2.1: The Open Provenance Specification. Technical report, University of Southampton, November 2006. The specification is composed of the following documents [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50].

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-OpenSpecification-D321-Month24.pdf

[18] Steve Munroe, Simon Miles, Victor Tan, Paul Groth, Sheng Jiang, Luc Moreau, John Ibbotson, and Javier V´azquez-Salceda. D3.3.1: PrIMe: A Methodology for Developing Provenance-Aware Applications. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13215/

[19] John Ibbotson, Neil Hardman, and Victor Tan. D4.1.1: Security Specification - version 1. Technical report, IBM United Kingdom, September 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-SecuritySpecV1-D411-Month12.pdf

[20] John Ibbotson, Neil Hardman, and Victor Tan. D4.2.1: Security Specification - version 2. Technical report, IBM United Kingdom, February 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-SecuritySpecV2-D421-Month18.pdf

[21] John Ibbotson, Paul Groth, and Simon Miles. D5.1.1: Scalability Specification - version 1. Technical report, IBM United Kingdom, September 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-ScalabilitySpecV1-D511-Month12.pdf

[22] John Ibbotson. D5.2.1: Scalability Specification – version 2. Technical report, IBM United Kingdom, February 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-ScalabilitySpecV2-D521-Month18.pdf

[23] Omer F Rana. D6.1.1: Tools Description Document. Technical report, University of Cardiff, September 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-ToolsSpec-D611-Month12.pdf

[24] Omer F Rana, Arnaud Contes, and Vikas Deora. D6.2.1: Setup Protocol Implementation. Technical report, University of Cardiff, February 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-SetupProtocol-D621-Month18.pdf

[25] Omer F Rana, Arnaud Contes, and Vikas Deora. D6.3.1: Configuration Tool Implementation. Technical report, University of Cardiff, November 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-ConfigTools-D631-Month27.pdf

[26] Guy K. Kloss and Andreas Schreiber. D7.1.1: Application 1: Aerospace Engineering. Specification of Mapping to Provenance Architecture, and Domain Specific Provenance Handling. Technical report, German Aerospace (DLR), September 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-AerospaceSpec-D711-Month12.pdf

[27] Guy K. Kloss and Andreas Schreiber. D7.2.1: Application 1: Evaluation Report. Technical report, German Aerospace (DLR), November 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-AerospaceEvaluationReport-D721-Month27.pdf

[28] Guy K. Kloss and Andreas Schreiber. D7.3.1: Application 1: Final Deployment. Technical report, German Aerospace (DLR), November 2006.

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-AerospaceDeployment-D721-Month27.pdf

[29] Javier V´azquez-Salceda, Steve Willmott, Kifor Tamás, and Laszlo Zs. Varga. D8.1.1: Application 2: Organ Transplant Management. Specification of Mapping to Provenance Architecture, and Domain Specific Provenance Handling. Technical report, UPC, September 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-OTMSpec-D811-Month12.pdf

[30] Javier V´azquez-Salceda, Sergio ´Alvarez, L´aszl´o Zs. Varga, and Kifor Tamás. D8.2.1: Application 2: Evaluation Report. Technical report, UPC, November 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-OTMEvaluationReport-D821-Month27.pdf

[31] Javier V´azquez-Salceda, Sergio ´Alvarez, L´aszl´o Zs. Varga, and Kifor Tamás. D8.3.1: Application 2: Final Deployment. Technical report, UPC, November 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-OTMDeployment-D821-Month27.pdf

[32] Fenglian Xu, Alexis Biller, Liming Chen, Victor Tan, Paul Groth, Simon Miles, John Ibbotson, and Luc Moreau. D9.1.1: A proof of Concept Design for Provenance. Technical report, University of Southampton, February 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-PrePrototypeReport-D911-Month6.pdf

[33] Neil Hardman and John Ibbotson. D9.3.1: Functional Prototype. Technical report, IBM United Kingdom, September 2005. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-FunctionalPrototype-D931-Month12.pdf

[34] John Ibbotson, Neil Hardman, and Alexis Biller. D9.3.2: Functional Prototype (Public Release). Technical report, IBM United Kingdom, February 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-FunctionalPrototype-D932-Month18.pdf

[35] John Ibbotson and Sheng Jiang. D9.3.3: Final Functional Prototype. Technical report, IBM United Kingdom, November 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-FinalPrototype-D933-Month27.pdf

[36] Sheng Jiang, Luc Moreau, Paul Groth, Simon Miles, Steve Munroe, and Victor Tan. D9.3.3a: Client Side Library Design and Implementation. Technical report, University of Southampton, November 2006. http://www.gridprovenance.org/deliverables/GRID_PROVENANCE-ClientSideLibrary-D933a-Month27.pdf

[37] Luc Moreau. PC1: Collaboration Report. Technical report, University of Southampton, December 2004. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-CollaborationReportv1-PC1-Month3.pdf

[38] Luc Moreau. PC2: Collaboration Report. Technical report, University of Southampton, September 2005.

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-CollaborationReportv2-PC2-Month12.pdf

[39] Omer F Rana and Luc Moreau. PC3: Collaboration Report. Technical report, University of Cardiff, November 2006. http://www.gridprovenance.org/deliverables/restricted/GRID_PROVENANCE-CollaborationReportv3-PC3-Month27.pdf

9.2 Open Provenance Specification

[40] Steve Munroe, Victor Tan, Paul Groth, Sheng Jiang, Simon Miles, and Luc Moreau. The Provenance Standardisation Vision. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13201/

[41] Steve Munroe, Paul Groth, Sheng Jiang, Simon Miles, Victor Tan, and Luc Moreau. Data model for Process Documentation. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13200/

[42] Paul Groth, Victor Tan, Steve Munroe, Sheng Jiang, Simon Miles, and Luc Moreau. Process Documentation Recording Protocol. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13053/

[43] Simon Miles, Luc Moreau, Paul Groth, Victor Tan, Steve Munroe, and Sheng Jiang. Provenance Query Protocol. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13204/

[44] Simon Miles, Steve Munroe, Paul Groth, Sheng Jiang, Victor Tan, John Ibbotson, and Luc Moreau. Process Documentation Query Protocol. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13052/

[45] Victor Tan, Steve Munroe, Paul Groth, Sheng Jiang, Simon Miles, and Luc Moreau. A Profile for Non-Repudiable Process Documentation. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13054/

[46] Steve Munroe, Victor Tan, Paul Groth, Sheng Jiang, Simon Miles, and Luc Moreau. A WS-Addressing Profile for Distributed Process Documentation. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13057/

[47] Victor Tan, Steve Munroe, Paul Groth, Sheng Jiang, Simon Miles, and Luc Moreau. Basic Transformation Profile for Documentation Style. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13202/

[48] Simon Miles, Luc Moreau, Paul Groth, Victor Tan, Steve Munroe, and Sheng Jiang. XPath Profile for the Provenance Query Protocol. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13203/

[49] Steve Munroe, Victor Tan, Paul Groth, Sheng Jiang, Simon Miles, and Luc Moreau. A SOAP Binding For Process Documentation. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13056/

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

[50] Victor Tan, Paul Groth, Sheng Jiang, Simon Miles, Steve Munroe, and Luc Moreau. WS Provenance Glossary. Technical report, University of Southampton, November 2006. http://eprints.ecs.soton.ac.uk/13048/

9.3 Project Publications

[51] Sergio Alvarez, Javier V´azquez-Salceda, Tamás Kifor, Laszlo Varga, and Steven Willmott. Applying Provenance in Distributed Organ Transplant Management. In International Provenance and Annotation Workshop (IPAW'06), 2006. http://www.gridprovenance.org/publications/IPAW-OTM-EHCR.pdf

[52] Thibaut Assandri. An Investigation into Provenance Visualisation (Summer Project Report). Technical report, University of Southampton, 2006. http://www.gridprovenance.org/publications/confidential/PReView2.doc

[53] Raj Bose, Ian Foster, and Luc Moreau. Report on the International Provenance and Annotation Workshop (IPAW06). Sigmod Records, September 2006. http://www.sigmod.org/sigmod/record/issues/0609/sigmod-record.september2006.pdf

[54] Liming Chen, Victor Tan, Fenglian Xu, Alexis Biller, Paul Groth, Simon Miles, John Ibbotson, Michael Luck, and Luc Moreau. A Proof of Concept: Provenance in a Service Oriented Architecture. In Proceedings of the Fourth All Hands Meeting (AHM), September 2005. http://www.allhands.org.uk/2005/proceedings/papers/503.pdf

[55] Stephen Davey, Ali Anjomshoaa, Mario Antonioletti, Malcolm Atkinson, Dave Berry, Ann Chervenak, Adrian Jackson, Chris Jordan, Peter Kunszt, Allen Luniewski, and Luc Moreau. OGSA Data Scenarios v0.13. Technical report, Global Grid Forum, 2006. https://forge.gridforum.org/sf/go/doc13605?nav=1

[56] Vikas Deora, Arnaud Contes, Omer F. Rana, Shrija Rajbhandari, Ian Wootten, Kifor Tamas, and Laszlo Z. Varga. Navigating Provenance Information for Distributed Healthcare Management. In IEEE/WIC/ACM Web Intelligence Conference, 2006. http://www.gridprovenance.org/publications/vdeora-provenance.pdf

[57] Paul Groth, Sheng Jiang, Simon Miles, Steve Munroe, Victor Tan, Sofia Tsasakou, and Luc Moreau. An Architecture for Provenance Systems — Executive Summary. Technical report, University of Southampton, February 2006. http://eprints.ecs.soton.ac.uk/12025/

[58] Paul Groth, Simon Miles, and Steve Munroe. Principles of High Quality Documentation for Provenance: A Philosophical Discussion. In Luc Moreau and Ian Foster, editors, International Provenance and Annotation Workshop (IPAW'06),, volume 4145 of Lecture Notes in Computer Science. Springer, May 2006. http://eprints.ecs.soton.ac.uk/12568/

[59] James Halford. Analysing the Quality of Results in Grid Based Systems. Part III project, University of Southampton, May 2007.

[60] John Ibbotson. Provenance and Compliance. Technical report, IBM UK, 2006. http://www.gridprovenance.org/publications/ProvenanceCompliance.doc

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

[61] Sheng Jiang, Luc Moreau, Paul Groth, Simon Miles, Steve Munroe, and Victor Tan. The provenance faq, October 2006. http://www.gridprovenance.org/publications/ProvenanceFAQ.pdf
[62] Andrej Kazakov. An Investigation on the Performance of Storing Process Documentation in a Relational Database (Summer Project Report). Technical report, University of Southampton, 2006. http://www.gridprovenance.org/publications/confidential/PerformanceReport.doc
[63] Tamas Kifor, Laszlo Varga, Sergio ´Alvarez, Javier V´azquez-Salceda, and Steven Willmott. Privacy Issues of Provenance in Electronic Healthcare Record Systems. In First International Workshop on Privacy and Security in Agent-based Collaborative Environments (PSACE2006), AAMAS 2006, 2006. http://www.gridprovenance.org/publications/EHCR-Prov-Privacy.pdf
[64] Tamás Kifor, Laszlo Varga, Sergio ´Alvarez, Javier V´azquez-Salceda, and Steven Willmott. Privacy Issues of Provenance in Electronic Healthcare Record Systems. Journal of Autonomic and Trusted Computing (JoATC), 2007. http://www.gridprovenance.org/publications/EHCR-Prov-Privacy.pdf
[65] Tamás Kifor, Laszlo Varga, Javier V´azquez-Salceda, Sergio ´Alvarez, and Steven Willmott. EHCR: An EU Provenance Case Study. Technical report, SZTAKI, 2006. http://www.gridprovenance.org/publications/EHCRSCS.doc
[66] Tamás Kifor, Laszlo Z. Varga, Javier V´azquez-Salceda, Sergio ´Alvarez, Steven Willmott, Simon Miles, and Luc Moreau. Provenance in Agent-mediated Healthcare Systems. IEEE Intelligent Systems, Nov/Dec 2006. http://www.gridprovenance.org/publications/ProvenanceInAgentMediatedHealthcareSystems-V19.doc
[67] Guy K. Kloss and Andreas Schreiber. Provenance Implementation in a Scientific Simulation Environment. In Proceedings of the International Provenance and Annotation Workshop (IPAW), Chicago, Illinois, USA, May 2006. http://www.gridprovenance.org/publications/IPAW-06-DLR.pdf
[68] David Luna. Creation of a Provenance-Aware RSS System. Part III project, University of Southampton, May 2007.
[69] Simon Miles, Paul Groth, Steve Munroe, Sheng Jiang, Thibaut Assandri, and Luc Moreau. Extracting Causal Graphs from an Open Provenance Data Model. Concurrency and Computation: Practice and Experience, 2007.
[70] Simon Miles, Victor Tan, Danielli Turi, K. Wollstencroft, and Jun Zhao. MIAS-Grid: An EU Provenance Case Study of Security Issues in a Provenance System. Technical report, University of Southampton, 2006. http://www.gridprovenance.org/publications/miasscenario.doc
[71] Simon Miles, Victor Tan, Danielli Turi, K. Wollstencroft, and Jun Zhao. MyGrid: An EU Provenance Case Study. Technical report, University of Southampton, 2006. http://www.gridprovenance.org/publications/MyGrid.doc
[72] Luc Moreau. Usage of ‘provenance’: A Tower of Babel. Towards a concept map — Position paper for the Microsoft Life Cycle Seminar, Mountain View, July 10, 2006. Technical report, University of Southampton, June 2006. http://www.ecs.soton.ac.uk/_lavm/papers/babel.pdf
[73] Luc Moreau, Liming Chen, Paul Groth, John Ibbotson, Michael Luck, Simon Miles, Omer Rana, Victor Tan, Willmott, and Fenglian Xu. Logical

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

Architecture Strawman for Provenance Systems. Technical report, University of Southampton, April 2005. http://eprints.ecs.soton.ac.uk/10796/
[74] Luc Moreau and Ian Foster, editors. Provenance and Annotation of Data — International Provenance and Annotation Workshop, IPAW 2006, volume 4145 of Lecture Notes in Computer Science. Springer-Verlag, May 2006. http://www.springer.com/uk/home/generic/search/results?SGWID=3-40109-22-173681711-0
[75] Luc Moreau, Paul Groth, Simon Miles, Javier Vazquez, John Ibbotson, Sheng Jiang, Steve Munroe, Omer Rana, Andreas Schreiber, Victor Tan, and Laszlo Varga. The Provenance of Electronic Data. Communications of the ACM, 2007. http://www.ecs.soton.ac.uk/_lavm/papers/cacm06.pdf
[76] Luc Moreau and John Ibbotson. Standardisation of Provenance Systems in Service Oriented Architectures— White Paper. Technical report, University of Southampton, 2006. http://eprints.ecs.soton.ac.uk/12198/.
[77] Luc Moreau and Bertram Ludaescher, editors. Special Issue on the First Provenance Challenge. Wiley, (forth coming 2007).
[78] Luc Moreau, Bertram Ludaescher, Roger S. Barga, Luciano Digiampietri Jennifer Goldbeck Yogesh L. Simmhan, Beth Plale, Ales Krenek, Daniele Turi, Carole Goble, Robert Stevens, Jun Zhao, Juliana Freire, James Frew, Dominic Metzger, Peter Slaughter, Sarah Cohen-Boulakia, Susan Davidson, Shirley Cohen, Shawn Bowers, Timothy McPhillips, Norbert Podhorszki, Ilkay Altintas, David Holland, Margo Seltzer Ewa Deelman, Yolanda Gil, Jihie Kim, Gaurang Mehta, Varun Ratnakar, Jim Myers, Joe Futrelle, Simon Miles, Steve Munroe, Paul Groth, Sheng Jiang, Karen Schuchardt, Tara Gibson, Eric Stephan, George Chin, Ben Clifford, Mike Wilde, and Ian Foster. The First Provenance Challenge. Concurrency and Computation: Practice and Experience, 2006.
[79] Steve Munroe, Simon Miles, Luc Moreau, and Javier V´azquez-Salceda. PrIMe: A Software Engineering Methodology for Developing Provenance-Aware Applications. In ACM Digital Proceedings of the Software Engineering and Middleware Workshop (SEM'06), 2006. http://eprints.ecs.soton.ac.uk/13062/
[80] Steve Munroe, Simon Miles, Victor Tan, Paul Groth, Sheng Jiang, and Luc Moreau. Linking 101. Technical report, University of Southampton, 2006. http://www.gridprovenance.org/publications/confidential/Linking101.doc
[81] Shrija Rajbhandari, Arnaud Contes, Omer F.Rana, Vikas Deora, and Ian Wootten. Establishing Workflow Trust Using Provenance Information. In 1st IEEE International Workshop on Modelling Autonomic Communications Environments, October, 25-26 2006. http://www.gridprovenance.org/publications/manweek-ranaetal.pdf
[82] Shrija Rajbhandari, Arnaud Contes, Omer F.Rana, Vikas Deora, and Ian Wootten. Trust Assessment Using Provenance in Service Oriented Application. In Inderscience Publishers, editor, Service Intelligence and Service Science Workshop (SISS'2006), Proceedings of the 10th International Enterprise Distributed Object Computing Conference (EDOC'2006), pages 1–8, Hong Kong, October 2006. http://www.gridprovenance.org/publications/EDOC.pdf

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

[83] Shrija Rajbhandari, Ian Wootten, Ali Shaikh Ali, and Omer F. Rana. Evaluating Provenance-based Trust for Scientific Workflows. In CCGrid06. IEEE Computer Society Press, 2006. http://www.gridprovenance.org/publications/CCGRID-06.pdf

[84] O. Rana. Provenance Use Case: Gravitational Wave Analysis. Technical report, University of Cardiff, 2006. http://www.gridprovenance.org/publications/CardiffUseCase2.pdf

[85] Timothy Rice. Provenance in Web Services Workflow Enactment. Part III project, University of Southampton, May 2007.

[86] Victor Tan, Paul Groth, Simon Miles, Sheng Jiang, Steve Munroe, Sofia Tsasakou, and Luc Moreau. Security Issues in a SOA-based Provenance System. In Proceedings of the International Provenance and Annotation Workshop (IPAW'06), Chicago, Illinois, 2006. Springer-Verlag. http://eprints.ecs.soton.ac.uk/12569/

[87] Ian Wootten, Shrija Rajbhandari, and Omer Rana. Provenance Use Case: BioDiversity Informatics. Technical report, University of Cardiff, 2006. http://www.gridprovenance.org/publications/CardiffUseCase.pdf

[88] Ian Wootten, Shrija Rajbhandari, Omer Rana, and Jaspreet Pahwa. Actor Provenance Capture with Ganglia. In CCGrid06. IEEE Computer Society Press, 2006. http://www.gridprovenance.org/publications/wootten-ActorProvGanglia-CCGRID06.pdf

[89] Ian Wootten, Omer Rana, and Shrija Rajbhandari. Recording Actor State in Scientific Workflows. In Proceedings of the International Provenance and Annotation Workshop (IPAW), 2006. http://www.gridprovenance.org/publications/wootten-actorstate-IPAW06.pdf

9.4 Project Presentations

[90] Vikas Deora. Demonstration of Visualisation Tools. Presented at the Open Grid Forum at the "Provenance Challenge" event, Washington DC, September 2006.

[91] Vikas Deora. Portlet Development in eXo. At the Virtual Research Environments workshop on "Developing and Deploying Tools and Services in the Emerging Portal Frameworks", January 2006. http://www.gridprovenance.org/talks/portal-talk-deora.pdf

[92] Vikas Deora. Tools for Navigating and Analysis of Provenance Information. at UK eScience All Hands Meeting, Nottingham, September 2006. http://www.gridprovenance.org/talks/AHM-Demo-2006.ppt

[93] Paul Groth. Principles of High Quality Documentation for Provenance: A Philosophical Discussion, May 2006. http://www.ipaw.info/ipaw06/slides/groth ipaw phil.ppt

[94] Guy K. Kloss. Grid Provenance. Simulation and Software Technology Seminar, DLR, Cologne, January 2006. http://www.gridprovenance.org/talks/GridProvenanceProjektvorstellung.pdf

[95] Guy K. Kloss. Provenance Implementation in a Scientific Simulation Environment, May 2006. http://www.ipaw.info/ipaw06/slides/IPAW2006-Presentation-kloss.pdf

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

[96] Simon Miles. A Proof of Concept: Provenance in a Service Oriented Architecture. Paper presentation at All Hands Meeting (AHM'05), Nottingham, UK, July 2005. http://www.gridprovenance.org/talks/preprototypeAHM05.ppt
[97] Simon Miles. Southampton Entry to the Provenance Challenge, October 2006. http://twiki.ipaw.info/pub/Challenge/WorkshopAgenda/Southampton.ppt
[98] Luc Moreau. Provenance: an Open Approach to Experiment Validation in e-Science. University of Birmingham, Departmental Seminar, Birmingham, UK, November 2005. http://www.gridprovenance.org/talks/Birmingham05.ppt
[99] Luc Moreau. Provenance: an Open Approach to Experiment Validation in e-Science. Intelligence Agents Multimedia Group, University of Southampton, Group Seminar, Southampton, UK, December 2005. http://zepler.tv/_ecstv/data/media/IAM SEM/slides/2005-12-12-1-IAM.ppt
[100] Luc Moreau. Provenance-Based Reasoning in e-Science. Invited Talk at Automated Reasoning Workshop ARW'05, Edinburgh, UK, July 2005. http://www.gridprovenance.org/talks/arw05.ppt
[101] Luc Moreau. Provenance: Concepts, Architecture and Envisioned Tools. Invited Talk at Grid@Work'05, Sophia-Antipolis, France, October 2005. http://www.gridprovenance.org/talks/gAtw05.ppt
[102] Luc Moreau. An Open Provenance Model for Scientific Workflows. Presentation at the HPC'06 Workshop (High Performance Computing and Grids), July 2006. http://www.gridprovenance.org/talks/hpc06.ppt
[103] Luc Moreau. Provenance: an Open Approach to Experiment Validation in e-Science. University of Kent, Departmental Seminar, Canterbury, UK, February 2006. http://www.gridprovenance.org/talks/kent06.ppt
[104] Luc Moreau. Provenance: an Open Approach to Experiment Validation in e-Science. University of Harvard, Institute of Innovative Computing talk and University of Chicago, Computation Institute talk, March 2006. http://www.gridprovenance.org/talks/harvard06.ppt
[105] Luc Moreau. Provenance: an Open Approach to Experiment Validation in e-Science. IBM Watson talk, May 2006. http://www.gridprovenance.org/talks/IBM06.ppt
[106] Luc Moreau. Provenance: an Open Approach to Experiment Validation in e-Science. Talk at Information Sciences Institute, University of Southern California, Marina del Rey, CA, August 2006. http://www.gridprovenance.org/talks/isi06.ppt
[107] Luc Moreau. Provenance: Progress Update. Presentation at CT1 Technical Collaboration Meeting, Heathrow 06, February 2006. http://www.gridprovenance.org/talks/heathrow06.ppt
[108] Steve Munroe. PrIMe: A Software Engineering Methodology for Developing Provenance-Aware Applications. Presented at the Software Engineering Middleware Workshop (SEM'06), Portland Oregon, USA, November 2006. http://www.gridprovenance.org/talks/SEMPresentation.ppt
[109] Omer Rana. 'Center of Excellence' model for Collaborative Problem Solving: A Case Study from Modelling/Optimisation for Engineering Design. Presented at GridAsia 2006, Singapore, May 2006.
[110] Omer Rana. Distributed Scientific Workflows. Tutorial at IEEE CCGrid

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

[111] Omer Rana. Importance of Provenance in Scientific Collaborations over Grids. Workshop on Trend, Technologies and Collaborative Opportunities in High Performance and Grid Computing, Bangkok, May 2006.
[112] Omer Rana. Provenance Support in SLAs. System Adaptation Workshop at Vrije University, Amsterdam, The Netherlands, September 2006.
[113] Andreas Schreiber. Numerical Simulation Software Integration with TENT. Joint ESTEC-DLR Workshop, ESA/ESTEC, Noordwijk, May 2006. http://www.gridprovenance.org/talks/Software Integration04052006.pdf
[114] Victor Tan. Security Issues in a SOA-based Provenance System, May 2006. http://www.ipaw.info/ipaw06/slides/ipaw2006sec.ppt
[115] The Southampton Provenance Team. Provenance architecture tutorial, March 2006. http://twiki.gridprovenance.org/bin/view/Provenance/ProvenanceTutorial
[116] Javier V´azquez-Salceda. Applying Provenance in Distributed Organ Transplant Management, May 2006. http://www.ipaw.info/ipaw06/slides/IPAW-OTMpaperv4.ppt
[117] Javier V´azquez-Salceda. EU Provenance project: an open provenance architecture for distributed applications. Paper presentation at ECAI, the Fourth Workshop on Agents Applied in Health Care, 2006. http://www.gridprovenance.org/talks/ECAIws-PROVENANCE.ppt
[118] Steven Willmott. Privacy Issues of Provenance in Electronic Healthcare Record Systems. First International Workshop on Privacy and Security in Agent-based Collaborative Environments (PSACE2006), 2006. http://www.gridprovenance.org/talks/WS16PIPEHRS-slides-v01.pdf

9.5 Reference to the Project in the Press or Other Publications

[119] Peter Abrahams. Provenance the Next Step in Governance, November 2005. http://it-analysis.com/business/content.php?cid=8149
[120] Southampton Bulletin. Grid Users Reassured by Provenance, February 2006. http://www.bulletin.soton.ac.uk/1212/research.htm
[121] Cordis. Data Provenance Project Endorsed by Industry, January 2006. http://istresults.cordis.lu/index.cfm/section/news/tpl/article/BrowsingType/Features/ID/80202
[122] Michael Luck, Peter McBurney, Onn Shehory, Steve Willmott, and the AgentLink Community. Agent Technology: Computing as Interaction, chapter Provenance (section 8.2 Specific Challenges), page 82. University of Southampton, 2005. http://www.agentlink.org/roadmap/al3rm.pdf
[123] ECS News. Data Provenance Project Endorsed by Industry, December 2005. http://www.ecs.soton.ac.uk/news/834
[124] ECS News. Provenance: Improving Authenticity of Computer-Generated Information, January 2005. http://www.ecs.soton.ac.uk/news/671
[125] ECS News. Building Trust and Validation into Distributed Computer Networks, January 2006. http://www.ecs.soton.ac.uk/news/855
[126] CoreGRID Newsletter. Provenance for Grid Applications, March 2006. http://www.cetic.be/article452.html
[127] Association of Computing Machinery Technology News. Building Trust and Validation Into Distributed Computer Networks, January 2006.

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

http://technews.acm.org/archives.cfm?fo=2006-02-feb/feb-01-2006.html#247165.
[128] Richard Veryard. Data Provenance, October 2005. http://www.veryard.com/so/2005/10/data-provenance.htm.

The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme