JISC DEVELOPMENT PROGRAMMES

Project Document Cover Sheet

CORE VRE Evaluation Final Report

Project

Project Acronym	CORE	**Project ID**	
Project Title	Collaborative Orthopaedic Research Environment		
Start Date	01 November 2004	**End Date**	31 November 2006
Lead Institution	University of Southampton		
Project Manager & contact details	Dr Gary Wills Intelligence, Agents, Multimedia Group School of Electronics and Computer Science University of Southampton Southampton, SO17 1BJ		
Project Web URL	www.core.ecs.soton.ac.uk		
Programme Name (and number)	*Virtual Research Environments (05/04) Strand III*		
Programme Manager	Ms Frederique M. van Till		

Document

Document Title	CORE VRE Evaluation Progress Report		
Reporting Period	Final report		
Author(s) & Project Role	Gary Wills (Project Manager), Lester Gilberts (Technical Manager), Matthew Stenning (Co-Investigator), Simon Grange (Co-Investigator)		
Date	19/05/2006	**Filename**	CORE VRE Evaluation Final Report 2v1
ISBN			
Technical Report Number	ECSTR-LSL06-001		
Access	■ Project and JISC internal	☐ General dissemination	

Document History

Version	**Date**	**Comments**
0a	9th May 2006	Initial Draft of report
0b	19th May 2006	Second Draft of report
0c	14 February 2007	Final Draft of report with results of evaluations included

Keywords; *Grid; Musculoskeletal; Orthopaedics; Service Oriented Architecture; Virtual Research Environment*

List of Acronyms

AH	Adaptive Hypermedia
CORE	Collaborative Orthopaedic Research Environment
CPD	Continuing Professional Development
DOH	Department of Health
DRJ	Dynamic Review Journal
HIS	Hospital Information Systems
NHS	National Health Service (United Kingdom)
PorTAR	Portsmouth Trauma Admissions Registry
SOA	Service Oriented Architecture
STAR	Southampton Trauma Admissions Registry
VE	Virtual Environment
VRE	Virtual Research Environment
VOEU	Virtual Orthopaedic European University

List of Figures

List of Tables

CORE VRE Evaluation Final Report

Gary B. Wills[2], Lester Gilbert[2], Wendy Hall[2], Edward M H Gardner[3], Matthew J Stenning[3], Simon A.W. Grange[1]

1. Royal College of Surgeons of England, London, UK,
2. Electronics and Computer Science, University of Southampton, UK
3. Southampton General Hospital, University of Southampton, UK

E-mail: {gbw, lg3, sg01v}@ecs.soton.ac.uk

Abstract

Purpose

Clinicians have responsibilities for audit and research, often participating in projects with colleagues in basic science. Whilst e-Scientists and e-Clinicians would ideally share different perspectives of the same virtual working environments, differences in language, conflicting agendas and security issues make it a major challenge to relate information from bench to bedside and back to bench. Our approach is to initiate a transition to service oriented architecture and use Grid technologies to minimise relearning and reengineering

In the Collaborative Orthopaedic Research Environment (CORE) project(1), we report on a pilot study for proof of concept of this work. Users are mapped to a personal profile, implemented using XML and a Service Oriented Architecture (SOA) (2;3) demonstrate the ability to provide a secure working environment for data collection and analysis that may be used for research clinical production and practice, thus bridging the e-Health and e-Science domains.

Methods

To enhance access and control of these virtual workspaces an eXtensible Mark-up Language (XML) based interface has been developed. This links the clinical data collection from ongoing trials in Orthopaedics to the educational environment of the Web Based Training (WBT) scheme. The underlying *Collaborative Orthopaedic Research Environment (CORE)* infrastructure encompasses the normal working environment of engineers and clinicians adopting dedicated interactive media.

Adaptive hypermedia is used to associate multiple hyperlinks to the clinical data collected. The material is prepared from the actual patient operative information, integrating the data collection with the orthopaedic research modules that are generated for the advancement of orthopaedic surgery.

Results

An XML based interface enables users to communicate using material mediated for their specific needs allowing adaptive media based upon user experience and knowledge base. This combines declarative (factual) content with feedback from a clinical (procedural) case-based training and evaluation environment. By using the XML interface, we were able to cater for the different user hardware and software resources, media content and even the language of presentation, incorporated via the virtual research environment. Proof of concept involved demonstration of the system with a scenario that used clinical data collection for everyday management. This information can then be used for the collection of data for audit and research.

Conclusion

By constructing a framework based upon already established standards, we anticipate the applicability to other surgical disciplines. We also perceive this as a way of building patient specific datasets – libraries (atlases) of pathologies and of results of various interventions. This will enable the development of networking computer architectures to assist the assimilation of multiple sources and media from different basic science resources. The interface offers the opportunity to review data from orthopaedic surgical systems embedded in an educational environment that is quantitative rather than descriptive. This will ultimately help the development of data repositories for mining, providing feedback upon clinical case management. Future work should focus upon the process of patient data collection and refinement of the data analysis using grid technologies. The intention is to develop this as part of the interface for basic science integration, especially using the use of the virtual research environment for the preparation of collaborative work both at National and International levels.

1 Introduction

E-Health & e-Science, the very dichotomy reflects the organisation of our society rather than the ones and noughts that construct the data on which we rely. Because we have a context dependent working environment, where individuals have assigned status as health workers or scientists we adopt a compartmentalised world view. We use semantics to establish a mental framework (personal ontology) for the data that creates relevance in information. Inroads have already been made toward developing the Semantic Web (using eXtensible Mark-up Language – XML) to reflect this.

Whilst this satisfies most situations, life is never that simple. The same data can relay different information to different users in a different context. We thus require context dependent data interpretation by experts employing different technical skills. This can also be addressed by a *Semantic Web* by responding to user profiles.

Even when we come to terms with the language barriers and security issues, we are faced with cultural and ethical issues. Users perceive information in different ways applying their own mental filters and so they not just interpret but also unfortunately misinterpret information. Safeguards need to be put in place to overcome this, especially with critical information in healthcare.

Once we have come to terms with the *quality issues* we need to scale up! The *quantity issues* surrounding health are not just big – they are massive. We need to work on a par with the terabytes of data a major research institution such as CERN might address….

There are already major initiatives underway laying the future infrastructure for our healthcare networks. Each intends to provide scalability and future proofing. Each group needs to answer to their own hierarchies – application, database, system and storage administrators all having different valid agendas on each side.

We need to first look at what problems are created by the current approach of isolated islands of information technology (IT) resource; underutilization of database resources; high cost of database and information management; limited scalability and flexibility with respect to storage, servers, software infrastructure and operating systems.

Grid computing offers potential solutions to these issues. It is not a new concept – Carl Kesselmann and Ian Foster(4) first referred to it in 1998. Nearly 10 years on the majority of healthcare applications have yet to embrace the concept which was originally developed for scientific research. For this reason, we endeavoured to take on the challenge of converting or Virtual Research Environment (VRE) originally built as a monolithic structure to service oriented architecture so that it may exploit this potential.

Through the adoption of Grid technology, flexibility has been designed in whilst sharing resources and reducing costs to meet the peek demands. The old and new systems parallel the concept of vertical hierarchies in computing. We have transited from the original one organisation does all, to a cacophony of voices offering different resources. We have large organisations attempting to regain the control that once bound users to one company. There is no single solution.

One truth in computer science is that most problems can be solved by adding another layer of complexity. The art is to add the benefits whilst simplifying the solution and in an ideal world satisfying market forces as well. In effect the Grid can do both, making access for the end user easier whilst creating a portal layer to manage the 'middleware' across the resources (see figure 1).

To reach this level of resonance we need toadopt a stepwise approach;

1. Establish secure middleware platform – OMII/.net
2. Ensure that the middleware supports the plug-ins – the service oriented architecture paradigm
3. Integration of applications and workflows
4. Develop and test trial examples
5. Extend applications to include semantic and grid tools.

1.1 Service Oriented Architecture Paradigm

Service oriented architecture (SOA), also known as service oriented computing, or Web services – based computing is broadly synonymous with GRID computing. The service is delivered with the desired quality of service along with cost-effectiveness and agility when it comes to responding to advances in parallel areas of development.

The service is the capability delivered by data centre components. At the physical layer this includes the storage, server, and network at the physical layer. Database and application servers are found at the infrastructure layer, and atop of this, workflows at the process platform layer (figure 1).

The goal of SOA is to achieve a loose coupling between the interacting services. The services deliver an object oriented encapsulation for workflows of healthcare tools and their associated component functions. The Web services are used to perform these interactions in the Service oriented architecture. Organisations such as W3C are developing standards for the SOA.

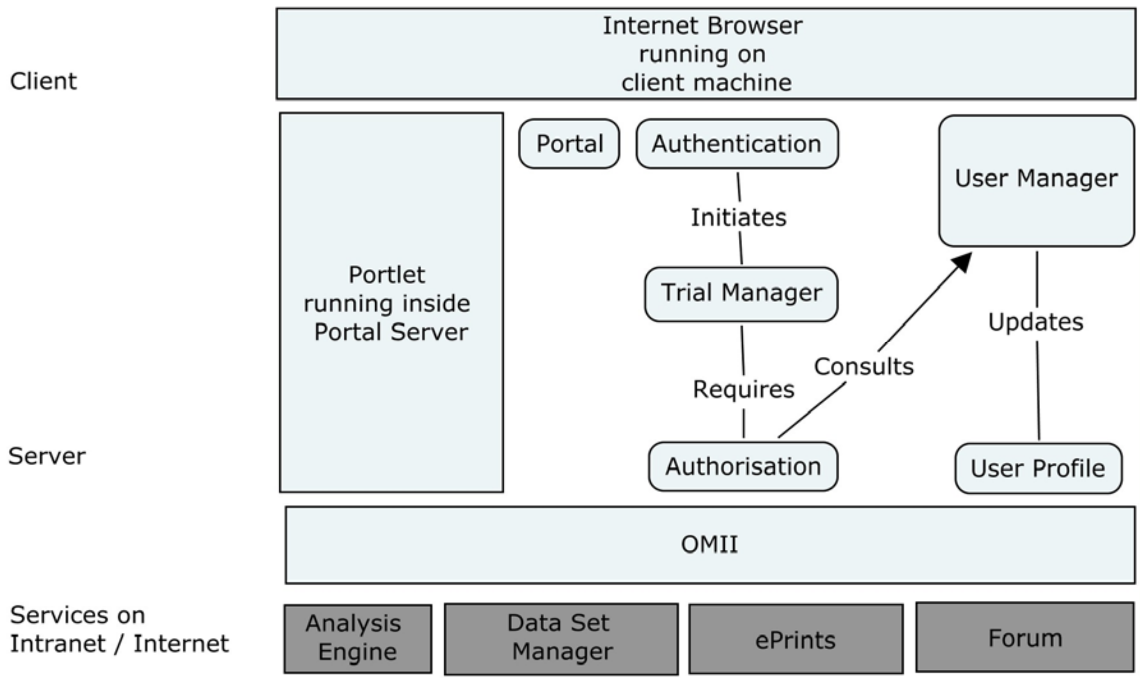

Figure 1 Service Oriented Architecture

1.2 Integration of Applications and work flows - Every journey starts with a single step

E-Scientists and e-Clinicians working together in an ideal shared environment is the utopian goal. With differences in language and conflicting agendas resolved, the harmony would be palpable. In reality this transfer of ideas from bench to bedside and back to bench is often tortuous, with false dawns and failed demonstrations. Pragmatic accommodation of legacy technologies is in part responsible, as is legacy work practice.

This relationship between the Integrated Health Record, e-Health and e-Science agendas is not just a hypothetical mix of experience and motive, it is an everyday challenge. Many of the issues of inter-organisational coordination of requirements capture, work practice, data sets, data quality measures and coding schemas were addressed by prior projects (5). The aim is to demonstrate that these can be effectively be brought together in a cohesive manner.

2 Project Planning

The contributors to the evaluation and their individual roles are outlined in table 1 below.

Name	Role	Abbreviation	Contact
Lester Gilbert	Project specialist	LG	lg3@ecs.soton.ac.uk
Gary Wills	CORE Project manager	GBW	gbw@ecs.soton.ac.uk
Simon Grange	Clinical Lead	SG	bonesculptor@hotmail.com
Matt Stenning	MPhil student	MS	mj.stenning@tiscali.co.uk
Edward Gardner	Clinical Manager	EG	egardner@doctors.org.uk

Table 4 Contributors to the Evaluation process for CORE

2.1 *Evaluation of the CORE VRE*

The major tasks for the evaluation of the Virtual Research Environment (VRE) are outlined in Table 2 below.

Task	Responsible	Subtasks	Due Date
Planning	LG, GBW, MS, SG	What instruments need to be developed?	May, 2006
Analysis	SG, MS	Who is the intended audience, What tools need to be tested	May, 2006
Design	SG, MS	Design of instruments and preparation of pilot documentation and operating procedures	May, 2006
Pilot	MS, SG	Pilot study testing the evaluation methodology	May, 2006
Revise	SG, GBW	Revise the evaluation methodology	June, 2006
Main study	SG, MS, EG	Run the study in multiple centres	September, 2006
Data analysis	LG, GBW	Use the Data analysis engine in the CORE VRE	October, 2006
Report	**SG, GBW**	**Report upon the evaluation of the CORE VRE**	November, 2006

Table 5 Time table for evaluation of CORE VRE

3 Methodology for Analysis

3.1 Who is the intended audience?

The main user groups in the CORE project were;

1. Orthopaedic Surgeons
    a. In Training
    b. Established
2. Basic Scientists
    a. Bone Biology
    b. Musculoskeletal Medicine
    c. Biomechanicists
    d. Computer Science
3. System Administrators
    a. Hospital Based
    b. Medical School Based

The stakeholders who are also relevant to the project are;

1. Hospital Senior staff
    a. Responsible for research
    b. Responsible for Audit
2. Research Funding Organisations
    a. Infrastructure development
    b. Medical Research Charities

3.2 Implementation

The study took place in three sites, an independent clinical service, a state district hospital and a regional teaching hospital setting in collaboration with the medical school computer services as part of the Collaborative Orthopaedic Research Environment (CORE) project. The proof of concept work included 14 subjects. As users, their personal profile is implemented and the service oriented architecture employed. The aim of CORE is to bridge between e-Health and e-Science in the orthopaedic (musculoskeletal) domain. Earlier work developed such applications as part of a monolithic structure.

To demonstrate effectiveness of the approach of transitioning toward Service Oriented Architecture, it is necessary to demonstrate the ability to support user empowerment, through profiling, whilst ensuring responsibility for the consistency of data collection though data management and schemas. This is supported by the shared working environment by providing tools for communication, collection of data, collation of data and unbiased semi-automatic reporting(5) to enhance extensibility and scalability.

The process mapping addresses the normal workflow for medical and nursing staff from operating theatres and ward based environments, providing a software environment which ensures security and confidentiality whilst offering a component library(6) so that the service tools can evolve independently and then be offered to users once tested using a thin client. The evaluation techniques used were user discussion groups, survey and observation.

3.3 Component Architecture Design – The Dynamic Review Journal

This is an example of a Service Oriented Architecture Transition. The application tested (figure 2) was referred to as the Southampton Trauma Admissions Registry (STAR) which allows users to record data for admission, clinical management and audit. It is representative of the simplest project that reflects the developing e-Science and e-Health applications.

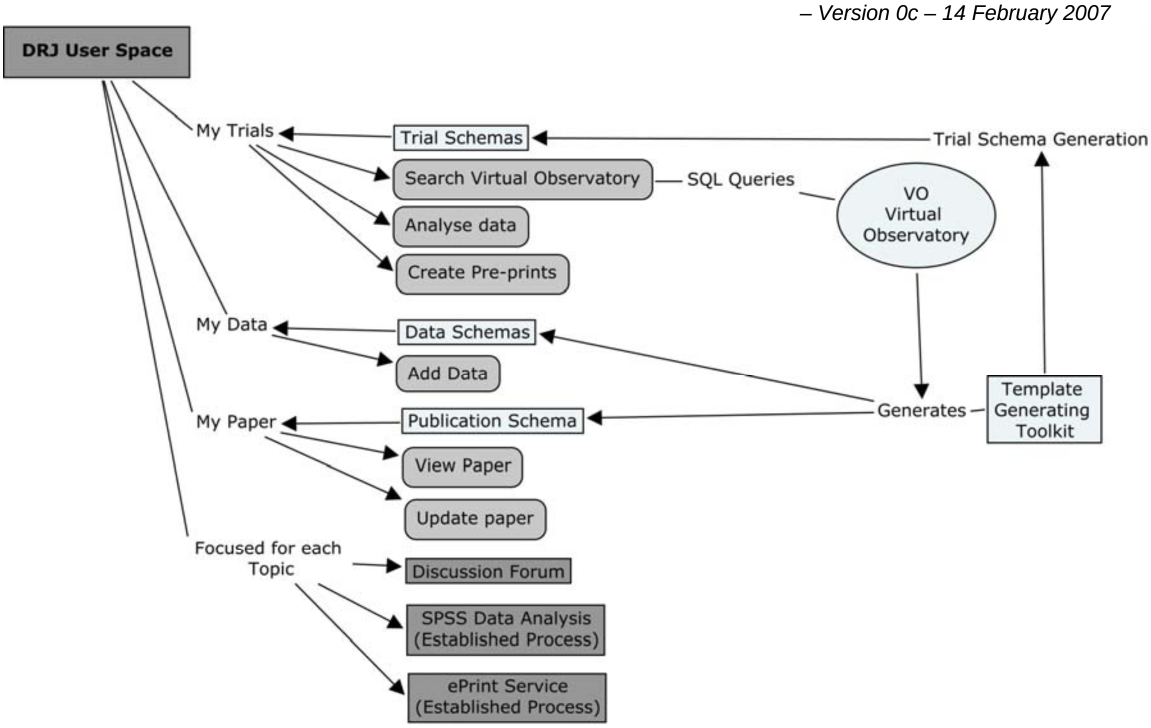

Figure 2 Dynamic Review Journal Architecture

Dealing with patient specific potentially sensitive data requires the chief investigator (or a nominated individual investigator) to have data controller registration as both a clinical and research data controller. Users are securely logged on using a unique password protected system serving so that;

1. Prototype research tools can be applied to solve clinical problems.
2. Security and software are managed through the University School of Medicine firewall.
3. Patients undergoing orthopaedic procedures are consented for records to be used for research as routine.
4. No patient information is released to individuals beyond those who are currently authorised to access this information as part of their routine clinical practice.

3.4 Anonymised Data

Data is anonymised for transfer to research applications to avoid registration of each user as a data controller and to obviate the need for individual consent forms for each analysis. The anonymised data was be investigated with this current approach in order to develop research tools using anonymised data, managed by users with qualified clinical profiles able to access patient specific data, even though this was unnecessary.

3.5 What tools need to be tested & how?

The aim is to manage a personalized collaborative research environment that allows individuals to carry out their research tasks in a way that is facilitated by the access to resources ‘*under one roof*’. To this end the environment needs to be user friendly. It should display a high degree of usability that can be measured both subjectively through the questionnaires and objectively through structured observation.

The HCI interface needs to engage the user and simplify their tasks. For this reason it is important to measure the users’ ability to navigate through the environment with a clearly defined set of tasks that represent an actual ‘workflow’ pattern of activity.

3.5.1 The Scenario - Example Workflow for VRE testing

An example workflow for the data management using the VRE is demonstrated by the process of recoding trauma patients for hospital admission. They are then prioritised for surgical intervention and then analysis of this data. Various outputs can be generated. This is outlined in figure 3 below.

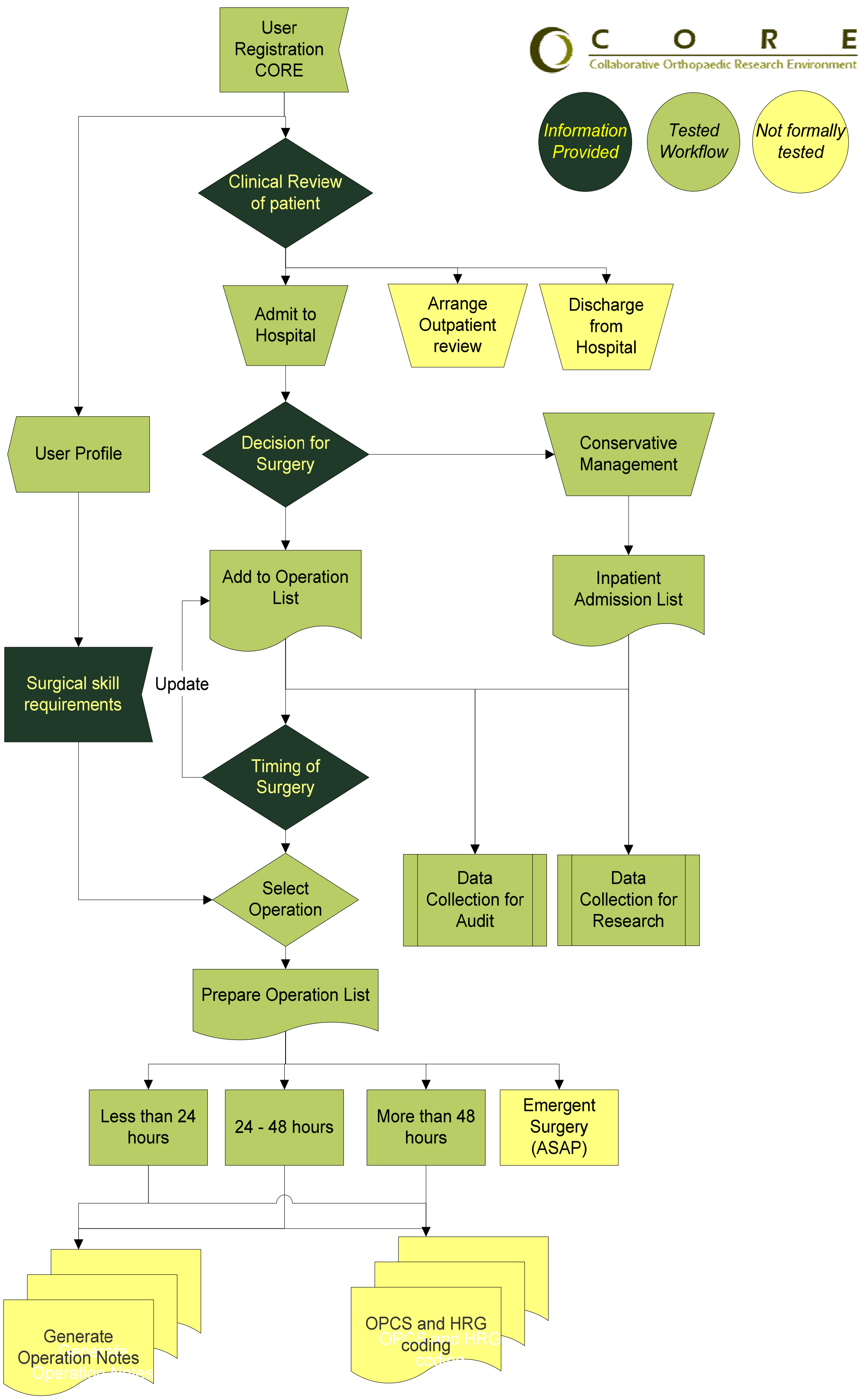

Figure 3 - Clinical evaluation workflow

4 Evaluation Design

4.1 Design of instruments

The instruments for the evaluation of CORE are derived from the successful EU project (VOEU IST-1999-13079) which used on-line questionnaires managed through an on-line trials system in 2003. The questionnaires have since been reviewed and modified in light of feedback from the evaluation team. In particular, the fact that the questions demonstrated a poor degree of correlation, and involved unnecessary duplication of questions for the issues addressed, it has been necessary to reduce the number of questions and this has been checked by two members of the design team.

The structured analysis included comments form the rest of the design team, and the methodology focused upon observational study rather than formal movement tracking as has been used in other evaluation studies due to the limitation of resources.

4.2 Main study validation methodology

The intention is to ensure the reliability of the main study of the CORE Usability by developing this from established methodologies of good pedigree and also the preparation of a pilot study which was then revised to reflect the necessary changes. The time table for evaluation allowed for review of the pilot study and modification of the instruments prior to the main study.

4.2.1 What instruments need to be developed?

In order to evaluate both the subjective and objective aspects of system performance two types of instruments are adopted;

A. **Survey** - User evaluation questionnaires
B. **Observational analysis** – User observational studies monitoring workflows through the system

4.2.2 Survey (A) - User evaluation questionnaire

This is questionnaire-driven, as detailed in Appendix I. The questionnaire consisted of 23 radio button questions and 8 free text boxes for comments. It was evaluated as part of the pilot study (section 4.3.1 below).

4.2.3 Observational analysis (B) - protocol

This is protocol-driven, as detailed in Appendix II. The underlying principle is to allow users to enter data as they normally would as part of their everyday clinical practice. The process relies upon an understanding of the everyday workflow and a reasonable model of this. A user scenario was generated by the clinical members of the team. In this, users are asked to enter the details of clinical cases to a trauma unit using a trauma admissions registry. This is then used for the collection and sorting of cases for clinical management, audit and research. Due to the limitations of time available for testing of specialist clinicians, the approach adopted involved the use of simple well defined cases. Observations were made upon the ability to use the system and the efficiency of the processes using the web interface.

4.3 Platform for testing

As the VRE is based upon web-based research service oriented architecture, this will be adopted for the studies. Such tools are likely to become both the dominant method of performance data collection from disparate sources. The cross-platform tool will be tested using the CORE toolkit to support this analysis, specifically the Data Manager. This is protocol-driven, detailed in Appendix I. The web-based platforms to be tested include those outlined in *Table 3*. This covers most of the major platforms and so the studies employed *IE v6 [Windows]* as the default browser even though IEv7 has now been released.

Browser	**Testing for Conventional Web Services**	**Testing for Service Oriented Architecture Tools**
IE v6 [Windows]	No problems	No problems
Firefox v1.5 [Windows & Mac]	No problems	**?**
Avant Browser v10.2 [Windows]	No problems	?
Safari v2.0 [Mac]	Basic functions seem ok. Admin section not usable due to javascript syllabus menus.	?
IE v5.3 [Windows]	Unusable!	?
PSP - Playstation Portable 2.0	Basic site viewable. Library material is readable but cannot read discussion forum messages.	?

Table 6 Browser Compatibility testing

Future competition between the main players in the field is likely to impact upon the design, with the need for distributed database access having a significant influence upon the potential for XML implementation. A design strategy that minimises this risk would be of benefit. *MS.net* and *MS Internet Explorer 6.0* or later, which includes *XML 1.0* support, was therefore adopted. Usability engineering involves identifying the user groups, analysing tasks and setting usability specifications. It leads to developing prototypes, which are then tested via iterative cycles.

The evaluation consisted of usability analysis of the STAR application running over a Service Oriented Architecture.

Whilst different display configurations were attempted the optimum was found to be a dual projection with a pervasive image archiving and caching system (PACS) system for radiological imaging was used to support data entry and decision making with screen profiles evaluation. It was also necessary to evaluate user cultural acceptance which would be required for the implementation of such a system.

Dual Projection Operation List using the STAR system with PACS medical imaging allowed users to prepare a clinical admissions list and to build operating lists, with the intention of linking to theatre logs. This provides functionality detailed (table 4) below.

Admissions	***Discussions***	***Research***
Tab controlled lists for step through data collection	Supports the threaded discussions	Dynamic Review of records to support clinical audit and research data collection
Supports the Edinburgh data collection for Trauma Admissions Registry	Mainly used for bug reporting!	Allow integration with surgical logbooks
STAR and Portsmouth (PorTAR) versions – institutional profiling	Will link this into image reporting, case handover and administrative duties	Use in conjunction with complex media for education and training.

Table 4 Functionality for clinical case management designed into the application.

Ultimately development of such a clinical application requires integration with coding systems for audit and to track payment, in the UK this requires mapping onto OPCS & HR coding. It has been possible to connect the user to more sophisticated tools such as MatLab™ and SPSS™ for analyses and these are GRID enabled for basic science primary research which our group also participates in. Clinical Teaching is supported by library archives, surgical records and regional presentations for training. This links the curriculum and syllabus to the learning agreements.

The aim is antegrade and retrograde analysis of data, with the establishment of focused trials based around schema generated to collect specified data. By using validated scoring systems, starting with simple analyses, bugs relating to the interface are removed.

4.4 Study Protocol Outline

As larger quantities of data are collected the opportunity arises for both ‘antegrade and retrograde’ analysis of data through the establishment of focused trials based around schemas that are generated to collect specified data using validated scoring systems.

By starting with simple analyses, interface is evaluated and bugs removed before introducing this to the basic scientists (7) who will depend upon the GRID tools via SOA for their analyses.

In future studies we will depend upon the GRID tools via SOA for their analyses of patient specific and potentially sensitive data. This will have to comply with COREC regulations(8) and this is currently being developed as part of the DRJ service.

The purpose of scenario generation (figure 4) for evaluation is to mimic everyday clinical practice and the need to minimize duplication of data entry. The system was reviewed by a multidisciplinary team of 14 Orthopaedic surgeons, theatre and ward, administration staff and an associate specialist as a representative group of potential end-users. Their purpose was to assess the interface and potential issues of workflow. The Surgical User Interface Score (SUIS) usability questionnaire results are detailed in table 5 below.

Figure 4 Example of Clinical implementation with dual projection for group meetings (Radiographic Imaging – PACS - on left and clinical data – STAR - on right)

4.4.1 Strategy for pilot studies

A small pre-study was performed to confirm the structure of the main study. This study consisted of two main parts:

A. A focus group will be established to provide the initial feedback on the *CORE VRE* and to test the survey questionnaire. Its evaluation was modified in the main study after review by Drs Gary Wills & Simon Grange. This produced the *Version 2* form and was incorporated into the main study accessed by users as *‘CORE Usability Analysis Questionnaire’ (Appendix III).*

B. A pilot study for the usability analysis of *CORE VRE* will be performed at the same time to assess the effectiveness of the CORE VRE system. The *Version 2* protocol incorporated into the main study accessed by evaluators as *‘CORE Observational Analysis Protocol’ (Appendix II).*

4.5 Preparation of pilot documentation

The following documents were required for the establishment of the studies;

1. Letter of Interest in Core Participation
2. Training facility checklist
3. Notification of Acceptance / Rejection of the subject
4. Core studies information pack for subject

   a. Overview of the study
   b. Aims and Objectives of CORE for future users
   c. Protocol for the study
5. CORE Site registration
   a. Issuing of site password for access to CORE
   b. Completing personal profile information

They are all available for download or forwarded by ‘push’ technologies to the personal workspace of the users involved.

4.6 Standard Operating Procedures (SOPs)

In order to ensure the smooth running of trials over multiple sites a set of CORE Standard Operating Procedures have been designed and outlined in *figure 5* below.

4.7 Pilot study testing the evaluation methodology

This involves scenario generation where users are registered, logged in and then use the system for selection of patient’s details for admission and then the allocation of procedures for clinical management including selection from common operation lists. The user should complete a scenario that allows them to build operating lists and prepare the information required by the hospital team to continue their everyday duties.

4.8 Pre study evaluation

The ‘pre-study’ provided feedback for the design of the final study and its proposed methods for data collection. This emphasized the need for greater integration of end-users into the design process.
The role of evaluation included the collection of users’ opinions and experiments to confirm these findings.

Using the feedback from the initial review changes were made generating the main study questionnaire.

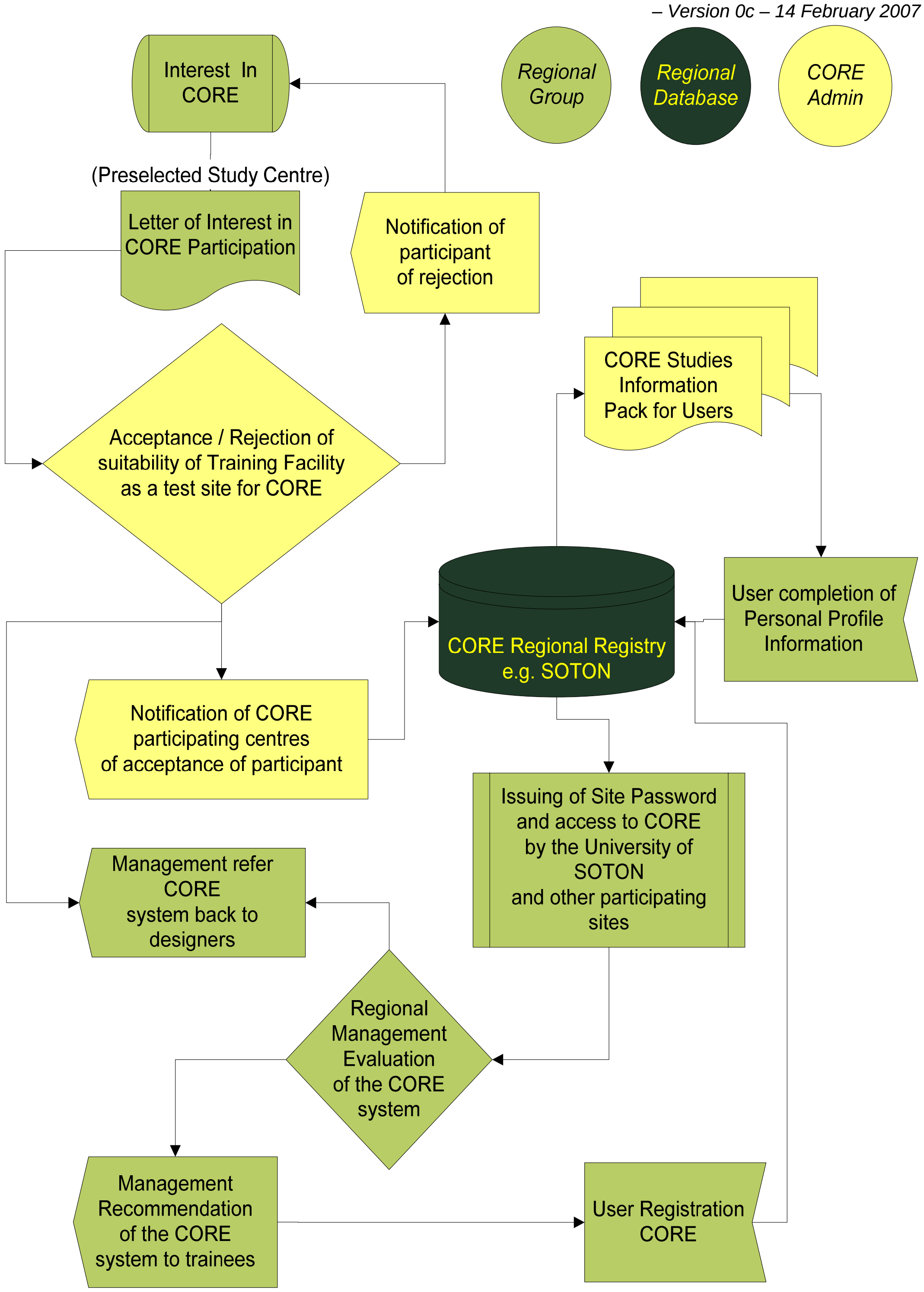

Figure 5 - CORE Standard Operating Procedures Overview

5 Main Study

5.1 Running the study in multiple centres

The centres chosen for the main study evaluation include those detailed in table 5 below. This was to ensure a representative end user population with different roles and academic achievements.

Site	**Study Population**	**Name of Coordinator**	**Role of Coordinator**	**Short Name**	**Contact**
QAH & POSM	Orthopaedic Registrars	Simon Grange	Clinical Lead	SG	bonesculptor@hotmail.com
SDH	Orthopaedic Registrars	Matt Stenning	MPhil student	MS	mj.stenning@tiscali.co.uk
SGH	Orthopaedic Registrars	Edward Gardner	Clinical Manager	EG	egardner@doctors.org.uk
Bone Laboratory	Basic Scientists	Ben McArthur	Basic Scientist Lead	BM	B.D.MacArthur@soton.ac.uk

Table 5 - Test Centres

6 Data analysis

6.1 Overall opinion

Of the 19 evaluation questions (table 6), only one was answered significantly negatively on average (“I was unsure if I was using the right command”). Four questions were answered neutrally on average (“I found the system awkward to use”, “I found the interaction with the system cumbersome”, “The screen seemed cluttered and confusing”, and “The system help files provided enough information to use the system”). The remaining 14 questions were all answered significantly positively on average. Assessment of significance was made using the 95% confidence interval for the question mean score.

Question number & text	**Mean**	**Std. Dev**	**Std. Err**	Sig
1 I found the system awkward to use	2.71	.83	.22	ns
2 The system is one that I would want to use on a regular basis	2.36	.50	.13	<3
3 I would recommend the system to my colleagues	2.36	.50	.13	<3
4 Information was attractively presented	2.14	.36	.10	<3
5 I was unsure if I was using the right command	3.64	.84	.23	>3
6 I felt that I was in control when using the system	2.36	.84	.23	<3
7 I found the interaction with the system cumbersome	2.57	.76	.20	ns
8 I was able to move around the information easily	2.00	.00	.00	<3
9 I could find the information I needed easily	2.21	.58	.16	<3
10 I understood the icons in the menus	2.00	.00	.00	<3
11 The screen seemed cluttered and confusing	2.71	.99	.27	ns
12 Learning to use the system was easy	1.86	.36	.10	<3
13 I had enough time to learn to use the system	2.14	.36	.10	<3
14 I felt at ease trying different ways to get to the information I needed	2.36	.63	.17	<3
15 The error messages were not easy to understand	2.50	.86	.23	<3
16 The system help files provided enough information to use the system	3.07	.27	.07	ns
17 Using the system enabled me do my job effectively	2.21	.70	.19	<3
18 Using the system allowed me to accomplish the task more quickly	2.50	.76	.20	<3
19 Using the system allowed me to obtain more accurate information	2.07	.48	.13	<3
N=14				

Table 6 Questions asked to obtain a Surgical User Interface Score (SUIS)

6.2 Differences between opinions

Although average opinion differed between questions, none of these differences were significant, except as follows. Average response to question 5, “I was unsure if I was using the right command” was significantly more negative than the average response to questions 2, 3, 4, 6, 8, 9, 10, 12, 13, and 19, and not significantly different from the average response to questions 1, 5, 7, 11, 14, 15, 16, 17, and 18. Average response to question 16, “The system help files provided enough information to use the system”, was significantly more negative than the average response to questions 4, 8, 10, 12, 13, and 19, and not significantly different from the average response to questions 1, 2, 3, 5, 6, 7, 9, 11, 14, 15, 16, 17, and 18. Assessment of significant differences between average question responses (table 7) was made using the Sidak-adjusted 95% confidence interval for the difference.

Question	**Question**	**Mean Difference**	**Std. Error**	Sig (p)
5	2	1.29	.22	.01
	3	1.29	.24	.03
	4	1.50	.20	.001
	6	1.29	.24	.03

	8	1.64	.23	.001
	9	1.43	.29	.05
	10	1.64	.23	.001
	12	1.79	.24	.001
	13	1.50	.25	.01
	19	1.57	.31	.04
16	4	.93	.13	.001
	8	1.07	.07	.00
	10	1.07	.07	.00
	12	1.21	.11	.00
	13	.93	.13	.001
	19	1.00	.15	.002

Table 7 Differences between opinions

6.3 Cluster analysis

To explore the correlations between responses to the various questions, an Average Linkage hierarchical cluster analysis (figure 6) using squared Euclidean distance was calculated.

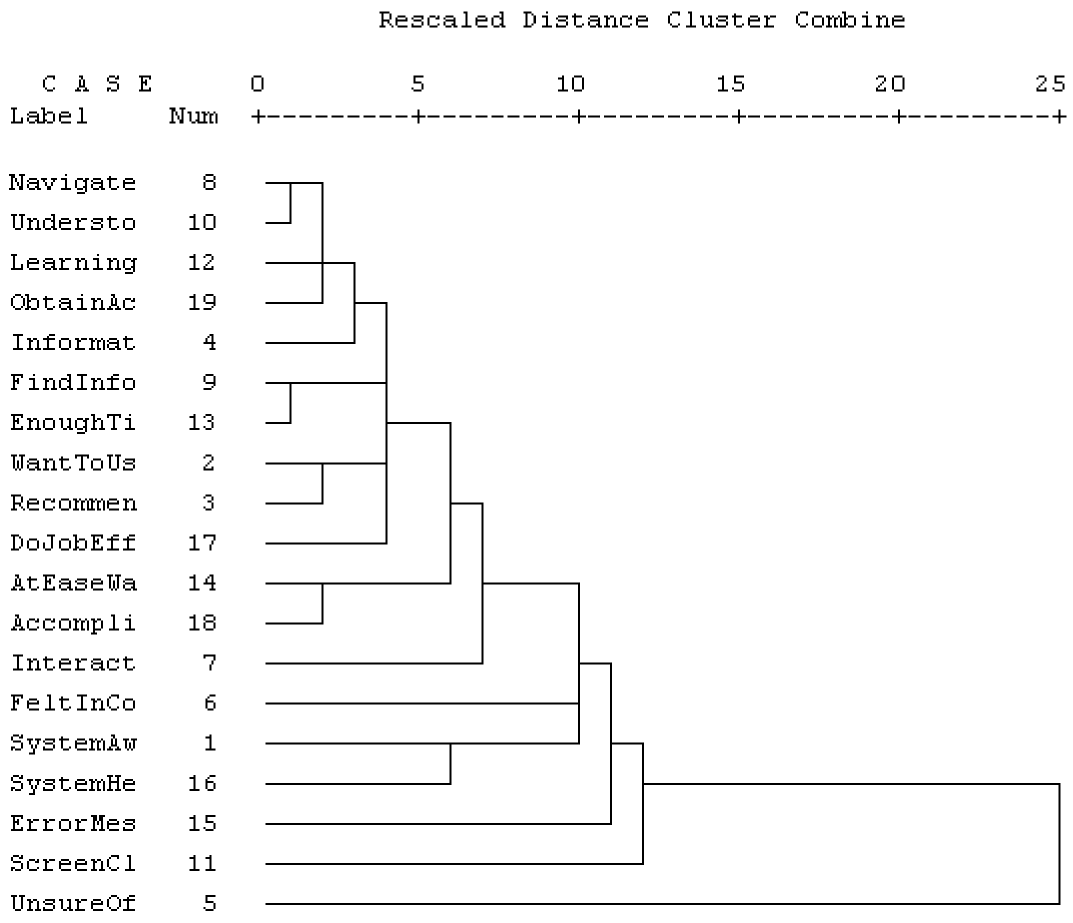

Figure 6 Average linkage hierarchical cluster analysis

"I was able to move around the information easily" linked with "I understood the icons in the menus". "Learning to use the system was easy" linked with "Using the system allowed me to obtain more accurate information". These four questions linked together, and then linked with "Information was attractively presented".

Separately, "I could find the information I needed easily" linked with "I had enough time to learn to use the system". "The system is one that I would want to use on a regular basis" linked with "I would recommend the system to my colleagues". These four questions linked together, and then linked

with “Using the system enabled me do my job effectively”.
Finally, “I felt at ease trying different ways to get to the information I needed” linked with “Using the system allowed me to accomplish the task more quickly”, and then all of these questions linked together into a cluster.

While the remaining questions each linked to this cluster at subsequent steps in the analysis, an examination of the intercorrelations matrix indicates that this cluster captured those questions which showed the most significant intercorrelations.

6.4 Contribution of other experience with computers

A number of questions assessed the respondents’ current level of use of computers. To see if such other use influenced opinions, a linear regression analysis was run using these questions as independent (predictor) variables against the aggregate score given by the responded for their opinion of the system. The result was that the current use of computers did not account for a significant proportion of the variance in aggregate opinion scores (R sq = 0.36, F = 1.24, df = 4,9, ns).

The predictor questions used were “Do you use any Internet search engines?”, “I use the Network/Web to store information more reliably”, “Do you use ftp to transfer files?”, and “I find the use of computers a better means of sharing information than a paper-based system”. The other possible predictor questions (“I find the use of computers straightforward”, “I use the Network/Web for convenience”, “I use the Network/Web to make searches easier”, and “I use the Network/Web to speed up retrieval of information”) were not be entered into the regression because all respondents gave identical answers.

7 Discussion

The facilitating technical advance is at the middleware layer - Open middleware and Microsoft .net™. Processes are being refined to run over a portlet architecture separating security from applications. Handling data offers analysis of the clinical record keeping practice but still has implications for data protection. This work represents the initial roll-out. Once implementation involves multicentre clinical trials[1] then it will require data flow directly to and from the NHS.

7.1 Security issues and ownership of Data

User 'ownership' of data with selective authorisations for data release ensure that for the process of research it is necessary to use the relationship established between the medical school and the teaching hospital as outlined in figure 7 below. This method would not be acceptable for the roll-out of the technologies as it necessitates indirect communication between the university and the hospital. Patients undergoing orthopaedic procedures are consented for records to be used for research as part of routine practice. No patient information was released to individuals beyond those who are currently authorised as part of their routine clinical practice

The clinical information is in effect collected for research purposes as is authorised by the patient consent forms and then made available for the clinical application which can be viewed via the secure Web browser. This is possible for all sites but does require that users are securely logged on using a unique password protected system. The prototype research tools can be applied to solve clinical problems. The security and software are managed through the University School of Medicine firewall, with the authorisations of the Medical school systems administrator.

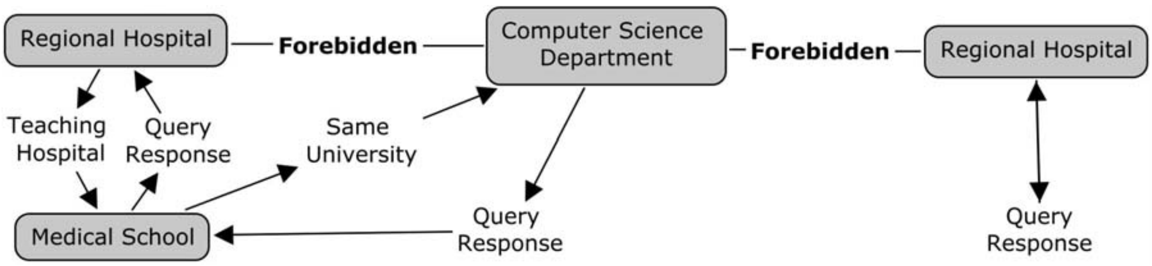

Figure 7 Relation ship between institutions for clinical evaluation of the SOA

7.2 Difficulties encountered

Access to data is prohibited and restricted by the use of firewalls. There is also a physical barrier where certain hospital units avoid having networked machines to minimise cost of service but this (hardware) policy will soon become historic. During the evaluation, the backup was provided free of charge by the medical school servers. This would of course need to meet the quality of service standards required for clinical data management if implemented.

Surgeons often encounter 'shifting sand' when developing clinical systems as many aspects of the system are being developed independently simultaneously. In the case of the STAR application the foundation was a database structure originally designed for trauma management but this is not validated and so the design has to support its possible future replacement by using data entry schemas which can be updated. Data entry in the present NHS system is in the form of *.pdf* files *i.e.* it is completed on paper.

The outcome measures also have a patchy history of validation and so it is necessary for the study to adopt a generic task as an output. By generating an operating list, a task which is universal and represents simple audit of cases the study task allows for the development of more complex components such as searching and sorting of data, and logging of changes. Scoring systems for clinical outcomes is addressed in later versions by developing a database modeling clinical management

[1] This has been evaluated in the UK and Australia where such trials are being established as detailed in the CORE sustainability report.

workflow. The work is in progress.

7.3 Extending applications to include Semantic Grid tools

This work makes a case for the development of a semantic grid (figure 8). This is perhaps best described by the quote from Professor De Roure(9):

> *'Semantic Grid computing has allowed us to bring resources together to achieve something that was not previously possible. We now look forward to working on some of the remaining challenges, which include for example the intersection between the grid and the physical world through pervasive computing devices and the self-management, self-optimisation and self-healing (so called 'autonomic' behaviour) necessary for large scale distributed computing.'*

Our strategy employs open middleware (10) and Microsoft ***.net™***. Processes run over a portlet (11;12) architecture separating security from applications. This offers analysis of the clinical record keeping practice. Once implementation involves multicentre clinical trials, it will necessitate data flow directly to the NHS, thence to research, avoiding registration of each user as a data controller and ensuring that every patient is covered by the individual consent forms when only anonymised data will be investigated. The Grid will offer the potential for authorised anonymised data to be analyzed according to different schemas remotely.

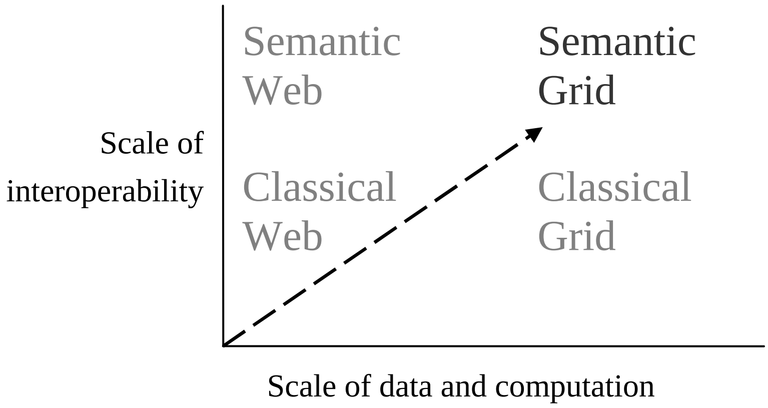

Figure 8 Development of the Semantic Grid

This current approach allows us to develop research tools using anonymised data with only those users with qualified clinical profiles being able to access patient specific data. Any change in work practice needs to be implemented with the users being informed and made aware of the potential advantages. User profiling started in Adaptive Hypermedia (AH) as a way of mapping the user's ontology onto the workflow process (13). As this evolves, it offers the following advantages;

1. Focused effort increasing efficiency
2. Accommodation of users' limitations *e.g.* 1st language adaptation.
3. Targeting driven work *e.g.* learning objectives.
4. User 'ownership' of data with selective authorisations for data release.
5. Updating as user profiles change converting the e-Portfolio into a truly dynamic C.V. which is particularly relevant as the modernisation of medical careers will provide a new structure for training.

8 Conclusions & Future Work

From the opinions expressed and the analysis thereof, it appears tat the navigation is the weakest link for users. It is likely that we are reaching the limits for handling large information spaces and the users need greater support. To this end we are addressing this issue through the development of ontology mapping which is the basis for building the semantic grid as the semantic Web components require enhancement as a prelude to full grid integration, certainly facilitation of the OMII Grid access needs to be seamless to ensure end-users are not involved directly in its implementation.

8.1 Why use the GRID

Whilst the Grid is clearly a paradigm that will be absorbed into the future way that we work, it needs to be seen in context. The following table 8 outlines the pros and cons of Grid implementation.

Pros	Cons
Extend Reach	Not a panacea, need to start small.
Overcome Limitations	Unrealistic expectations: same platform machines are realistically required for clusters
Part of a shared process	Partisan protection of resources and influence
Suitable for different user groups Non-clinical Scientists Clinical Scientists Clinicians	Web service applications may be easier to expose as services but this requires a common set of exposed names, attributes and semantics to create dynamic networks – See argument for the ORBS below.
Thin Client, Portal architecture	Many machines will not be considered secure or appropriate for SOA applications

Table 8 Pros and Cons of transitioning to Grid architectures

We can conclude that Service Oriented Architecture Transition offers; user empowerment can be achieved through adaptive hypermedia profiling of individuals ensuring consistency of data collection, management and schemas. The enhancement of communication is important for the collection and collation of data and by integrating a dynamic review process; it is intended to encourage unbiased semi-automatic reporting

Extensibility and scalability; the co-design is intended to model normal workflow which varies between different medical and nursing staff both in operating theatres and ward based environments. The software environment ensures security and confidentiality and the component library continues to expand, the beauty of it though is that service tools can evolve independently and then be offered to users once tested using a thin client.

8.2 Future Work

Online form completion for feedback can reduce time delay. Not overly intrusive for formal Beta testing. In the authors' experience, the online form completion for feedback helps to address the time delay in seeking the necessary opinions and is not overly intrusive. Within the context of CORE, the need to build and sort data for analysis across the e-Science, e-Health bridge is fundamental to developing multidisciplinary research potential, and should build upon this successful work.

8.3 Collaboration

User Interfaces will need to include National level databases, reflecting the role, performance and possibly efficiency of individuals in clinical practice. This warrants analysis of clinical workflows as part of the development of e-Science – e-Health integration. A major step forward on this path would be the development of a 'ORBS' a Grid infrastructure specifically designed to accommodate the needs of medical and biomedical researchers covering all scales of research from the population at large right down to the genetic and epigenetic layers, the development of which is still in the draft stages of development.

This depends also upon the potential resources available to build a Bioinformation Multilayer GRID technology service industry (ORBS) which will represent the transition to semantic Web technologies integrating multiscale modelling. This will assist with expansion (14;15) including ontology mapping, modelling, multimedia, and assist non-repudiation through the clear ownership of data.

This will act as a fulcrum for the modernisation of medical careers, research & industrial partnerships. The usability analysis suggests that to develop this innovative pathway requires cyclical implementation and testing to keep users in the iterative design loop. The political tussle between maintaining the status quo and expediency in changing clinical practice demands that for clinicians, Continuing Professional Development (CPD) will need to accommodate these approaches.

As intended, CORE was the start of a new way of working, successfully laying the infrastructure foundations for the next generation of multidisciplinary research and education, using applications otherwise inaccessible to the average user. I therefore recommend it to the project review committee.

9 List of Acronyms

AH	Adaptive Hypermedia
CPD	Continuing Professional Development
DOH	Department of Health
DRJ	Dynamic Review Journal
HIS	Hospital Information Systems
NHS	National Health Service (United Kingdom)
PorTAR	Portsmouth Trauma Admissions Registry
SOA	Service Oriented Architecture
STAR	Southampton Trauma Admissions Registry
VE	Virtual Environment
VOEU	Virtual Orthopaedic European University

10 References

(1) University of Southampton. CORE Project Proposal. web 2004Available from: URL: http://www.core.ecs.soton.ac.uk/overview/

(2) Wilson S, Blinco K, Rehak D. Service-Oriented Frameworks: Modelling the infrastructure for the next generation of e-Learning Systems. Joint Information Systems Committee (JIS C). article available from web: 2004Available from: URL: http://www.jisc.ac.uk/uploaded_documents/Alti labServiceOrientedFrameworks.pdf

(3) Booth D, Champion M, Ferris C, McCabe F, Newcomer E, Orchard D. Web Services Architecture. web 2004 November 2Available from: URL: http://www.w3.org/TR/ws-arch/

(4) B Goyal, S Lawande. The evolution of grid computing. In: l McLain, M Karmendy, editors. Grid revolution. 1 ed. New York: McGraw Hill; 2005. p. 30-46.

(5) University of Southampton. Virtual Orthopaedic University. web 2006Available from: URL: http://www.voeu.ecs.soton.ac.uk/voeu

(6) Grange S, Wills G, Power G, Miles Board T, Carr L, Hall W. Building a dynamic review journal (DRJ) - Extending the role of the Virtual Orthopaedic University. Marbella, Spain, CAOS International; 2003 p. 122-3.

(7) Sim YW, Wang C, Gilberts L, Wills GB. User Requirement Study for a Virtual Research Environment. web 2005Available from: URL: http://eprints.ecs.soton.ac.uk/10969

(8) Central Office for Research Ethics Committees. Application for Ethical Committee Approval. web 2006Available from: URL: http://www.corec.org.uk/applicants/apply/apply.htm

(9) de Roure D, Jennings NR, Shadbolt N. The Semantic Grid: A future e-Science infrastructure. In: Berman FFGaHAJG, editor. *Grid Computing - Making the Global Infrastructure a Reality*. John Wiley and Sons Ltd.; 2003. p. 437-70.

(10) University of Southampton. OMII Web site. web 2006Available from: URL: http://www.omii.ac.uk/

(11) R.Allan, C.Awre, M.Baker, A.Fish. Portals and Portlets. web 2003Available from: URL: http://www.nesc.ac.uk/technical_papers/UKeS-2004-06.pdf

(12) Portals: Frequently Asked Questions. article available from web: 2006Available from: URL: http://www.jisc.ac.uk/index.cfm?name=ie_portalsfaq

(13) Carr L, Miles-Board T, Wills G, Power G, Bailey C, Hall W, et al. Evolving a Digital Library Environment to the Changing Needs of its Users.: Bath, UK.; 2004.

(14) Hey T, Trefethen A. Cyberinfrastructure for e-Science. Science, 308(5723), 308[5723], 817-821. 2005.
Ref Type: Journal (Full)

(15) Buetow K. Cyberinfrastructure: Empowering a "Third Way" in Biomedical Research. Science, 308[5723], 821-824. 2005.

1.

11 Appendix I - User evaluation questionnaire

lease note that your answers to this questionnaire and any additional comments will only be used as part of the CORE project evaluation and associated academic reporting, being conducted by the University of Southampton. The data will remain the property of the individual held with their permission. By completing the questionnaire, it is accepted that the results will be used for analysis and development of this system.

Name:

Email :

Status : (Not set)

Age: 10

Approximate Length of service within Surgery: 0 Years 0 Months

Experience of using the Internet/World Wide Web:

Do you use the Web at home: Daily

Do you use the Web at work (not just for work related information):

Daily

Do you find the:	**Agree**	**Disagree**	**Neither**
Use of computers straightforward	○	○	●
Use of computers a better means of sharing information than a paper-based system	○	○	●
Do you use the Network/Web?	**Agree**	**Disagree**	**Neither**
For convenience	○	○	●
To make searches easier	○	○	●
To speed up retrieval of information	○	○	●

Do you use ftp files to transfer files? Yes

Do you use an Internet search engines? *e.g.* Yahoo, Alta Vista etc. Yes

Impression- *user's feelings or emotions*	**Strongly**	**Disagree**	**Agree**	**Strongly**

when using the WESSEX software.	**Disagree**			**Agree**
I found the WESSEX system awkward to use.	○	○	◉	○
The system is one that I would want to use on a regular basis.	○	○	◉	○
I would **not** recommend the WESSEX system to my colleagues.	○	○	◉	○

Additional comments about your feeling or emotions when using the software:-

Command - *the measure to which the user feels that they are in control.*	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
I was unsure if I was using the right command.	○	○	◉	○
I felt that I was in control when using the WESSEX system.	○	○	◉	○
I found the interaction with WESSEX cumbersome.	○	○	◉	○

Additional comments about whether you feel in control:-

Navigability - *the degree to which the user can move around the application.*	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
I was able to move around the information in WESSEX easily.	○	○	◉	○
There were plenty of ways to find the information I needed.	○	○	◉	○
I did not understand the icon in the menus	○	○	◉	○
The screen became cluttered and confusing.	○	○	◉	○

Additional comments on how you easy you found it to locate the information :-

Learnabillity - *the degree to which the user feels that the application is easy to become familiar with.*	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
Learning to use the system was easy.	○	○	◉	○
I did not have enough time to learn to use the WESSEX system.	○	○	◉	○
I felt at ease trying different ways to get to the information I needed.	○	○	◉	○

Additional comments about how easy you felt the software was to become familiar with:-

Helpfulness - *the degree to which the application assists the user to resolve a situation.*	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
The error messages were **not** easy to understand.	○	○	●	○
The system help files provided enough information to use the system.	○	○	●	○

Additional comments about how helpful the system is in assisting you resolve a situation:-

Effectiveness - *the degree to which the user feels that they can complete the task while using the system.*	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
When using WESSEX I found it difficult to obtain the information I needed.	○	○	●	○
Using WESSEX will enable me do my job effectively.	○	○	●	○
Using WESSEX allows me to accomplish the task more quickly	○	○	●	○

Additional comments about how effective you feel the software was:-

Any other addition comments you wish to make?

12 Appendix II – CORE observational analysis protocol