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FINAL REPORT

WP5 – Task 5.1

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Abstract: This document constitutes the final report of the CrossGrid project, augmenting the three yearly reports and the twelve quarterly reports submitted earlier, summarizing the development, its results and their exploitation as undertaken by the CrossGrid consortium. The document is intended as a single-step introduction to the project, its structure, history and results, covering all important aspects of CrossGrid in a summarized manner.

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CONTENTS

LIST OF ACRONYMS

CG	CrossGrid
EDG	European DataGrid
FP	Framework Programme
G-PM	Grid Performance Monitoring
GT	Globus Toolkit
GVK	Grid Visualization Kernel
LCG	LHC Computing Grid
LHC	Large Hadron Collider
MPI	Message Passing Interface
OGSA	Open Grid Services Architecture
PPC	Performance Prediction Component
WP	Work Package

1. INTRODUCTION

1.1. PROJECT OVERVIEW

The CrossGrid project undertook to extend the functionality of Grid computing networks to a new category of applications - ones, which include a human in a processing loop. As a three-year project, it officially concluded in early 2005, having delivered a package of new Grid services and tools, as well as Grid-ready applications, and having created a major European testbed for Grid computing, which, among others, involves key supercomputing centers in new EU member states - Poland and Slovakia - in European computing and research.

The aim of the CrossGrid project was to create a coherent computing platform, which would enable interactive processing in a Grid environment, and to apply that platform to solving societally-important problems within the CrossGrid consortium's areas of expertise. As such, the Project involved the development of Grid-enabled applications, a set of new Grid tools designed to aid Grid application developers, a collection of Grid services which extended the basic functionality of Grid middleware to provide further optimization and monitoring capabilities for system administrators, and – finally – a European testbed which will utilize computing resources of various European partners (both academic and commercial) in testing CrossGrid solutions and applying them to real-life cases.

1.2. PROJECT OBJECTIVES

CrossGrid, as an Integrated Project, had several objectives that needed to be fulfilled in order to achieve successful conclusion to the development activities. As outlined in the previous section, the research and development effort concentrated on several key areas. Thus, the objectives of the Project (as described in its Technical Annex - Description of Work) can be divided into the following items:

- Development of a set of user-friendly Grid-enabled applications, both to serve as proof of concept for the CrossGrid approach and to solve actual societally-important problems within the EU.
- Development of a set of tools which would enable Grid developers to create new applications, suited to the needs of the Grid, as well as to adapt existing applications for use within a Grid environment.
- Development of a batch of Grid services, specifically supporting interactivity in Grid computing, through the presence of a human in a processing loop. These services ranged from high-level ones (concentrating on user-friendly access), through job submission and execution mechanisms, to low-level monitoring utilities designed for experienced Grid users and system administrators.
- Development of a pan-European Grid testbed to be used for development and production runs of CrossGrid software as well as testing purposes, including sites in new EU Member States and being fully compatible with other European Grid infrastructure projects.

In addition to these main objectives, the Project was also expected to contribute to maintaining European leadership in the emerging field of Grid technologies (as defined in the Lisbon Strategy), to foster further Grid development through creating expertise and to contribute to the organization of groups of experienced users and developers of Grid applications, tools and infrastructures throughout the European Union. To this end, the Project was to undertake extensive dissemination and training activities, organize and participate in conferences and other scientific events, both European and national, and prepare a set of tutorials intended to familiarize new users with Grid technologies in general as well as with CrossGrid products in particular.

1.3. PROJECT CONSORTIUM

CrossGrid commenced in March 2002 as a three-year Integrated Project under the auspices of the EU 5th Framework Programme (IST), within the Grids for Large Problem Solving priority. Throughout the development of the Project, 21 partners from 11 European Union Member and Associated States participated in the effort. The list of partners included 19 academic and 2 commercial institutions, as follows:

Partic. Role*	Partic. no.	Participant name	Participant short name	Country	Date enter project	Date exit project
CO	1	Academic Computer Centre CYFRONET AGH	CYFRONET	Poland	Start	End
AC	2	Interdisciplinary Centre for Mathematical and Computational Modelling, University of Warsaw	ICM	Poland	Start	End
AC	3	The Henryk Niewodniczanski Institute of Nuclear Physics, High Energy Physics Department	INP	Poland	Start	End
AC	4	The Andrzej Soltan Institute for Nuclear Studies, Laboratory for High Energy Physics	INS	Poland	Start	End
CR	5	Universiteit van Amsterdam, Faculty of Science	UvA	Netherlands	Start	End
AC	6	Ustav Informatiky, Slovenska Akademia Vied, Departement of Parallel and Distributed Processing	II SAS	Slovakia	Start	End
AC	7	Institut für Technische Informatik und Telematik, Johannes Kepler Universität Linz, Abteilung für Graphische und Parallele Datenverarbeitung	Univ. Linz	Austria	Start	End
CR	8	Forschungszentrum Karlsruhe GmbH. Central Information and Communication Technologies Department	FZK	Germany	Start	End
AC	9	Universität Stuttgart, Rechenzentrum Universität Stuttgart	USTUTT	Germany	Start	End
AC	10	Technische Universität München, Lehrstuhl für Rechnertechnik und Organisation/Parallelrechner Architektur, Fakultaet für Informatik	TUM	Germany	Start	End
CR	11	Poznan Supercomputing and Networking Center Affiliated to the Institute of Bioorganic Chemistry of PAN	PSNC	Poland	Start	End
AC	12	University of Cyprus, Department of Computer Science, University of	UCY	Cyprus	Start	End

		Cyprus				
AC	13	DATAMAT S.p.A.	DATAMAT	Italy	Start	End
AC	14	Department of Computer Science, Trinity College Dublin	TCD	Ireland	Start	End
CR	15	Consejo Superior de Investigaciones Cientificas	CSIC	Spain	Start	End
AC	16	Universitat Autonoma de Barcelona	UAB	Spain	Start	End
AC	17	Universidade de Santiago de Compostela	U.S.C.	Spain	Start	End
AC	18	National Centre for Scientific Research 'Demokritos', Institute of Nuclear Physics	Demo	Greece	Start	End
AC	19	Aristole University of Thessaloniki, Division of Nuclear and Particle Physics, Department of Physics	A.U.Th.	Greece	Start	End
AC	20	Laboratorio de Instrumentacao e Fisica Experimental de Particulas LIP Computer Centre	LIP	Portugal	Start	End
AC	21	Algosystems S.A., Applied Research Department	ALGO	Greece	Start	End

The composition of the consortium remained stable throughout the lifetime of the Project, although a private SME (Websoft Inc. from Poland) was later subcontracted in order to help with the quality assurance procedures (in particular static code analysis and reporting).

1.4. STRUCTURE OF THE PROJECT

The Project was structured into five separate Work Packages, each of which was subdivided into individual tasks. The Work Packages were as follows:

1.4.1. Work Package WP1: CrossGrid Application Development

The main objective of this work package was to design and develop large-scale Grid-enabled applications for simulation and visualization that require real-time responses from the system. The main challenges included the distribution of source data, simulation and visualization tasks, virtual time management, simulation/visualization rollback due to user actions, and platform-independent VR visualization. This work package provided a representative collection of sample applications from various fields exploiting the specific interactive functionalities developed in the CrossGrid project.

1.4.2. Work Package WP2: Application Development Support

The aim of this work package was to specify, develop, integrate and test tools that facilitated the development and tuning of parallel distributed, compute- and data-intensive, interactive applications on the Grid. In order to make parallel applications portable and reproducible, this work package developed a debugging and verification tool for MPI programs - MARMOT. In addition, WP2 also developed tools for automatic extraction of high-level performance properties of Grid applications, online performance monitoring tools and tools for detecting bottlenecks within applications. Custom-tailored benchmarks were being prepared with regard to data transfer, synchronization, I/O delay and CPU utilization.

The tools developed by WP2 were integrated into the testbed and tested with the real end-user applications of WP1.

1.4.3. Work Package WP3: New Grid Services and Tools

The aim of this Work Package was to extend the functionality of the Grid environment itself, through addition of new services aimed specifically at interactive applications. Among others, this WP addressed user-friendly Grid environments and portal access to the Grid infrastructure and user applications, independent of the user location. Thus, WP3 provided the Migrating Desktop and Portal services, enabling access to the Grid from any workstation with the sole requirement being a functional Web browser. Furthermore, WP3 also took care of implementing the notion of roaming access, i.e. a mobile personalized environment, supported by a dedicated Roaming Access Server. WP3 also addressed the construction of new resource management techniques for scheduling particular parallel applications submitted to the Grid. As a last objective, WP3 developed a prototype infrastructure for the needs of monitoring-related activities for automatic extraction of high-level performance properties and for tool support for performance analysis in Work Package 2.

The services developed by WP3 were integrated into the testbed and tested with the real end-user applications of WP1 and tools of WP2.

1.4.4. Work Package WP4: International Testbed Organization

The role of the international testbed is to assure the integration of all the applications, programming tools and new Grid services developed in this Project. Organizational issues, performance and security aspects, including network support, can only be evaluated with a testbed relying on a high-performance network (provided by the Géant project), with participation of an adequate number of computing and data resources distributed around Europe. The main objectives of the testbed organization were to:

- provide distributed computer resources where the Project developments could be tested in a Grid environment,
- integrate national Grids,
- integrate software developed within the Project,
- co-ordinate software releases,
- assure interoperability with other Grids, in particular with DataGrid,
- support the construction of Grid testbed sites across Europe.

Testbed sites were placed at 16 different institutions distributed across 11 different European countries, significantly expanding the Grid community.

1.4.5. Work Package WP5: Project Management

This work package was devoted entirely to coordination, management and dissemination of Project results. It developed no software but instead aimed at managing other Work Packages. WP5 involved such entities as the CrossGrid Architecture Team, devoted to developing the overall architecture of CrossGrid and its standard operating procedures, the Internal Review Board, the role of which was to review project documentation, the Dissemination Board, which publicized information regarding the project and promoted it on an international scale, the Quality Assurance team, working to verify the usability and overall quality of Project deliverables and software, and, finally, the Project Steering Group which oversaw the organizational issues pertaining to CrossGrid.

1.5. ROLE OF KEY PARTNERS

1.5.1. ACC CYFRONET AGH

ACC CYFRONET AGH served as coordinator of the Project and hence involved itself in all managerial affairs. CYFRONET staff manned the CrossGrid Office as well as other managerial and technical bodies, such as the Technical Architecture Team and the Quality Assurance team. Both the Project Coordinator and the head of the TAT hailed from CYFRONET; CYFRONET also operated the main CrossGrid Website and management portal including the Project documentation repository.

In addition to managerial duties, CYFRONET also took part in developing selected tools and services in technical workpackages, most importantly relating to Grid monitoring tools (OCM-G/G-PM and the JIMS infrastructure monitoring tools) and integration with Web Services standards. CYFRONET researchers also engaged in optimization of data access for the Grid environment (task 3.4).

CYFRONET was an active participant in the CrossGrid dissemination effort, organizing yearly Cracow Grid Workshop events and presenting the Project at numerous international conferences. CYFRONET staff was also responsible for preparing the CrossGrid presentation and movie.

Finally, CYFRONET operated a major CrossGrid testbed site.

1.5.2. ICM Warsaw

ICM was primarily responsible for developing and testing the climate modeling component of the environmental application, developed within task 1.4, in conjunction with CSIC in Spain.

1.5.3. INP

INP was involved in the development and testing of the high-energy physics application as part of task 1.3 as well as the submission of CERN Atlas data challenges to the CrossGrid testbed for testing purposes.

1.5.4. INS

The role of the Andrzej Soltan Institute for Nuclear Studies was collaboration in task 1.3 (high-energy physics application), with focus on developing that application’s Graphical User Interface using ROOT’s SVG output and its integration with the Migrating Desktop. INS also took over installation of network monitoring tools based on SNORT and SANTA-G.

1.5.5. UvA

In addition to coordinating the management of workpackage 1 (Grid applications), the University of Amsterdam was solely responsible for developing and testing the biomedical application for surgical interventional procedures (task 1.1) as well as enabling it for use in the CrossGrid testbed. To this end, UvA also developed the appropriate graphical user interface and integrated the application with the CrossGrid migrating desktop. Experimental work was also carried out at UvA with regard to the use of OGSA tools in CrossGrid development, in support of the Technical Architecture Team.

1.5.6. II SAS

The Institute of Informatics of the Slovak Academy of Sciences was solely responsible for developing and testing the flooding crisis decision support application (task 1.2) as well as enabling it for use in the CrossGrid testbed. II SAS carried out the necessary integration with the Migrating Desktop team as well as other CrossGrid tools, and organized a pilot site to test the application in the Vah river basin in Slovakia.

1.5.7. University of Linz

The Johannes Kepler University of Linz was responsible for developing the Grid Visualization Kernel service in order to handle graphical information on the Grid, in support of the application layer of the Project.

1.5.8. FZK

The Research Center of Karlsruhe was involved in management of workpackage 2 (i.e. new CrossGrid tools) as well as in operation of a major testbed site, serving both CrossGrid and EGEE projects. FZK was also responsible for liaisons and integration with the DataGrid project, with which there has been extensive cooperation throughout the lifetime of CrossGrid, including exchange of software solutions. Finally, FZK operated the CrossGrid CVS software repository and developers' portal, and participated in coordinating release integration for the entire Project software package.

1.5.9. USTUTT

The University of Stuttgart was responsible for developing the MARMOT MPI verification tool (task 2.2), whose aim was to verify the correctness of MPI applications prior to submission to the Grid and actual assignment of computing/storage resources.

1.5.10. TUM

The Technical University of Munich was initially involved in establishing the tools requirements definition in WP2. Later, when this task concluded, TUM cooperated in the development of the G-PM/OCM-G Grid monitoring tools, with focus on distributed evaluation of measurements.

1.5.11. PSNC

The Poznan Supercomputing and Networking Center was the primary coordinator and manager of workpackage 3 (new Grid services). In addition, PSNC was the primary developer of the CrossGrid user interface solutions in the form of Portal, Roaming Access Server and the Migrating Desktop. PSNC also operated a CrossGrid testbed site.

1.5.12. UCY

The University of Cyprus was the developer of the GridBench benchmarking package for gauging the performance of applications submitted to the Grid for processing.

1.5.13. DATAMAT

The role of DATAMAT was to support the development of CrossGrid user interface solutions (Roaming Access Server/Migrating Desktop) as well as to assist in the CrossGrid dissemination effort and participate in defining the exploitation policies for CrossGrid software.

1.5.14. TCD

The Technical College of Dublin supervised the Grid monitoring task (task 3.3) and developed the SANTA-G network trace analysis tool, deploying it in the CrossGrid testbed.

1.5.15. CSIC

CSIC of Spain was responsible for managing the CrossGrid testbed workpackage (WP4) and hence to create and implement policies for incremental testbed development and management. CSIC defined the schedule of integration of individual CrossGrid components in Project releases and scheduled the actual releases (in cooperation with developers), playing a key role at the periodical CrossGrid integration meetings.

1.5.16. UAB

The Autonomous University of Barcelona was responsible for providing scheduling solutions for the CrossGrid infrastructure. In collaboration with the DataGrid project, UAB was involved in developing a joint scheduler, later included in the software releases of both projects. The CrossGrid scheduler interfaces with the Roaming Access Server for the purposes of user interaction and submits Grid jobs for processing at selected testbed sites.

1.5.17. USC

The University of Santiago de Compostela managed the development of the weather forecasting and air pollution modeling application (task 1.4) in collaboration with ICM Warsaw. The actual development work at USC focused on the air pollution modeling aspect of the application. To this end, USC was involved in operating a pilot site centered on the As Pontes power plant in NW Spain. USC also managed integration of the application with CrossGrid user interface components. In addition, this group developed the Performance Prediction Component that provides information about the performance of the execution of some selected kernels in the testbed.

1.5.18. DEMO

The Demokritos National Center for Scientific Research was involved in operating a CrossGrid production testbed node.

1.5.19. AUTh

The Aristotle University of Thessaloniki was involved in operating a CrossGrid testbed node as well as in coordination of the CrossGrid testbed releases.

1.5.20. LIP

The Laboratory for Instrumentation and Experimental Particle Physics in Portugal was responsible for managing the verification and quality control (task 4.4) of the CrossGrid testbed workpackage as well as maintenance of a CrossGrid testbed site. LIP also generated testbed quality metrics for inclusion in the monthly Project QA reports.

1.5.21. ALGOSYSTEMS

Algosystems of Greece was the manager of the CrossGrid dissemination task (task 5.3). As such, the company coordinated CrossGrid participation in numerous international conferences and events. Furthermore, Algosystems prepared CrossGrid disseminative materials (posters, brochures, other promos) and maintained a separate dissemination Web portal.

1.6. PROJECT DELIVERABLES

The table below contains the list of deliverables submitted during the lifetime of the Project (gray fields represent internal deliverables which were not subject to delivery to the European Commission).

No.	Deliverable title	Month	Nature	Diss. level	Type of deliverable
D1.0.1	Joint requirements definition document	3	R	CO	Technical
D1.1.1	Application description, including use cases for Task 1.1	3	R	PU	Technical
D1.2.1	Application description, including use cases for Task 1.2	3	R	PU	Technical

D1.3.1	Application description, including use cases for Task 1.3	3	R	PU	Technical
D1.4.1	Detailed planning for air/sea pollution application including use cases	3	R	PU	Technical
D2.1	General requirements and detailed planning for programming environment	3	R	PU	Technical
D3.1	Detailed planning for all the tools and services including use cases for WP3	3	R	PU	Technical
D4.1	Detailed Planning for Testbed Setup	3	R	PU	Technical
D5.1.1	Quarterly report	3	R	PU	Managerial
D5.2.1	Quality assurance plan	3	R	PU	Technical
D5.2.2	The CrossGrid architecture requirements and the first definition of the architecture	3	R	PU	Technical
D5.3.1	CrossGrid Web page	3	P	PU	Disseminative
D1.0.2	Semi-annual managerial report for WP1	6	R	CO	Managerial
D2.2	WP2 internal progress report	6	R	CO	Technical
D3.2	WP3 internal progress report	6	R	CO	Technical
D4.2	First testbed set-up on selected sites	6	R	PU	Technical
D5.1.2	Quarterly report	6	R	PU	Managerial
D5.2.3	Full description of the CrossGrid standard operational procedures and specification of the structure of deliverables.	6	R	PU	Technical
D5.3.2	Dissemination and exploitation plan	6	R	PP	Disseminative
D5.3.3	Public (industrial) presentations	6	E	PU	Disseminative
D4.3	WP4 status internal report	9	R	CO	Technical
D5.1.3	Quarterly report	9	R	PU	Managerial
D5.3.8	CrossGrid Website	9	P	PU	Disseminative
D4.4	1st Testbed prototype release	10	P	PU	Technical
D5.3.9	Project leaflet / brochure	11	O	PU	Disseminative
D5.3.12	Dissemination and exploitation report	11	R	PP	Disseminative
D5.3.15	Yearly collaboration meeting	11	O	PP	Disseminative
D1.0.3	Extended yearly managerial report for WP1	12	R	CO	Managerial
D1.1.2a D1.1.2b	Internal progress report First internal software release	12	R SW	CO	Technical

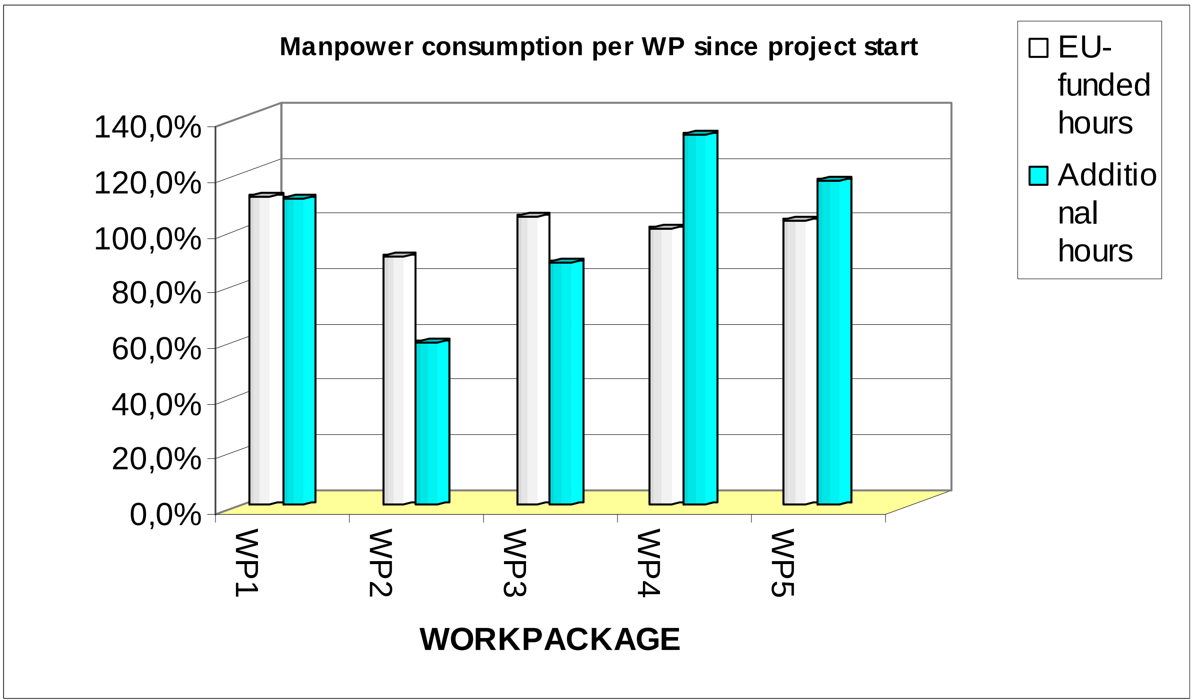
D1.2.2a D1.2.2b	Internal progress report First internal software release	12	R SW	CO	Technical
D1.3.2a D1.3.2b	Internal progress report First internal software release	12	R SW	CO	Technical
D1.4.2	Results of migration of data mining algorithms to GRID structure	12	R	CO	Technical
D2.3	Demonstration and report on WP2 1st prototypes	12	R, P	PU	Technical
D3.3	1st prototype – first WP3 software release for health and HEP applications build on local grid infrastructure.	12	P	PU	Technical
D5.1.4	Quarterly report	12	R	PU	Managerial
D5.1.13	Yearly report	12	R	PU	Managerial
D5.2.4	Report on requirements for integration and interoperability with DataGrid	12	R	PU	Technical
D5.3.4	Public (industrial) presentations	12	E	PU	Disseminative
D2.4	Internal progress report on WP2 software evaluation and testing	15	R	CO	Technical
D3.4	Internal progress report on WP2 software evaluation and testing	15	R	CO	Technical
D4.5	WP4 status internal report	15	R	CO	Technical
D5.1.5	Quarterly report	15	R	PU	Managerial
D5.2.5	Detailed report on the CrossGrid architecture	15	R	PU	Technical
D5.1.6	Quarterly report	18	R	CO	Managerial
D1.3	Report on application prototype 0 run	19	R	CO	Technical
D5.1.7	Quarterly report	21	R	CO	Managerial
D5.3.13	Dissemination and exploitation report *with appendices:* *5.3.5 Public (industrial) presentations* *5.3.10 Project leaflet / brochure* *5.3.16 Yearly collaboration meeting*	23	R	PU	Disseminative
D1.4	Internal progress report Second internal SW release	24	R SW	CO	Technical
D2.5	Demonstration and report on WP2 2nd prototypes	24	R, P	PU	Technical
D3.5	Report on the results of the WP3 2nd and 3rd prototype	24	R, P	PU	Technical

D4.6	WP4 status internal report update	24	R	CO	Technical
D5.1.8	Quarterly report	24	R	CO	Managerial
D5.1.14	Yearly report	24	R	CO	Managerial
D5.2.6	Current CrossGrid architecture assessment report	24	R	PU	Technical
D1.5	Evaluation of the WP1 2nd prototype	27	R	PU	Internal, not sent to Brussels
D2.6	Internal progress report on WP2 software evaluation and testing	27	R	CO	Internal, not sent to Brussels
D3.6	Internal progress report on WP3 software evaluation and testing	27	R	CO	Internal, not sent to Brussels
D5.1.9	Quarterly report	27	R	CO	Managerial
D1.6	Report on application prototype 1 run	30	R	CO	Internal, not sent to Brussels
D4.7	WP4 status internal report	30	R	CO	Internal, not sent to Brussels
D5.1.10	Quarterly report	30	R	CO	Managerial
D4.8	Final testbed with all applications integrated	33	P	PU	Internal, not sent to Brussels
D5.1.11	Quarterly report	33	R	CO	Managerial
D5.2.7	Final CrossGrid architecture and interoperability requirements description	33	R	PU	Technical
D5.3.14	Dissemination and exploitation report *with appendices:* *5.3.6 Public (industrial) presentations* *5.3.11 Project leaflet / brochure* *5.3.17 Yearly collaboration meeting* *5.3.18 CD-ROM*	35	R	PU	Disseminative
D1.0.4	Final managerial report for WP1	36	R	CO	Internal, not sent to Brussels
D1.7	Report on final application demonstration	36	R, D	PU	Technical

D2.7	Demonstration and documentation on the final versions and testing of all WP2 software components	36	R, D	PU	Technical
D3.7	WP3 final report	36	R, D	PU	Technical
D4.9	WP4 final demo and report	36	R, D	PU	Technical
D5.1.12	Quarterly report	36	R	CO	Managerial
D5.1.15	Yearly report	36	R	CO	Managerial
D5.2.8	Technology implementation plan	38	R	PU	Technical
D5.1.16	Final report	38	R	PU and CO	Managerial

1.7. MANPOWER CONSUMPTION

The graph below contains information on how much manpower was initially assigned to each workpackage of the project and on how much manpower (both EU-funded and additional) was actually utilized during the course of development.



2. PROJECT RESULTS AND ACHIEVEMENTS

CrossGrid, being a complex and far-reaching project, has yielded achievements in several distinct areas, all of them comprising a single, coherent architecture, which is presented in Figure 2.1. A thorough discussion of each CrossGrid software component can be found in the final definition of the CrossGrid architecture, which constitutes a separate Project deliverable (D5.2.7).

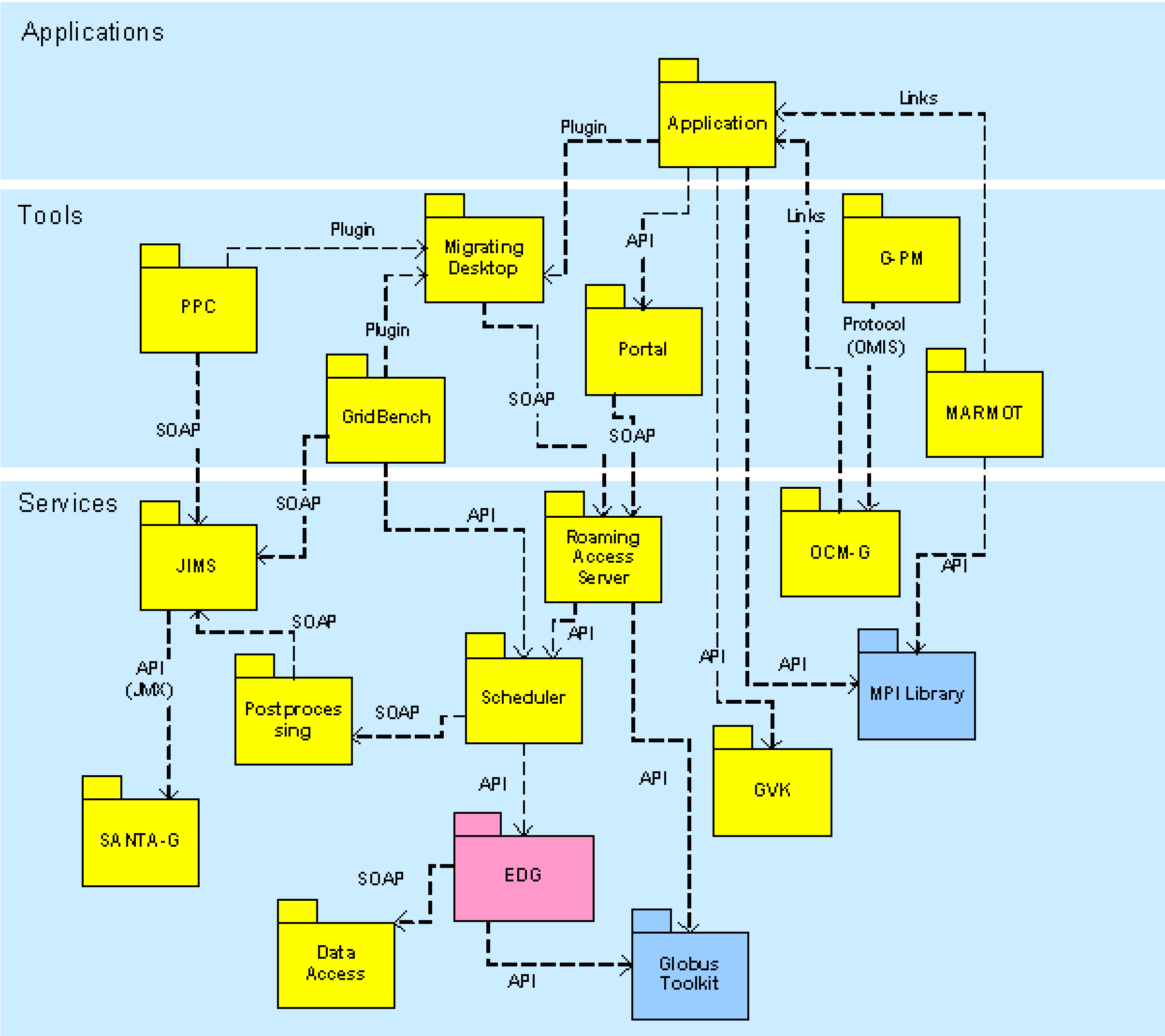


Figure 2.1: CrossGrid architecture

2.1. CROSSGRID APPLICATIONS

The applications selected for development within CrossGrid are at the same time compute- and data-intensive. Each of these applications has practical use and addresses a societally- or scientifically-important issue for the European Community. While the Project itself developed four applications, additional applications may be deployment on the CrossGrid testbed (see below).

2.1.1. Interactive simulation and visualization in a biomedical system

CrossGrid task 1.1, led by the University of Amsterdam, built a prototype of a Grid-based problem-solving environment (PSE) for virtual vascular surgery, using a set of hardware and software resources available via the CrossGrid infrastructure for building a specific framework to support vascular surgeons and interventional radiologists in their pre-operative decision-making. The task achieved secure Grid access, node discovery and registration, Grid data transfer, application initialization, medical data segmentation, segmented data visualization, computational mesh creation, job submission, distributed blood flow visualization, and bypass creation. The application incorporates vascular reconstruction tasks into the Grid. The input for experiments is the data from a medical image repository in Leiden. The patient's blood flow is simulated using Grid resources. An efficient mesoscopic computational haemodynamics solver for blood-flow simulations is based on parallel cellular automata. The application is able to simulate pulsatile Newtonian flow in a straight rigid 3D tube. To allow for the parallel execution, the simulation volume is divided into several sub-volumes, and each sub-volume is processed concurrently. To ensure good user experience a unique Virtual Reality system is built, which serves as the interaction-visualization front-end for the user manipulations over the Grid. End-users can interact with the system via a multi-modal interface, which combines natural input modes of context sensitive interaction by voice, hand gestures and direct manipulation of virtual 3D objects, called the Virtual Operating Theatre - users can "play" the role of a vascular surgeon planning and conducting the treatment of a vascular disease on a virtual simulated patient.

Exploitation: To ensure good user experience, a unique desktop Virtual Reality system (a Personal Space Station) will be built, which will serve as the interaction-visualization front-end for the user manipulations over the Grid. End-users can interact with the system via a multi-modal interface, which combines natural input modes of context sensitive interaction by voice, hand gestures and direct manipulation of virtual 3D objects. We call it the Virtual Operating Theatre, as a user can 'play' the role of a vascular surgeon planning and conducting the treatment of a vascular disease on a virtual simulated patient.

2.1.2. Flooding crisis team support system

The flood forecasting application framework with appropriate simulation models enable users to easily run desired sequence of simulations and respective post-processing tools, browse the results of simulations, register results into the replica management service and applicable metadata into the metadata catalogue for later search and retrieval. The flood forecasting application consists of several simulation models (meteorological, hydrological and hydraulics) and appropriate post-processing tools connected together, so constituting a workflow. Meteorological model is used to forecast precipitation, which is used by hydrological model for computation of discharge of the river. That is used in the final step for the actual computation of possible flood by the hydraulics model. All the models generate binary output data, which are then used by post-processing tools to generate pictures visualizing the situation. These pictures are then used by respective experts for situation evaluation. The flood forecasting application has two user interfaces to enable users to interact with the application in a more user-friendly way. One interface is implemented as a web portal accessible with standard web browser. It consists of a set of portlets – reusable web components – that are placed in the portlet portal framework. Another user interface is implemented as plug-in for Migrating Desktop (MD) – a desktop user environment for working with grids developed. While the portal interface focuses mainly on the flood application, MD is a general tool that enables a user to work with grid in a flexible way. It also integrates other applications via its plug-in system.

Exploitation: The flood application will be transferred to the EGEE project testbed and will be enhanced in such a way as to be useful for real users within the ESR VO (earth science research virtual organization).

2.1.3. Distributed data analysis in High Energy Physics

This task developed two parallel analysis applications for High Energy Physics: ANN, an interactive neural network training application to be used in search for new physics; and SLEUTH, an application to search for Higgs bosson, supersymetric particles and exotics physics in the CMS experiment. For both applications the Migrating Desktop (MD) plugin was developed in order to provide a graphical user interface. Also, a study on the feasibility of sending detector data in real time to remote locations for online processing using the grid infrastructure was performed. This research activity was focused on finding optimal settings for higher level communication protocols to efficiently exploit installed capacity of computer networks.

Exploitation: The analysis applications are foreseen to be used in the future CMS experiment at LHC. The network studies would need to continue access to the CrossGrid testbeds and close collaboration with GEANT and NREN operators. These studies may become a base for research for massive long-haul transfers in real time for other sciences.

2.1.4. Weather forecasting and air pollution modelling

This task has developed a representative collection of Grid applications for use by the atmospheric/oceanographic community, focusing on long- and medium-range weather forecasts for the Baltic Sea basin, as well as comprehensive air pollution modelling for selected sites. The air pollution application provides a high performance air quality simulation executing the STEM-II (Sulphur Transport Eulerian Model 2) program on a Grid platform. The MPI parallel version of the model, developed previously, was ported to the Grid by making use of the other CrossGrid components. Besides, the Grid enabled version was enhanced with a user interface that provides interactivity features, and the inclusion of a fault tolerance mechanism based on checkpointing.

Exploitation: Implementation of WAM model with COAMPS input: partner institutions (e.g. the Maritime Institute in Gdansk) running operational wave models will introduce high resolution COAMPS forecast to their operational practice.

As concerns air pollution modeling, the application was designed for use by the As Pontes power plant in Spain, but we have plans to show our product to other power plants interested in it. In case of a positive answer, the tool can be adapted to each particular case. We also plan to show the tool to local and national institutions interested in having control over air pollution produced by power plants.

2.2. GRID TOOLS

2.2.1. The MARMOT MPI verification tool

MARMOT is an MPI application development tool that checks automatically at run-time whether an application conforms to the MPI-standard and uses e.g. MPI resources such as communicators, groups or data types in a correct way. It also verifies if the application contains non-portable constructs and thus ensures that the application runs seamlessly on any platform in the Grid. The tool can also detect problems such as deadlocks and race conditions. Any CrossGrid application can be run with MARMOT. Using the Migrating Desktop, the application can be launched and the results of MARMOT can be monitored. Currently there are only two tools similar to MARMOT: MPI-CHECK from University of Iowa, which is restricted to Fortran code, and Umpire from Lawrence Livermore National Laboratory, which is not publicly available. MARMOT supports the MPI-1.2 standard (C and Fortran language binding) and is freely available. Extending its functionality, e.g. to MPI-2 or hybrid applications, is an ongoing effort.

Exploitation: The tool has been deployed in the CrossGrid testbed and also on two out of the three national high performance computing centres in Germany (HLRS in Stuttgart and NIC in Jülich). In 2005, we formed a consortium with ZHR (TU Dresden), GWT, GNS mbH, SCAI Fraunhofer. The goal of the “PERFECT’ project is the development of a software environment integrating existing tools such as Vampir or MARMOT. The proposal was submitted to the German Federal Ministry of Education and Research. Universität Stuttgart has also agreed with Intel on a research project funded by the Intel Advanced Computing Center. The scope of the project focuses on interoperability between Marmot and the Intel® Thread Checker.

2.2.2. The PPC Performance prediction component

The global purpose of the PPC tool is to provide performance information about some selected computational kernels when they are executed on the Grid. In some cases, this information is just predicted (execution times, communication overheads), in others it is, in fact, real (number of communications, load balance). The predicted data are based on analytical models obtained from exhaustive monitorized measurements. The kernels that are considered include both applications dependent and general purpose. In addition, the tool includes a Graphical User Interface (GUI) to help the user to establish the features of the grid, and then, to simulate their effects on the target parallel kernels. Therefore, information about the behavior of the kernels under different virtual system configurations can be extracted and visualized. This tool can be run in a single workstation or PC, because no grid computations are involved.

Exploitation: Currently we are completing the research with new functionalities and kernels, not previewed in the project. The final objective is to present the whole tool in a Ph.D. thesis next year. The tool will be used in our Ph.D. courses as a tool for practical exercises. Some of the main possible clients of our predictions are resource brokers; we therefore plan to contact developers of resource brokers to analyze the possibility of integrating our models.

2.2.3. The G-PM monitoring tool

G-PM is a performance evaluation tool for interactive Grid applications (both sequential ones and parallel applications based on MPI). It can be used by program developers as well as knowledgeable program users to investigate the performance of applications, especially, to help in discovering performance bottlenecks. The tool consists of three components: a Performance Measurement Component (PMC), a High Level Analysis Component (HLAC), and a User Interface and Visualization Component (UIVC). The distinguished new features of G-PM and especially the HLAC are: - It supports on-line analysis, i.e. the performance can be evaluated while the program is running. This allows immediate correlation to user interactions and is a prerequisite for interactive application steering. It supports both automatic and user-defined instrumentation. In addition, it enables the user to define new (possible application-specific) metrics, based on the existing metrics and the user-defined instrumentation. Such a feature has never before been implemented in an on-line performance analysis tool.

Exploitation: Developing automatic performance analysis systems - the research results will be integrated into future automatic performance analysis systems in cooperation with the University of Siegen. Further research and development of G-PM will include enhancements of the user interface and distributed evaluation of measurements.

2.2.4. The CrossGrid Portal

The Portal that was developed in the context of the CrossGrid project had as primary goal the provision of a user-friendly web-based interface, through which the potential user would be able to submit jobs to the Grid. There is co-operation between the Portal and the Job Submission Services (JSS), which is software that resides on the Roaming Access Server (RAS). These two “components” were developed and are being maintained by other project partners. The Portal's building blocks are the portlets, all of which are visible on the portal page. Each portlet performs a specific function and all of them provide the user with the ability of submitting a job on the Grid, watching its status, and retrieving the output files upon execution. Thus, they cover all steps of the lifecycle of a Grid job. First, there is the Proxy Manager portlet. This has a key role in the Portal, since it is responsible for the authentication and authorization of the user, in order to be able to have access to the rest of the portlets. The authentication and authorization take place as soon as the user has valid credentials delegated in a MyProxy server that is located in the CrossGrid testbed. The valid proxy certificate will be retrieved by the Proxy Manager portlet, and the user will automatically gain access to all portlets that can be found on the Portal page. These range from simple ones that perform submission of a simple job on the CrossGrid testbed to portlets that perform submission of specific large applications. As soon as the user submits any kind of job, he is immediately able to watch its status as it is being carried out, until it has finished. There are also some other generic portlets (Job List Match, Job Log Info), which give information about the available testbed machines that are able to run a specific job or trace each step of the job from the time that is submitted until the time that is finished and some output (or error) has been produced. The Job Get Output portlet is an important function of the Portal. Through this, the user can retrieve the output and/or error from a submitted job. The results can be obtained via HTML links to the output and error files, which are shown inside the portlet area.

Exploitation: The Grid Portal toolkit that was developed in the context of the CrossGrid project will be further developed, partly in collaboration with other partners. Some parts of it will be used in other Grid-related projects, such as MEDIGRID.

2.2.5. Migrating Desktop and Roaming Access Server

The Migrating Desktop is a ready-to-use GUI framework for accessing the Grid resources in a uniform way. The user can access their data and run applications from any Internet terminal equipped with the Java Virtual Machine. This facility offers the environment, which is fully configurable, and adaptable to the user needs, it gives a transparent user work environment, independent of the system version and hardware. The Migrating Desktop supports all the Grid paradigms such like the following: single sign-on and trust, monitoring jobs, job and data management, Virtual Organizations, interactive jobs, plugins, etc. This solution is a complete, production-deployed software environment with special focus on interactive Grid applications. These applications are simultaneously compute- as well as data-intensive and are characterized by the interaction with a person in a processing loop. It can be used by the scientific community for simulating of the complex problems and it covers the requirement for ‘utility computing’ concept in business too. The Migrating Desktop can also give access to a set of business applications by providing the graphical front-end to the applications and database engines distributed across the company. Utility computing is a combination of two approaches: according to the first one companies can call upon a third party to host and manage their IT infrastructure, and according to the second one, companies can pay for the resources they use. Grid computing is similar to utility computing but with a different approach. Grid computing is a form of virtualization that can handle computation-intensive tasks, using a large number of systems and combining them into one grid. Such grids can include widely distributed systems or systems within one data centers. Grid technology has enabled computing resources to be shared globally and easily managed, and the infrastructure becomes incredibly flexible. Nowadays the infrastructure is a pool of virtual resources that the user can call on as needed. The developed environment is offered for free in terms of the CrossGrid License Agreement. It means, that there are no additional costs for the installation packages, and TCO leads only on the used hardware and administrative prerequisites of the middleware – the Roaming Access Server, and related packages. The Roaming Access Server is an underlying layer that mediates between the Migrating Desktop and grid resources. Entire structure of proposed infrastructure bases on the CrossGrid License Agreement and other Open License models. There is no other Grid desktop with the support for interactive applications on the market.

Exploitation: MD is slated for further development and exploitation in the emerging BalticGrid project which will extend Grid infrastructure to the Baltic states. Within that project, MD will be extended with a mechanism that allows integration of applications and security mechanisms (VUS) as well as virtual user support (GAS). We also intend to better study the market possibility to introduce the MD+RAS (or their concept, or an extended version of) in the Grid Infrastructures DATAMAT would set up for potential customers, in partnership with the other "owners" of MD and RAS, mainly PSNC. Furthermore, MD and RAS will be exploited by the Computational Grid of Ireland.

2.2.6. Gridbench

GridBench is a tool for evaluating the performance of Grids and Grid resources through benchmarking. It facilitates easy definition of parameterized execution of benchmarks on the Grid, while at the same time allowing for archival and retrieval of results and the creation of customized charts from these results. GridBench comprises a framework of tools and a suite of benchmarks. The tools provide a user-friendly graphical interface for defining, executing and administrating benchmarks upon the resources of a Virtual Organization (VO), as well as for browsing results. Additionally, it provides tools for archiving and analysing results through the easy construction of custom graphs. GridBench leverages new and existing benchmarks from the HPC community. New Benchmarks complement the tried and respected HPC benchmarks, that have been adapted to run the Grid.

2.3. GRID SERVICES

This area deals with new Grid functionality as required by the interactive applications being considered by the CrossGrid project. Two distinct categories of services can be discerned:

- **Application-specific services**: This category includes services tailored to the needs of individual applications, such as the **Grid Visualization Kernel** (GVK) for image manipulation within the biomedical application or the User Interaction Services which translate requests submitted by users of each application into generic jobs which can be handled by Grid scheduling agents.
- **Generic services**: A layer of basic services which extend the backbone of the Grid. These typically augment the capabilities of standard Grid middleware (most notably the Globus and DataGrid toolkits, which are at the heart of most European Grid infrastructures; notably the EGEE infrastructure, with which CrossGrid is closely aligned) to provide advanced functionality and better optimization specifically within CrossGrid.

The developed components are described in more detail below.

2.3.1. SANTA-G

The SANTA-G NetTracer is a demonstrator of the SANTA-G framework. SANTA-G is a generic framework that was developed to support information sources that generate a large amount of data at a very fast rate in a form unsuitable for direct insertion to a Grid monitoring system. It does this by allowing direct access to the data through the Grid Information System. The NetTracer demonstrates this by allowing users to access log files stored in libcap (a network packet capture library) format through the EU DataGrid's (EDG) Relational Grid Monitoring Architecture (R-GMA) monitoring and information system. Examples of tools that generate logs in this format are Tcpdump, and Snort (a network intrusion detection system). It is aimed at system administrators for network traffic analysis across multiple sites within a Grid, and also for performance analysis. It is also intended to use the SNORT functionality of the NetTracer to construct a Grid-wide intrusion detection system.

Exploitation: The enabling technology for the SANTA-G framework, the CanonicalProducer, developed by this task, became an integral part of the R-GMA system. It is currently being further developed, as the OnDemandProducer, within the EGEE project, and is expected to be further exploited within EGEE and relying parties.

2.3.2. The JIMS service

JIMS - the JMX-based Infrastructure Monitoring System - is a result of three years of development during the CrossGrid project. Its current version 1.5.32 is available as an open source project under CrossGrid Licence, for use with Linux and Unix systems. Last validated version 1.5.23 is installed in CrossGrid production and development testbed. It uses Java Management Extensions what makes it platform independent grid monitoring tool with interoperable Web Service API (Application Programming Interface) and Java command line clients. JIMS is assigned rather to other middleware tools making use of monitoring parameters, including resource brokers, benchmarks or performance predictions mechanisms. Its command line client applications can be used also by network and Grid middleware administrators, to investigate the infrastructure configuration and resource usage. There are some barriers resulting from chosen Java technology, concerning memory usage, which makes it better suited for systems with large physical memory for Java Virtual Machine in which the JIMS is running.

Exploitation: JIMS exploitation plans concern Grid installations interested in modular system for monitoring infrastructure, network and Grid engines using the mechanism of pluggable modules loaded on demand.

2.3.3. The CrossGrid scheduler

The scheduler, developed in collaboration with the DataGrid project, enables assigning job to the respective computing resources with the aid of a job description metafile, written in the JDL language. The scheduler is fully compatible with the graphical user interface tools developed within other CrossGrid tasks, and can parse job description files generated automatically from user input in the Migrating Desktop and portal, while retaining the possibility of command-line operation. The actual resources are stored in a registry maintained by the low-level Globus Toolkit middleware.

Exploitation: Using GMDAT for data taking and predictions in EGEE and LCG - the tool is going to be used by researchers working on setting up operational Grid in federations within EGEE project. We also intend to disseminate the results related to CrossBroker (commercial name of the CrossGrid scheduler) to understand if there is a possibility to include it (or its concept, or an extended version thereof) in any future Grid service provisioning DATAMAT is thinking of, especially in fields such as prototype simulation activities and high performance technical computing, where the accurate and advanced allocation of resources to run jobs to be interactively steered and possibly running on more CPUs (i.e. true parallelism) is a real need.

2.3.4. The OCM-G monitoring service

The OCM-G (OMIS-Compliant Monitoring system for the Grid) is a system for monitoring of parallel applications running on the Grid. The OCM-G provides services for collecting and preprocessing information about applications at runtime. The OCM-G runs as an autonomous infrastructure exposing a standard interface. The OCM-G is designed as a basis for application-development-support tools, such as performance analyzers, debugger or visualizers. Using the services of the OCM-G, tools are (among others) enabled to obtain performance measurements of the monitored application, related to, for example, delay and volume of communication, CPU usage, etc. Information collected from the OCM-G is typically visualized in the form of graphical charts to show application progress, monitor activities of individual processes, observe communication patterns, detect bottlenecks, etc. Compared to existing systems with a similar purpose, the OCM-G provides some unique capabilities which, among others, are as follows: (1) Support for Grid applications running across multiple sites. (2) High performance: techniques for data rate reduction to ensure extremely low overhead and high responsiveness, enough even for monitoring of interactive applications. (3) Flexibility: rather than a fixed set of metrics, the OCM-G provides an extensive set of low level services; this allows for construction of a variety of performance metrics with desired semantics. (4) Extendibility: the OCM-G can be extended with additional services, loaded dynamically at run-time. (5) Compact and secure design: the OCM-G runs as a set of user processes, which use a lightweight and fast socket-based communication mechanism. At the same time, state-of-the-art techniques are applied to ensure secure communication. No special privileges (special access rights, additional open ports on firewalls, or other potential security holes) are required. (6) Design as an autonomous infrastructure exposing a standard interface OMIS (On-line Monitoring Interface Specification). The services of the OCM-G are available via this interface, which minimizes the effort of porting OMIS-based tools across platforms (basically only the OCM-G needs to be ported). (7) Interoperability: thanks to the design as an autonomous service with a well-defined protocol, the OCM-G supports the interoperability of multiple tools monitoring a single application. Currently the OCM-G is a fully operational grid-enabled system possessing the above-described features. The target applications are currently MPI-based ones, though the core design and implementation of the OCM-G does not in any way depend on the particular type of the application. The OCM-G is a flexible, extendible and powerful system which currently is used as a basis of the G-PM performance analysis tool, and in the future can be used to build various types of tools, not only performance analyzers, but also different types of visualizers, debuggers, load balancers, or other tools. The OCM-G can also easily be integrated as part of a larger infrastructure, for example as part of a generic Grid monitoring and information service. In such a system, the OCM-G could work as one of many systems collecting information about different Grid entities (infrastructure, applications, middleware, etc.)

Exploitation: Developing automatic performance analysis systems - the research results will be integrated into future automatic performance analysis systems in cooperation with the University of Siegen. Further research and development of OCM-G back-porting of OCM-G to clusters of PCs; use of developed monitoring concepts in other contexts; adaptation of a parallel debugger.

2.3.5. The Grid Visualization Kernel - GVK

The Grid Visualization Kernel aims at exploiting the power of the Grid to provide visualization services to the scientific user. Large amounts of data involved in such visualization process require optimized network transmission in order to achieve the required performance goals and minimize latency for interactive applications. The GVK is a standalone service responsible for handling visual data on the Grid and presenting it to higher-level components, with the use of optimization techniques, such as data compression or multiple connections

Exploitation: Continued Development: within the nationally-funded Austrian Grid project we will extend the functionality of GVK for supporting the visualization tasks arising within the Austrian Grid project.

2.3.6. Data Access Optimization - UDAL

The Unified Data Access Layer (UDAL) provided by task 3.4 of the CrossGird project, provides a flexible architecture for storage nodes and storage centers. UDAL allows for a very flexible optimization and control of the internal behavior access to data stored in heterogeneous devices. It is fully adaptable for future purposes, but currently is used only for organizing the estimation of data access latency and bandwidth of internal storage nodes. However, it is important to notice that the provided solution could be also directly used for other purposes. The current version of UDAL is distributed together with a set of specialized components for data access cost estimation for data stored in secondary and tertiary storage. The version of UDAL implemented during the CrossGrid project is expected to simplify access to Grid storage and make it simpler and more efficient as well as to cover Grid storage heterogeneity. This tool is a framework containing plugins, which are automatically selected by built-in expert system in order to be best matched to the current context. Those plugins called cecomponents are divided into categories (specializations) which are responsible for different services offered by UDAL. UDAL is released with a set of cecomponents for data access estimations for different storage devices. The UDAL release bundle contains cecomponents for data access cost estimation for secondary storages like HDDs, disk arrays, san disk as well as cecomponents estimating access cost for data stored in tertiary storages (HSM) like DiskXtenter (former UniTree), Castor. Hence, UDAL is a universal platform that might be useful for various data access purposes. There are also cecomponents for unifying data access to different data storages providing a universal API which conceals the heterogeneity of real storage devices installed at data centers. At the moment, cecomponents are available for accessing data in secondary storage as well as specialized ones for DiskXtender available trough FTP and Castor available trough RFIO. The UDAL platform is fully expandable for future purposes. Simply writing new cecomponents or modifying built-in expert system rules can make the tool applicable for new challenges as well as new data storage and service devices. cecomponents can be developed in almost any programming language, including a wide array of well-known scripting tools. Simply speaking, communication between UDAL and the registered cecomponents being under UDAL control is in the form of a shell environment; in other words it involves parameters passed to ordinary executables in the Unix environment. The output is passed as standard stdin / stdout streams.

Exploitation: UDAL is based on the Component-Expert Architecture making the layer very flexible and easy adaptable for changes. We want to exploits that approach to other problems such as automatic contextual service matching in a Grid infrastructure. In the nearest future we plan to re-implement some parts of the tool for Java platform to make the product more easily modifiable for future research activities.

2.4. INTERNATIONAL TESTBED ORGANIZATION

One of the principal aims of CrossGrid has been to create a pan-European testbed for developers of Grid applications, paving the way for further deployment and cooperation in a Grid environment, even after the Project concludes. These objectives have now been achieved - the Project testbed includes 16 separate sites in 11 countries, with over 200 CPUs and 4 TB of storage space dedicated to the Project. The Grid framework provided on this infrastructure is based on basic job submission services, information systems, authentication, authorization and data transfer provided by the Globus Toolkit. These services are extended by a workload management system, replica location services, improved information system and Virtual Organization management system developed by the EDG project, incorporating also other middleware components from packages such as Condor. This software is currently distributed in a version known as LCG-2, assembled and supported by the LHC Computing Project at CERN, and widely installed also in the EGEE project centers. For all purposes, the final version of the CrossGrid testbed includes two distinct setups. The “development” testbed, with limited resources in five different sites, supports deployment and test of new software, that once validated is deployed in a larger and more stable “production” testbed, where the applications are executed. Table 2.1 summarizes these contributions.

Site	***Location***	***Testbed***
AUTH	Thessaloniki – Greece	Production + Development
CESGA	Santiago – Spain	Production
CYFRONET	Cracow – Poland	Production
FZK	Karlsruhe – Germany	Development
ICM	Warsaw – Poland	Production
IISAS	Bratislava – Slovakia	Production
IFCA	Santander – Spain	Production + Development
IFIC	Valencia – Spain	Production
INS	Warsaw – Poland	Production
LIP	Lisbon – Portugal	Production + Test

PSNC	Poznan – Poland	Production
TCD	Dublin – Ireland	Development
UAB	Barcelona – Spain	Development
UCY	Nicosia – Cyprus	Production
UoA	Athens – Greece	Production + Test
Demokritos	Athens – Greece	Production + Development
UvA	Amsterdam – Netherlands	Production

Table 2.1: CrossGrid testbed sites

Exploitation: Maintenance of the testbed for further development of applications - we need to maintain the testbed for further development of those applications which need it (meteo, flooding, air pollution and high energy physics).

The evolution of the CrossGrid testbed is presented in Table 2.2 below.

Month	Sites	Users			Jobs			Uptime
		Total	Active	Ratio	Total	Ok	Ratio	
2003-Aug	16	79	28	35%	11424	11059	97%	90%
2003-Sep	16	79	39	49%	9278	8781	95%	85%
2003-Oct	16	81	32	40%	8919	8772	98%	82%
2003-Nov	16	83	32	39%	3118	1950	63%	56%
2003-Dec	16	87	29	33%	1627	1565	96%	77%
2004-Jan	16	92	46	50%	16882	16526	98%	76%
2004-Feb	15	96	40	42%	17471	17394	100%	92%
2004-Mar	15	100	55	55%	39674	39357	99%	-
2004-Apr	15	101	40	40%	18620	18501	99%	94%
2004-May	15	104	43	41%	18648	18307	98%	87%
2004-Jun	15	105	42	40%	25687	24403	95%	94%
2004-Aug	15	111	31	28%	6148	6125	100%	96%
2004-Sep	15	114	44	39%	15381	14610	95%	95%
2004-Oct	16	119	57	48%	23279	23235	100%	97%
2004-Nov	16	119	43	36%	27151	26899	99%	99%
2004-Dec	16	120	44	37%	18106	18056	100%	100%
2005-Jan	16	121	39	32%	25546	25521	100%	100%

Table 2.2: CrossGrid testbed evolution

The CrossGrid testbed, having installed the LHC-2 middleware distribution, is fully compliant with the infrastructure of the EGEE project (representing the next generation of European Grid computing), and will be further supported in the framework of this project.

2.5. INFLUENCE ON THE EUROPEAN GRID COMMUNITY

From the very beginning of the Project's development cycle, cooperation has been maintained between CrossGrid and other European and international Grid projects, such as Globus, DataGrid, GridLab and GridStart. Particularly close contacts have been maintained with the DataGrid project. As a result of the joint effort of both projects, a common European Grids Industry and Research Forum was formed, starting with the First European AcrossGrids Conference organized by the CrossGrid project in Santiago de Compostela in February 2003, and followed up by another event in the series, in February 2005, in Amsterdam. Another important event spawned by the CrossGrid project is the Cracow Grid Workshop - an international conference devoted to emerging trends in Grid computing, hosted annually by the Institute of Nuclear Physics and ACC Cyfronet in Cracow, Poland (the most recent edition was held in December 2004, with details at http://www.cyfronet.krakow.pl/cgw04).

Appendix A contains the full list of CrossGrid publications submitted during the lifetime of the Project, as a measure of the Project's impact on the area of Grid computing.

3. METHODOLOGIES

The methodologies utilized in the CrossGrid project can be divided into the following subsections. Each subsection will contain comments regarding the methodologies used and their relation to the global state of the art.

3.1. ARCHITECTURE

- The architecture of the project (see Section 3) proved that interactive applications can be successfully run on Grid infrastructure based on Globus and EDG services, with the help of new CrossGrid services and tools.
- Due to the heterogeneity and multiplicity of software modules in CrossGrid, it was impossible to apply a uniform methodology or programming model, which could unify the architecture. This is, however, unavoidable in such a large project, which reuses a lot of legacy software. The CrossGrid experience showed that integration of such software systems is possible and the effort can be reduced by using standard technologies such as Web services.
- Dependency and collaboration with EDG and (later) LCG proved to be a good solution due to the following factors:
  - **Building on others' experience,** allowed to extensively use the EDG project experience and software, to build a basis for new challenging types of interactive applications and provide useful tools facilitating the interaction with the Grid.
  - **Integration with the European Grid community**, allowed to integrate the partners of CrossGrid into a European-wide Grid infrastructure taking part in EGEE and LCG projects.

3.2. OGSA INTEROPERABILITY

From the beginning of the Project, CrossGrid had been evaluating both the possibility of migrating to the new OGSI-based Globus Toolkit and the necessity of gearing the scientific work towards the service-oriented architecture of the Grid that OGSA envisioned. However, the first implementation of OGSI-based Globus Toolkit 3.0 was only released in June 2003 - the middle of the second year of CrossGrid development. Because of the dependency on DataGrid software, which is based on Globus 2, and also for stability reasons we decided not to migrate to the new toolkit. Nevertheless, the Project focused on preparing software in such a way that it would be "OGSA-ready". This entailed the usage of Web Services and XML where appropriate to facilitate the possible future migration to an OGSA-based Grid environment. Moreover, many CrossGrid partners initiated scientific and development work in this area. From the development point of view, the current plans of the Globus Alliance are to concentrate on a new release, GT4.0, based on the new WS-RF standard. This release is announced to be available in 2005, putting it out of reach of the CrossGrid project.

We consider the approach CrossGrid took towards OGSA as a good solution for maintaining a long-term project in the midst of substantial changes and evolution of Grid technologies. The usage of GT2 is important for stability reasons and for the interoperability with LCG and EGEE (previously EU DataGrid) projects. On the other hand, it is important to prepare the new software in such a way that it will be easy to use in future Grid systems based on OGSA standards. The usage of Web Services not only makes integration of components an easy task, but also prepares them for migration to future OGSA standards. As Grid Services and Web Services merge, it should become possible to migrate to the future common technology.

The general experience from the CrossGrid interoperability efforts may be following. As it is impossible to predict the future directions of Grid standards evolution, and moreover these standards may be subject to further changes, we have to emphasize that it is the generosity of solutions that is important and makes the software usable outside the project. In terms of interoperability, general conclusion is that the service-based approach proves to be well suited for such a large project involving distributed computing, as is in the case of CrossGrid.

3.3. TESTBED

- Good integration with European Grid community (EDG, EGEE, LCG) was achieved – collaboration methodologies proved successful.
- Grid software was installed at new computing centers in many countries.

3.4. SOFTWARE ENGINEERING

- Industry-based development cycle and procedures proved to be difficult to implement, but useful in the scientific community
- Quality assurance caused improvement of developed software and increased quality awareness among developers
- Fruitful integration effort enabled bringing together application and tool developers.

4. EUROPEAN ADDED VALUE

CrossGrid partners are aware of the i2010 launched initiative and would very much like to support its objectives. The Project has contributed to the Lisbon strategy in yielding extensive results in furthering Grid awareness within the European Community and in contributing to European leadership in the emerging field of Grid technologies. As stated the Project developed applications in the area of medicine, environment and research, addressing important social and governmental aspects, shown in the Project demos. These applications will be exploited for production runs after the Project concludes, and some of them will be the focus of further research and development, within the framework of FP6 Grid research (on the path to Next Generation Grids, as defined by the European Commission). CrossGrid software and tools have made their mark on a number of high-profile Grid development projects, including the following initiatives:

- EGEE (a project aiming to establish a European Grid testbed infrastructure in support of the new LHC collider at CERN, while retaining the capability to support other applications),
- K-WfGrid (a project which aims at knowledge-based scientific workflow orchestration and execution in a Grid environment for complex applications, such as the ones implemented within CrossGrid),
- CoreGRID (a European Network of Excellence devoted to Grid computing issues and research).

Furthermore, CrossGrid has contributed significantly to European and international standardization bodies, in particular through its intensive and ongoing participation in the activities of the GRIDSTART initiative, as well as the Global Grid Forum, including the following Working Groups and Research Groups:

- Open Grid Service Architecture - OGSA-WG,
- Open Grid Service Infrastructure - OGSI-WG,
- Job Submission Description Language - JSDL-WG,
- User Program Development Tools for the Grid - UPDT-RG,
- Open Grid Service Common Management Model - CMM-WG,
- Grid Scheduling Architecture - GSA-RG,

5. OUTLOOK

In three years we have developed Grid-enabled solutions for compute- and data-intensive applications that are distributed and require near real-time responses. These solutions are suitable for applications with a person in a computing loop; CrossGrid enables monitoring the progress of application execution, changing its parameters and receiving output on the fly.

A number of advanced applications, which have potentially significant practical impact within their respective domains, have been ported to the Grid environment. In addition, we have also developed and implemented solutions for running MPI applications on the Grid. Finally, CrossGrid has developed other supporting tools and services, geared towards implementing the notion of interactivity in Grid computing.

CrossGrid services and tools are built upon the Globus Toolkit. Where applicable, developing GGF specifications have been applied and web service technologies are used for implementation of various Grid components, enabling interoperability with Grid tools and middleware being developed by other EU Grid projects, as well as porting CrossGrid software to future Grid systems.

CrossGrid software has been available since 2004 under an open source license that is based on the DataGrid General Public License. Most CrossGrid software tools and components will be supported beyond the end of the Project by CrossGrid partners.

The Project has developed a large European Grid testbed with 16 sites, complete with security certificates, virtual organizations, site administrators and support personnel, fully compatible with the EGEE Grid infrastructure. The CrossGrid tutorial is available for potential users and it is also used at the Institute of Computer Science AGH in Krakow, the University of Nicosia and the Amsterdam University as a teaching aid, accompanying M.Sc. lectures on Grid technologies.

The software development process was preceded by a research program which resulted in about 200 scientific publications; the best of them will be collected in a CrossGrid book which is now undergoing internal review and consolidation. This approach has also resulted in a series of successful AcrossGrids Conferences (in Santiago de Compostela, Nicosia, and Amsterdam).

Meanwhile, CrossGrid solutions are being taken up by next-generation research initiatives under the 6th Framework Programme of the European Community, including EGEE, K-WfGrid, CoreGRID, as well as national Grid initiatives (e.g. Austrian Grid Initiative, IrishGrid in Spain, Grid Ireland, CLUSTERIX in Poland, Hellas Grid Initiative in Greece). Currently, members of our Consortium are working on subsequent proposals for EU Grid projects: pilot Grids, transparent semantic Grids, Grid infrastructures for environmental and medical applications, etc.

6. CONCLUSIONS

The CrossGrid project can be considered a fruitful and successful contribution to both European and global Grid research. In addition to a large quantity of useful software, the Project has contributed to development of Grid technologies in numerous other ways, such as through the creation and development of testbed infrastructures in 11 EU countries, the spreading of awareness and expertise in the area of Grid computing within the academic community as well as within society at large, and in spawning a number of promising follow-up research initiatives, ensuring further exploitation of Project results. CrossGrid contribution to standardization efforts and its influence on other European Grid projects cannot go unnoticed and we hope that CrossGrid products, as well as its partners, will continue to shape European Grid research in the years to come.

APPENDIX A: LIST OF CROSSGRID PUBLICATIONS

Articles in journals

Partner/Author	Title	Event/Letter
G.D. van Albada et al.	AG-IVE: An Agent Based Solution to Constructing Interactive Simulation Systems	ICCS 2002, Amsterdam
R.G. Belleman, R. Shulakov	High Performance Distributed Simulation for Interactive Simulated Vascular Reconstruction	ICCS 2002, Amsterdam
Dieter Kranzlmüller et al.	Debugging Large-Scale Long-Running Parallel Programs	ICCS 2002, Amsterdam
J.C. Mouriño	A Grid-Enable Air Quality Simulation	1st European Across Grids Conference, Spain
D. Rodríguez	RAID-1 and Data Stripping Across the Grid	1st European Across Grids Conference, Spain
M.Bubak et al.	Grid Services for HLA-based Distributed Simulation Frameworks	1st European Across Grids Conference, Spain
Dieter Kranzlmüller et al.	Grid-Enabled Visualization with GVK	1st European Across Grids Conference, Spain
M. Kupczyk et al.	Mobile Work Environment for Grid Users	1st European Across Grids Conference, Spain
M. Dikaiakos et al.	Search Engines for the Grid: A Research Agenda	1st European Across Grids Conference, Spain
R. Wismüller	The G-PM Tool for Grid-oriented Performance Analysis	1st European Across Grids Conference, Spain
K. Korcyl	Network performance measurements as part of feasibility studies on moving part of the ATLAS Event Filter to off-site Institutes.	1st European Across Grids Conference, Spain
E. Zudilova; P.M.A. Sloot	"Virtual Reality and Desktop as a Combined Interaction-Visualisation Medium for a Problem-Solving Environment"	Proceedings of the International Conference on Computational Science ISBN 3-540-40194-6, 05/2003
A. Tirado-Ramos; Z. Zhao; P.M.A. Sloot; D. van Albada; K. Zajiac; M. Bubak	"Experimental Grid Access for Dynamic Discovery and Data Transfer in Distributed Interactive Simulation Systems"	International Conference on Computational Science 2003 and appearing in the associated proceedings (as above)
Zhao, D. van Albada, A. Tirado-Ramos, K. Zajiac, P.M.A. Sloot	"ISS-Studio: prototype of a user-friendly tool for constructing Interactive Simulation Systems in PSEs"	International Conference on Computational Science 2003 and appearing in the associated proceedings
Michal Kosiedowski,	"Mobile Work Environment for Grid	International Conference on

Partner/Author	Title	Event/Letter
Miroslaw Kupczyk, Rafal Lichwala, Norbert Meyer, Bartek Palak, Marcin Plóciennik, Pawel Wolniewicz, Stefano Beco	Users. Grid Applications' Framework"	Computational Science 2003 and appearing in Springer's LNCS 2658 Int. Conf. On Computational Science, ICCS 2003, Part II, Saint Petersburg, 2003, pp. 1052 – 1058
L. Dutka, J. Kitowski	"Flexible Component Architecture for Information WEB Portals"	International Conference on Computational Science 2003 and appearing in Springer's LNCS 2658 Int. Conf. On Computational Science, ICCS 2003, Part II, Saint Petersburg, 2003
B. Balis and M. Bubak and W. Funika and R. Wismüller	"Monitoring and Performance Analysis of Grid Applications"	International Conference on Computational Science 2003 and appearing in Springer's LNCS 2658 Int. Conf. On Computational Science, ICCS 2003, Saint Petersburg, 2003
M. Bubak, M. Malawski and K. Zajac	Architecture of the Grid for Interactive Applications	International Conference on Computational Science 2003 and appearing in Springer's LNCS 2658 Int. Conf. On Computational Science, ICCS 2003, Saint Petersburg, 2003
M. Bubak, M. Malawski, K. Zajac	"Grid Architecture for Interactive Applications"	PPAM'2003 - International Conference on Parallel Processing and Applied Mathematics, Czestochowa, Poland, 7-10/9/2003 and published in the Springer LNCS
M. Bubak, K. Gorka, T. Gubala, M. Malawski, K. Rycerz	"Automatic Flow Building for Component Grid Applications"	PPAM'2003 - International Conference on Parallel Processing and Applied Mathematics, Czestochowa, Poland, 7-10/9/2003 and published in the Springer LNCS
K. Zajac, M. Bubak, M. Malawski, P. Sloot	"Execution and Migration Management of HLA-based Interactive Simulations on the Grid"	PPAM'2003 - International Conference on Parallel Processing and Applied Mathematics, Czestochowa, Poland, 7-10/9/2003 and published in the Springer LNCS
D. Nikolow, R. Slota	"Gray Box Based Data Access Time Estimation for Tertiary Storage in Grid	Parallel Processing and Appl. Math. (PPAM2003),

Partner/Author	Title	Event/Letter
and J. Kitowski	Environment”	Czestochowa, Poland, September 2003
B. Balis, M. Bubak, W. Rzasa, T. Szepieniec, R. Wismüller	“Security in the OCM-G Grid Application Monitoring System”	Parallel Processing and Appl. Math. (PPAM2003), Czestochowa, Poland, September 2003
V. D. Tran, D. Froechlich, W. Castaings	Parallelizing Flood Model for Linux clusters with MPI	Parallel Processing and Appl. Math. (PPAM2003), Czestochowa, Poland, September 2003
L. Hluchy, J. Astalos, M. Dobrucky, O. Habala, B. Simo, V. D. Tran	Flood Forecasting in a Grid Environment	Parallel Processing and Appl. Math. (PPAM2003), Czestochowa, Poland, September 2003
M. Kunze	“The CrossGrid Project”	volume 502, issues 2 - 3 of Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment April 21, 2003
M. Bubak, W. Funika, R. Wismüller	“A Performance Analysis Tool for InteractiveGrid Applications”	Performance Analysis and Grid Computing, Kluwer Academic Publishers, V. Getov et al. Editors, November 2003
Paul Heinzlreiter, Dieter Kranzlmueller	“Visualization Services on the Grid - The Grid Visualization Kernel”	Parallel Processing Letters (PPL), Vol. 13, No. 2, pp. 135-148, June 2003
Edgar Gabriel, Rainer Keller, Bettina Krammer, Matthias S. Müller, Michael M. Resch	“MPI Development Tools and Hierarchical Optimizations for Applications on the Grid”	Journal of Grid Computing, September 1, 2003
B. Balis, M. Bubak, W. Funika, T. Szepieniec, R. Wismüller	“Monitoring of InteractiveGrid Applications”	Performance Analysis and Grid Computing, Kluwer Academic Publishers, V. Getov et al. Editors, November 2003
Paul Heinzlreiter, Dieter Kranzlmüller, Jens Volkert	“Network Transportation and Optimization for Grid-enabled Visualization Techniques”	Journal of Neural Parallel and Scientific Computations, November 30, 2003

Partner/Author	Title	Event/Letter
A.Tirado-Ramos, H.Ragas, D.Shamonin, H.Rosmanith, D.Kranzmueller	"Integration of Blood Flow Visualization on the Grid: the FlowFish/GVK Approach"	included in the CD-ROM proceedings of AxGrids 2004
L. Hluchy, V. Tran, B. Simo, O. Habala, J. Astalos, E. Gatial	Flood Forecasting in CrossGrid project	included in the CD-ROM proceedings of AxGrids 2004
D. Rodriguez, J. Gomes, J. Marco, R. Marco, C. Martinez-Rivero	MPICH-G2 Implementation of an Interactive Artificial Neural Network Training	included in the CD-ROM proceedings of AxGrids 2004
E. Heymann, M. A. Senar, A. Fernández, J. Salt	Managing MPI Applications in Grid Environments	included in the CD-ROM proceedings of AxGrids 2004
M. Malawski, M. Wieczorek, M. Bubak, E. Richter-Was	Lhcmaster - a System for Storage and Analysis of Data Coming from the ATLAS Simulations	included in the CD-ROM proceedings of AxGrids 2004
B. Balis, M. Bubak, M. Radecki, T. Szepieniec, R. Wismueller	Application Monitoring in CrossGrid and Other Grid Projects	included in the CD-ROM proceedings of AxGrids 2004
R. Wismueller, M. Bubak, W. Funika, T. Arodz, M. Kurdziel	Support for User-Defined Metrics in the On-line Performance Analysis Tool G-PM	included in the CD-ROM proceedings of AxGrids 2004
M. Bubak, M. Malawski, G. Mlynarczyk P. Nowakowski, R. Pajak, K. Rycerz	Software Engineering in the EU CrossGrid Project	included in the CD-ROM proceedings of AxGrids 2004
M. Dikaiakos, A. Artemiou	Ovid: A Browser for Grids	included in the CD-ROM proceedings of AxGrids 2004
R. Wismüller, M. Bubak, W. Funika, T. Arodz, M. Kurdziel	Support for User-Defined Metrics in the On-line Performance Analysis Tool G-PM	published in "M. Dikaiakos (Ed.): Grid Computing -- Second European AcrossGrids Conference AxGrids2004", LNCS 3165, Springer Verlag, October 2004
Roland Wismueller	Die Suche nach der Kraft des Gitters (In search of the power of the Grid)	Newspaper: Westfälische Rundschau, Nr. 293, Wednesday, Dec. 15th, 2004
Bettina Krammer, Matthias S. Müller, Michael M. Resch	MPI I/O Analysis and Error Detection with MARMOT	submitted to the EuroPVMMPI 2004 conference (Budapest, Hungary) in May 2004 for the

Partner/Author	Title	Event/Letter
		first time and the final paper submission took place on 05/07/2004; published in book form by Springer
R. Wismüller, M. Bubak, W. Funika, T. Arodz, M. Kurdziel	“Performance measurement model in the G-PM tool”	Intl. Conference on Computational Science, ICCS 2004, Krakow, Poland
M. Kupczyk, R. Lichwała, N. Meyer, B. Palak, M. Płóciennik, M. Stroiński, P.Wolniewicz	The Migrating Desktop as a GUI Framework for the "Applications on Demand"	published in LNCS 3036/ICCS2004 on 06/06/2004
V. Tran, L. Hluchy	Parallelizing flood models with MPI: approaches and experiences	published in Proc. of International Conference on Computational Science, Part III, LNCS 3038, Springer-Verlag, 2004, pp. 425-428, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
L. Hluchy, O. Habala, V. Tran, B. Simo, J. Astalos, M. Dobrucky	Infrastructure for Grid-based Virtual Organizations	published in Proc. of International Conference on Computational Science, Part III, LNCS 3038, Springer-Verlag, 2004, pp. 124-131, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
B. Baliś, M. Bubak, W. Rząsa, T. Szepieniec	Efficiency of the GSI Secured Network Transmission	published in Bubak, M., van Albada, G. D., Sloot, P. M. A., Dongarra, J. J. (Eds.), Computational Science - ICCS 2004. 4th International Conference, Kraków, Poland, June 2004, LNCS, no. 3036, vol. I, Springer, 2004, pp. 107-115.
R. Wismüller, M. Bubak, W. Funika, T. Arodź, M. Kurdziel	Performance Measurement Model in the G-PM Tool	published in Bubak, M., van Albada, G. D., Sloot, P. M. A., Dongarra, J. J. (Eds.), Computational Science - ICCS 2004. 4th International Conference, Kraków, Poland, June 2004, LNCS, no. 3036, vol. I, Springer, 2004, pp. 462-465.
B. Baliś, M. Bubak,	Adaptation of Legacy Software to	published in Bubak, M., van

Partner/Author	Title	Event/Letter
M. Węgiel	Grid Services	Albada, G. D., Sloot, P. M. A., Dongarra, J. J. (Eds.), Computational Science - ICCS 2004. 4th International Conference, Kraków, Poland, June 2004, LNCS, no. 3038, vol. III, Springer, 2004, pp. 26-33
M. Bubak, T. Gubała, M. Kapałka, M. Malawski, K. Rycerz	Grid Service Registry for Workflow Composition Framework	published in Bubak, M., van Albada, G. D., Sloot, P. M. A., Dongarra, J. J. (Eds.), Computational Science - ICCS 2004. 4th International Conference, Kraków, Poland, June 2004, LNCS, no. 3038, vol. III, Springer, 2004, pp. 34-41.
K. Rycerz, M. Bubak, M. Malawski, P. Sloot	Support for Effective and Fault Tolerant Execution of HLA-based Applications in the OGSA Framework	published in Bubak, M., van Albada, G. D., Sloot, P. M. A., Dongarra, J. J. (Eds.), Computational Science - ICCS 2004. 4th International Conference, Kraków, Poland, June 2004, LNCS, no. 3038, vol. III, Springer, 2004, pp. 848-855
B. Baliś, M. Bubak, W. Rząsa, T. Szepieniec	Efficiency of the GSI Secured Network Transmission	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
W. Funika, M. Bubak, M. Smętek	Monitoring System for Distributed Java Applications	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
T. Arodź	On New Radon-Based Translation, Rotation and Scaling Invariant Transform for Face Recognition	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow,

Partner/Author	Title	Event/Letter
		Poland
Z. Balogh, M. Laclavik, L. Hluchy, I. Budinska, K. Krawczyk	REMARK - Reusable Agent-Based Experience Management and Recommended Framework	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
K. Krawczyk, M. Majewska, M. Dziewierz, R. Slota, Z. Balogh, J.Kitowski, S. Lambert	Reuse of Organisational Experience Harnessing Software Agents	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
D. Nikolow, R. Słota, J. Kitowski, Ł. Skitał	Virtual Storage System for the Grid Environment	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
J. Midura, K. Balos, K. Zieliński	Global Discovery Service for JMX Architecture	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
L. Kawulok, K. Zieliński, M. Jaeschke	Trusted Group Membership Service for JXTA	published in Proc. of International Conference on Computational Science, LNCS 3038, Springer-Verlag, 2004, ISSN 0302-9743, ISBN 3-540-22116-6, June 6-9, Cracow, Poland
K. Balos, K. Zielinski	JIMS – the Uniform Approach to Grid Infrastructure and Application Monitoring	In Advances in Grid Computing: EGC 2005 Amsterdam; Lecture Notes in Computer Science, Springer Verlag 2005.
L. Dutka and J. Kitowski	Stochastic Approach for Secondary Storage Data Access Cost Estimation	In Advances in Grid Computing: EGC 2005 Amsterdam; Lecture Notes in Computer Science, Springer

Partner/Author	Title	Event/Letter
		Verlag 2005.
G. Tsouloupas, M. Dikaiakos	GridBench: A WorkBench for Grid Benchmarking.	submitted to the European Grid 2005 Conference (EGC2005) on 18/11/2004 and published in the proceedings
George Tsouloupas, Marios Dikaiakos	GridBench: A Workbench for Grid Benchmarking	submitted to the European Grid Conference 2005, Amsterdam, The Netherlands in October 2004 and published in the proceedings
W. Xing, M. Dikaiakos, H. Yang, A. Sphyris, G. Eftychidis	A Grid-enabled Digital Library System for Natural Disaster Metadata	submitted to the European Grid Conference 2005, Amsterdam, The Netherlands in October 2004 and published in the proceedings

Conference contributions

Author(s)	Contribution	Event
CrossGrid SG (M.Turala et al.)	"CrossGrid-Development of Grid Environment for Interactive Applications"	PIONIER 2002 Poznan April 23, 2002
M. Kupczyk, R. Lichwala, N. Meyer, B. Palak, M. Plociennik, P. Wolniewicz	"Common Graphical User Interface for Grid"	Proceedings of Parallel and Distributed Computing and Networks as a part of the 22nd IASTED International Multi-Conference on Applied Informatics
P. Słowikowski et al.	"Authorization Mechanisms for Portal Accessible Services"	Cyfronet Proceedings: ISBN 83-915141-0-2
W. Alda, J. Kitowski	"On Models of Distributed Scientific Visualization"	Cyfronet Proceedings: ISBN 83-915141-0-2
B. Baliś et al.	"Monitoring of Multithreaded Applications on SGI Computers"	Cyfronet Proceedings: ISBN 83-915141-0-2
M. Bubak et al.	"European Grid Projects: an Overview"	Cyfronet Proceedings: ISBN 83-915141-0-2
M. Bubak et al.	"Current Status of the CrossGrid Architecture"	Cyfronet Proceedings: ISBN 83-915141-0-2
M. Bubak et al.	"Integration of the CrossGrid Services into the OGSA Model"	Cyfronet Proceedings: ISBN 83-915141-0-2
M. Bubak et al.	"A Proposal of the Services For Managing Interactive Grid Applications"	Cyfronet Proceedings: ISBN 83-915141-0-2

Author(s)	Contribution	Event
M. Bubak et al.	“Performance Analysis of Grid Interactive Applications with G-PM Tool”	Cyfronet Proceedings: ISBN 83-915141-0-2
B. Baliś et al.	“OCM-G - a Grid Application Monitoring System: Towards the First Prototype”	Cyfronet Proceedings: ISBN 83-915141-0-2
B. Ławniczek et al.	“Jiro-Based Grid Infrastructure Monitoring - First Prototype Functionality”	Cyfronet Proceedings: ISBN 83-915141-0-2
Ł. Dutka et al.	“Component-Expert Architecture as Flexible Environment for Selection Data-handlers and Data-Access-Estimators in CrossGrid”	Cyfronet Proceedings: ISBN 83-915141-0-2
D. Nikołow et al.	“Data Access Time Estimation for HSM Systems in Grid Environment”	Cracow, Poland (15/1/03)
P. Nyczyk et al.	“CrossGrid WP4 Testbed Status at ACK Cyfronet UMM”	Cyfronet Proceedings: ISBN 83-915141-0-2
L. Hluchy et al.	Problem Solving Environment for Flood Forecasting	9th EUROPVM/MPI
D.Kranzlmueller et al.	Optimizations in the Grid Visualization Kernel	IPDPS 2002
O. Ponce et al.	Training of Neural Networks: Interactive Possibilities in a Distributed Framework	9th EUROPVM/MPI
M.Bubak et al.	The CrossGrid Performance Analysis Tool for Interactive Grid Applications	9th EUROPVM/MPI
B.Balis et al.	An Infrastructure for Grid Application Monitoring	9th EUROPVM/MPI
D.Kranzlmueller et al.	A Grid Middleware Extension for Scientific Visualization	PDPTA 2002
P. Heinzlreiter et al.	Interactive Visualization in Large-Scale Distributed Computing Infrastructures with GVK	SCI 2002
D. Nikolow et al.	Access Time Estimation for Tertiary Storage Systems	Euro-Par2002
L. Dutka et al.	Application of Component-Expert Technology for Selection of Data-handlers in CrossGrid	9th EUROPVM/MPI
P. Heinzlreiter et al.	Interactive Virtual Reality Volume Visualization on the Grid	4th DAPSYS
P. Heinzlreiter et al.	GVK - Visualization Services for the Grid	CGW '02, Cracow
Tomasz Bold et al.	ATLAS data challenges using Cyfronet cluster	CGW '02, Cracow

Author(s)	Contribution	Event
Krzysztof Korcyl et al.	Network performance measurements for massive data transfers between CERN Geneva and Cyfronet Cracow	CGW '02, Cracow
M.Bubak et al.	CrossGrid - Development of Grid Environment for Interactive Applications	PIONIER 2002, Poznan
L. Hluchy et al.	Virtuálna organizácia pre predpoved' povodní na báze technolo'gie Grid	MOSIS '02
J.M. Gutiérrez et al.	Probabilistic Networks For Statistical Downscaling And Spatialisation of Meteorological Data.	Geophysical Research Abstracts, Vol. 4, 194 (2002)
M. Kupczyk et al.	Roaming Access and Migrating Desktop	CGW '02, Cracow
M. Kupczyk et al.	Mobile Work Environment for Grid Users. Testbed	Terena Networking Conference, Croatia
Peter M.A. Sloot et al.	Grid-Based Interactive Visualization of Medical Images	1st European HealthGrid Conference, France
N. Meyer, M. Bubak, J. Marco, H. Marten, P. M. A. Sloot, and Michał Turała	"First Prototype Version of Crossgrid Tools and Services"	PIONIER 2003 Conference May 15, 2003
M. Kupczyk, R. Lichwała, N. Meyer, B. Palak, M. Płóciennik, P. Wolniewicz	"Mobile Work Environment for Grid Users Testbed"	TERENA Networking Conference, May 21, 2003
George Tsouloupas, Marios Dikaiakos	"GridBench: A Tool for Benchmarking Grids"	4th International Workshop on Grid Computing (Grid 2003), June 13, 2003
Bettina Krammer, Katrin Bidmon, Matthias S. Müller, Michael M. Resch	"MARMOT: An MPI Analysis and Checking Tool"	ParCo 2003 conference, Dresden, Germany, August 27, 2003
K. Stockinger, H. Stockinger, L. Dutka, R. Slota, D. Nikolow, J. Kitowski	"Access Cost Estimation for Unified Storage Systems"	Supercomputing 2003 Conference, Phoenix, Arizona, US, from 15-21/11/2003 and appeared in the associated IEEE Proceedings
Paul Heinzlreiter, Dieter Kranzlmueller, Jens Volkert	"Network Transportation Within a Grid-based Visualization Architecture"	published in June 2003 in Proc. PDPTA 2003

Author(s)	Contribution	Event
M. Bubak, K. Gorka, T. Gubala, M. Malawski, K. Rycerz	"Component-Based System for Grid Application Workflow Composition"	Proceedings of Recent Advances in Parallel Virtual Machine and Message Passing Interface, 10th European PVM/MPI User's Group Meeeting, Venice, Italy, September/October 2003, 2003, pp. 611-618
L. Hluchy, V. D. Tran, D. Froechlich, W. Castaings	Methods and Experiences for Parallelizing flood Models	Proceedings of Recent Advances in Parallel Virtual Machine and Message Passing Interface, 10th European PVM/MPI User's Group Meeeting, Venice, Italy, September/October 2003
L. Hluchy, O. Habala, B. Simo, J. Astalos, V. D. Tran, M. Dobrucky	Problem Solving Environment for Flood Forecasting	7th World Multiconference on Systemics, Cybernetics and Informatics (SCI 2003), Orlando, Florida, USA, July 27-30, 2003
M. Bubak, T. Gubala, M. Malawski, K. Rycerz	"Grid Application Worklfow Composition"	Workflow Management RG BOF, October 8, 2003
M. Kupczyk, R. Lichwala, N. Meyer, B. Palak, M. Plociennik, P. Wolniewicz	"Common Graphical User Interface for Grid"	submitted to PDCN 2004, Innsbruck, Austria, on October 10, 2003 and published in the proceedings of the conference
Marcus Hardt, Ariel Garcia, Yannick Patois, Ulrich Schwickerath	"Collaborative Development Tools"	Cracow Grid Workshop CGW'03, October 15, 2003
K. Rycerz, M. Bubak, M. Malawski, P. Sloot	"Towards a Grid Management System for HLA-based Interactive Simulations"	Proceedings of The Seventh IEEE International Symposium on Distributed Simulation and Real Time Applications, 23-25/10/2003,Delft, the Netherlands, pp. 4-11
Ł. Dutka and J. Kitowski	"Automatic Application Builder for Grid Workflow Orchestration"	Cracow Grid Workshop '03, Cracow, Poland, October 27, 2003

Author(s)	Contribution	Event
Bartosz Balis, Marian Bubak, Wojciech Rzasa, Tomasz Szepieniec, Roland Wismüller	"Two Aspects of Security Solution for Distributed Systems in the Grid on the Example of the OCM-G"	Cracow Grid Workshop '03, Cracow, Poland, October 27, 2003
Kazimierz Balos, Leszek Bizon, Michal Rozenau, Krzysztof Zielinski	"Interoperability Architecture for Grid Networks Monitoring Systems"	Cracow Grid Workshop '03, Cracow, Poland, October 27, 2003
M. Bubak, T. Gubala, M. Malawski, K. Rycerz	"Design of Distributed Grid Workflow System"	Cracow Grid Workshop - CGW'03, 27-29/10/2003, and published in the CGW'03 Proceedings
M. Malawski, M. Wieczorek, M. Bubak, and E. Richter-Was	"Storage and Analysis System for Data Intensive High Energy Physics Applications"	Cracow Grid Workshop - CGW'03, 27-29/10/2003, and published in the CGW'03 Proceedings
Marian Bubak and Michal Turala	"CrossGrid in Its Halfway: Achievements and Challenges"	Cracow Grid Workshop - CGW'03, 27-29/10/2003, and published in the CGW'03 Proceedings
K. Rycerz, M. Bubak, M. Malawski, P. Sloot	"Execution Support for HLA-based Distributed Iteractive Applications"	Cracow Grid Workshop - CGW'03, 27-29/10/2003, and published in the CGW'03 Proceedings
M. Bubak, M. Malawski, G. Mlynarczyk, P. Nowakowski, R. Pajak, K. Rycerz, and M. Turala	"Software Development in the EU CrossGrid Project"	Cracow Grid Workshop - CGW'03, 27-29/10/2003, and published in the CGW'03 Proceedings
K. Stockinger, H. Stockinger, L. Dutka, R. Slota, D. Nikolow, J. Kitowski	"Access Cost Estimation for Unified Grid Storage Systems"	4th International Workshop on Grid Computing (Grid2003) which was held in conjunction with SuperComputing 2003, Phoenix, Arizona, USA
Peter Praxmarer, Paul Heinzlreiter, Dieter Kranzlmüller	"GMF: A Framework for Module Management on the Grid"	Cracow Grid Workshop CGW'03, November 19, 2003

Author(s)	Contribution	Event
M. Turała	"Computing needs of future physics experiments and world-wide computing LHC Computing Grid project"	published in the proceedings of the 4th Conference on "Computer Methods and Systems in Scientific Research and Engineering Studies", Cracow, 26-28 Nov. 2003, pp. 15-20
H. Marten, K.-P. Mickel	"The German Regional Tier-1 Computing Centre: Status, Strategy and Future Plans"	Proceedings of the Cracow Grid Workshop CGW'03, November 2003
M. Bubak, M. Malawski, G. Mlynarczyk, P. Nowakowski, R. Pajak, K. Rycerz, M. Turala	"Inżynieria oprogramowania w projekcie EU CrossGrid"	Chapter XL in: Huzar, Z., Mazur, M. (eds): Topics and Methods of Software Engineering, pp. 597-611, WNT 2003 (in Polish)
H.S.M. Cramer, V. Evers, E.V. Zudilova, and P.M.A. Sloot	"Usability Evaluation of a Simulated Vascular Reconstruction System"	International Workshop "Designing and Evaluating Virtual Reality Systems" (22-23/1/2004, University of Nottingham, UK)
L. Hluchy, O. Habala, B. Simo, J. Astalos, V. D. Tran, M. Dobrucky	Problem Solving Environment for Flood Forecasting	1st International NAISO Symposium on Information Technologies in Environmental Engineering (ITEE'2003), Gdansk, Poland, June 24-27, 2003
L. Hluchy, J. Astalos, M. Dobrucky, O. Habala, B. Simo, V. D. Tran	Grid-based Problem Solving Environment for Flood Forecasting	37th Spring International Conference Modelling and Simulation of Systems, Brno, Czech Republic, April 28 - 30, 2003
Z. Zhao, D. van Albada, P. Sloot	Interaction Scenario: orchestrating agents in a multi agent system	4th Workshop on Agent Based Simulation ABS4, Montpellier, France, April 2003
Gatial E., Maliska M., Habala O., Simo B., Hluchy L.	FloodGrid portal with built-in workflow management	published in the proceedings of MOSIS'04 "Modelling and Simulation of Systems", Roznov p.R., Czech Republic, place of publication: Ostrava, Czech Republic, April, 2004

Author(s)	Contribution	Event
Marian Bubak, Maciej Malawski, Katarzyna Rycerz, Michal Turala	CrossGrid - Tools and Services for Interactive Grid Applications	published in the proceedings of the 8th Annual ACM International Conference on Supercomputing, Saint-Malo, France.
Y. Perros, Z. Mosurska, S. Beco, M.Kokkosoulis, G.Eftihidis	Results and products of the CrossGrid IST project and their exploitation	published in the proceedings of the 1st International workshop on 'Data Processing and Storage Networking: Towards Grid Computing‘ which took place in the context of “Networking 2004”, 14/05/2004 Athens, Greece.
Herbert Rosmanith, Jens Volkert	Glogin – Interactive Connectivity for the Grid	submitted to the 5th Austrian-Hungarian Workshop on Distributed and Parallel Systems (DAPSYS 2004) and published in September 2004
Paul Heinzlreiter, Jens Volkert	Scheduling and Resource Brokering within the Grid Visualization Kernel	submitted to the 5th Austrian-Hungarian Workshop on Distributed and Parallel Systems (DAPSYS 2004) and published in September 2004
Dieter Kranzlmüller, Herbert Rosmanith, Paul Heinzlreiter, Martin Polak	Interactive Virtual Reality on the Grid	submitted to the 8th IEEE Intl. Symposium on Distributed Simulation and Real Time Applications, Budapest, Hungary and was published in October 2004
Herbert Rosmanith, Dieter Kranzlmüller	glogin - A Multifunctional, Interactive Tunnel into the Grid	published in the Proceedings of the 5th IEEE/ACM International Workshop on Grid Computing, Pittsburgh, PA, USA in November 2004
M. Dikaiakos, A. Artemiou	Navigating the Grid Information Space: Design and Implementation of the Ovid browser.	submitted to the IEEE/ACM CCGrid 2005, Cardiff, UK on 31/11/2004 and published in the proceedings
G. Tsouloupas, M. Dikaiakos	Characterization of Computational Grid Resources Using Low-level Measurements.	submitted to the IEEE/ACM CCGrid 2005, Cardiff, UK on 31/11/2004 and published in the proceedings

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Herbert Rosmanith, Jens Volkert	Traffic forwarding with GSH/GLOGIN	submitted to the EUROMICRO-PDP, and published in Lugano, Switzerland in February 2005.
George Tsouloupas, Marios Dikaiakos	Characterization of Computational Grid Resources Using Low-level Measurements	published in the Technical Report TR-2004-05, Department of Computer Science, University of Cyprus in October 2004
T. Szepieniec, M. Radecki, K. Rycerz, M. Bubak, and M. Malawski	Tools and Services for Interactive Grid Applications on the Grid - The CrossGrid Tutorial	published in the proceedings of the 11th European PVM/MPI Users' Group Meeting, Budapest, Hungary in September 2004.
B. Baliś, M. Bubak, W. Funika, R. Wismueller, M. Radecki, T. Szepieniec, T. Arodź, and M. Kurdziel	Performance Evaluation and Monitoring of Interactive Grid Applications	published in the proceedings of the 11th European PVM/MPI Users' Group Meeting, Budapest, Hungary in September 2004.
K. Balos	JMX-based Grid Management Services	Published in the proceedings of the Grid Nets 2004 Confrence, USA, California, San Jose, 28 October, 2004.
L. Hluchy, O. Habala, J. Astalos, V. Tran, B. Simo, M. Dobrucky, E. Gatial, M. Maliska	Software Environment of a Grid-based Virtual Organization for Flood Prediction	published in Pahl-Wostl, C., Schmidt, S. and Jakeman, T. (eds) iEMSs 2004 International Congress: "Complexity and Integrated Resources Management". International Environmental Modelling and Software Societey, Osnabrück, Germany, June 2004. CD-ROM.

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R. Byrom, B. Coghlan, A. Cooke, R. Cordenonsi, L. Cornwall, A. Datta, A. Djaoui, L. Field, S. Fisher, S. Hicks, S. Kenny, J. Magowan, W. Nutt, D. O'Callaghan, M. Oevers, N. Podhorszki, J. Ryan, M. Soni, P. Taylor, A. Wilson, X. Zhu	The CanonicalProducer: an instrument monitoring component of the Relational Grid Monitoring Architecture (R-GMA)	published in proceedings of The 3rd International Symposium on Parallel and Distributed Computing in association with HeteroPar'04, University College Cork, Ireland, July 5-7, 2004
D. Martinez, J. Mourino, T. F. Pena, M. Martin, P. Gonzalez. R. Doallo	Balanceo dinamico de la carga en la simulacion de la dispersion atmosferica de contaminantes	published in proceedings of XV Jornadas de paralelismo, Almeria, Spain, September 15-17, 2004
L. Hluchy, O. Habala, V. Tran, B. Simo, P. Heinzlreiter, E. Gatial, M. Maliska, J. Astalos, M. Dobrucky	Collaborative Grid Environment for Scientific Virtual Organizations. In: Special Session on Collaborative and Cooperative Environments	published in proceedings of the PDCS 2004, San Francisco, CA, USA, September 15-17, 2004
Paul Heinzlreiter, Dieter Kranzlmüller, Jens Volkert	Network Transportation and Optimization for Grid-enabled Visualization	published in Neural, Parallel & Scientific Computations, September 2004
M.Bubak, M. Turala, K. Zielinski	CYFRONET in Grid Technologies	published in the proceedings of CGW'04
M. Maliska, B. Simo, L. Hluchy	The Workflow Engine for the CrossGrid Flood Forecasting Application	published in the proceedings of CGW'04
P. Lason, A. Ozieblo, M. Radecki, T. Szepieniec	CrossGrid and EGEE Installations at Cyfronet: Present and Future	published in the proceedings of CGW'04
K. Balos, K. Zielinski	JIMS - the Uniform Approach to Grid Infrastructure and Application Monitoring	published in the proceedings of CGW'04
B. Balis, M.Bubak, M. Radecki, T. Szepieniec, R. Wismüller[(3)]	OCM-G - Advanced, Grid-Enabled System for On-line Application Monitoring	published in the proceedings of CGW'04
M. Bubak, W. Funika, R. Wismüller, T. Arodz, M. Kurdziel	Performance Measurements for Interactive Applications in CrossGrid	published in the proceedings of CGW'04
K. Rycerz, M. Bubak, M. Malawski, P. Sloot	Supporting HLA-based Distributed Interactive Simulations on the Grid - Current Status	published in the proceedings of CGW'04

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Harald Kornmayer, FZK	Article about CrossGrid in general and its interactivity features	Published in the r2b (research to business) newsletter of FZK
Rycerz, K., Bubak, M., Malawski, M., Sloot, P.	A Framework for HLA--based Interactive Simulations on the Grid	In: Simulation: Transactions of the Society for Modeling and Simulation International Special Issue: Applications of Parallel and Distributed Simulation in Industry
K. Rycerz, B. Balis, R. Szymacha, M. Bubak and P.M.A. Sloot	Monitoring of HLA Grid Application Federates with OCM-G	In S.J. Turner; D. Roberts and L. Wilson, editors, Eighth IEEE International Symposium on Distributed Simulation and Real-Time Applications (DS-RT'04), pp. 125-132. IEEE, Budapest, Hungary, October 2004. ISBN 3-540-22116-6.
B. Balis, M. Bubak, W. Funika, R. Wismueller, M. Radecki, T. Szepieniec, T. Adrodz, and M. Kurdziel	Grid Environment for On-line Application Monitoring and Performance Analysis	In Scientific Programming, 12(4):239-251, 2004.