4th annual report
June 2004 – June 2005

CERN openlab
for DataGrid applications

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Fourth Annual Report of the CERN openlab for DataGrid Applications
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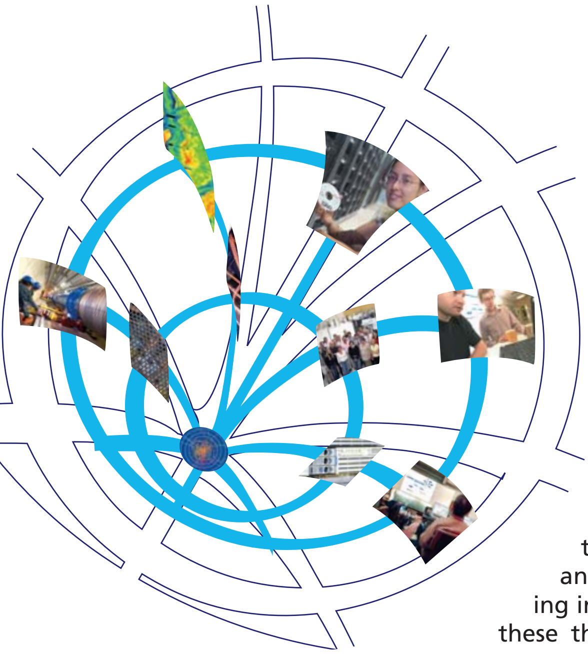
CERN openlab – the power of partnership



In 2004, the top priority that I set my new management team was to pursue with determination the completion of the three key aspects of the LHC, the accelerator, the experiments and the computing infrastructure. Of these three, computing presents a unique challenge, as the underlying technology is evolving much faster than in any other area of LHC engineering. In this context, the CERN openlab is playing a valuable service to the LHC project, by testing and verifying some of the hardware and software solutions that LHC computing will rely on in the years to come.

As well as the many excellent technical results that the openlab has provided over the last year, which are described in this annual report, the partnership has given CERN a means to share our vision of the future of scientific computing with leading IT companies, and gain deep insights into how industry sees computing hardware and IT services evolving in the future. This exchange of information is valuable to all involved. For CERN, it helps us chart a path for LHC computing in years to come. For the industry partners, the sort of global Grid being pioneered for the LHC holds significant promise for industrial applications – everyone is aware that this may be a new World Wide Web in the making.

I had an opportunity to experience this fruitful exchange first-hand at a special brainstorming session arranged during the Computing in High Energy and Nuclear Physics (CHEP'04) conference, which was sponsored by the openlab partners. In the room were some of our top physicists and computing specialists, as well as leading experts from the industry partners. It was gratifying to see how much interest and enthusiasm there was all around the table for pursuing and even expanding the scope of the CERN openlab partnership in future.

As the CERN opencluster project has demonstrated, the CERN openlab is an effective framework for collaboration between multiple industrial partners, in a pre-competitive spirit and based on open standards. I am encouraged by this successful outcome to believe that, as the opencluster project draws to a close this year, it will prove to be the first of many important projects that we will develop jointly with our industrial partners in the coming years.

I therefore thank all CERN openlab partners for ensuring this first phase of CERN openlab reaches a successful conclusion, and I look forward to continuing this valuable partnership in the future. Ultimately, the benefits of this sort of partnership will be enjoyed by the entire high-energy physics community, and more broadly by society, as advances in the underlying technologies help the LHC experiments to increase mankind's understanding of the Universe, and enrich our common scientific culture.

Robert Aymar
Director General of CERN

THE CONTEXT
The challenges of the Large Hadron Collider

In 2007, the world's largest and most powerful particle accelerator, the Large Hadron Collider (LHC), will begin operation at CERN, the European Organization for Nuclear Research. Currently being assembled in a 27km circular tunnel previously used by CERN's LEP accelerator, the LHC will collide beams of protons at an energy of 14 TeV. Beams of lead nuclei will be also accelerated, smashing together with a collision energy of 1150 TeV.

These unprecedented particle energies require novel superconducting magnet technology to keep the particles on track (see picture). There will be four detectors on the LHC ring, ALICE, ATLAS, CMS and LHCb, each a massive instrument several stories high, and each optimised for probing different aspects of the high-energy collisions. Already now, these detectors are taking shape in deep underground caverns.

The LHC will be used to answer some of the most fundamental questions of science. A prime target of the LHC is to pin down the Higgs boson, a particle hypothesised to explain the origin of the different masses of fundamental particles. However, the LHC will address a host of other fundamental questions, too, such as the origin of "dark matter" in the universe, the unification of electroweak and strong forces and the origin of the asymmetry between matter and antimatter.

How much data will the LHC produce? Current estimates are 15 Petabytes (15 million Gigabytes – the equivalent of several million DVDs) per year. And this number will increase significantly as the LHC is improved over its lifetime. For comparison, worldwide annual production of information in all forms has been estimated at about 5000 Petabytes in 2002. In other words the LHC will on its own account for a few per mill of global information production.

It is not only the total amount of data produced that is astounding. The rate at which this data is produced is also pushing the envelope for what advanced networking equipment can handle. Data rates in excess of 1 Gigabyte per second are anticipated. And the resulting data must be analysed, and compared with simulated data based on different theoretical models, all of which adds up to huge processing requirements – the equivalent of roughly 50,000 standard PCs in 2005.

From the early stages of planning the LHC in the 1990s, it was clear that the storage and processing requirements would dwarf any facility that could reasonably be assembled at CERN. As a result, a distributed solution – a data and computing Grid – was chosen, based on the fact that CERN has over 250 institutional partners in Europe and 200 more in the rest of the world, most of which have significant computing resources to contribute to such a Grid.

Installation of the first LHC dipole magnets in March 2005

CERN in a nutshell

CERN is the world's largest particle physics centre. Founded 50 years ago, the laboratory was one of Europe's first joint ventures and includes today 20 Member States. With a staff of 2500, and a community of 6500 physicists from universities and laboratories around the world who are users of CERN's facilities, CERN provides the ultimate tools to explore what matter is made of and what forces hold it together. These tools, the accelerators and detectors, are complemented by massive computing facilities to support the analysis of the data.

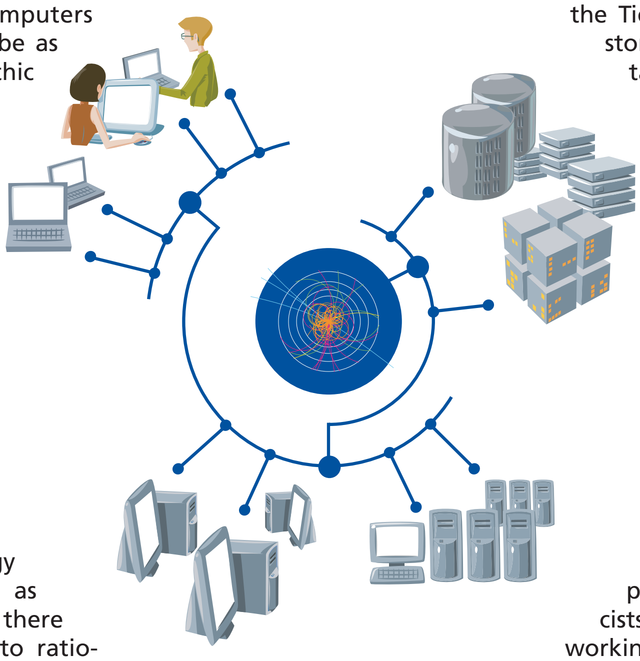
A Grid by any other name

The term Grid was coined to describe the concept of globally distributed computing and data storage. While the notion of distributed computing has been around since the beginning of electronic computing, the idea of extending it to a global scale is only conceivable thanks to the amazing progress that telecommunications has made over the last few years, allowing large amounts of data to be shipped over high-speed networks to major computing centres around the world. Another key ingredient in making such a Grid work is developing the necessary "middleware" to run computers distributed around the globe as though they were a monolithic resource.

Today, there are many varieties of Grid technology, distinguished in part by their area of application and the sort of computing environment they are being deployed in. Unlike the Web, where a simple set of standards and protocols have dominated the evolution of the technology, there are myriad Grid standards. However, as Grid technology matures, and in particular as industry learns to adopt it, there will be a strong pressure to rationalise. This requires developing open standards that create a level playing field for all IT companies. It is precisely this philosophy that is at the core of CERN openlab, both in name and in spirit.

Grid middleware to harness the combined power of idle PCs in a single organisation is already commercially available. And distributing computing tasks to thousands of private PCs, as done by the popular screen-saver program SETI@home, is now common for many scientific applications. But the objective of developing a Grid for the LHC is altogether more ambitious. This requires storing the Petabytes of data from the LHC in a distributed fashion, so that they are easily accessible to thousands of scientists around the world, along with the necessary computing power to analyse them.
This sort of Grid goes far beyond simple "cycle harvesting" – it means a sophisticated infrastructure to monitor resources, distribute the computing load efficiently over the Grid, move date rapidly from CERN to partner centres and ensure that relevant data is easily accessible when and where it is needed. This also requires providing the necessary security and accounting mechanisms to satisfy users and resource providers, as well as managing the access policies of different computing centres.

The Grid architecture for the LHC also builds on a definite hierarchy of sites. CERN, the Tier-0 centre, is a central hub, storing a copy of all data on tape, and also distributing this to Tier-1 centres, of which there are ten so far. The Tier-1 centres will store data from one or more experiments, for access by regional Tier-2 centres, of which there are already over 100. The Tier-2 centres are typically the physics departments via which the LHC users, at Tier-3 sites, will be running their analysis. The social dimension of such a Grid should not be underestimated. It is perhaps no surprise that high-energy physicists, with a long tradition of working in large, international and multi-institutional teams, should be pioneering this kind of Grid technology.



Schema of the tiered structure of the LHC Computing Grid, with CERN as the Tier-0 hub, Tier-1 centres providing regional access to data, and Tier-2 centres via which the physicists do the analysis from Tier-3 sites

LCG: the world's largest science Grid

In March 2005, the LHC Computing Grid (LCG) project announced that the Grid it is operating had surpassed 100 sites distributed over 31 countries. This makes it the world's largest international scientific Grid. The sites participating in the LCG project are primarily universities and research laboratories. They contribute more than 10,000 central processor units (CPUs) and a total of nearly 10 million Gigabytes of storage capacity on disk and tape. This Grid receives substantial support from the EU-funded project Enabling Grids for E-sciencE (EGEE), which is a major contributor to the operations of the LCG project.

Yet despite the record-breaking scale of the LCG project today, the current processing capacity of this Grid is estimated to be just 5% of the long-term needs of the LHC. Therefore, an overriding challenge for the LCG project is to continue to grow its capacity rapidly over the coming two years, both by adding sites, increasing resources available at existing sites, and ensuring interoperation with other Grid projects that are contributing to the overall LHC computing infrastructure, such as Grid3/OSG and NorduGrid. In addition, the exponential increase in processor speed and disk storage capacity inherent to the IT industry will help to achieve the LHC's ambitious computing goals.

In 2004-05, LCG continued to run data challenges with the individual LHC experiments, which simulate the sort of data processing and storage demands that the experiments will make of the LCG. In addition, LCG launched a new set of service challenges, which test the underlying ability of the Grid to cope with the huge data flow anticipated from the LHC.

Map indicating sites contributing to LCG as of spring 2005. The total number of participating sites had reached 130

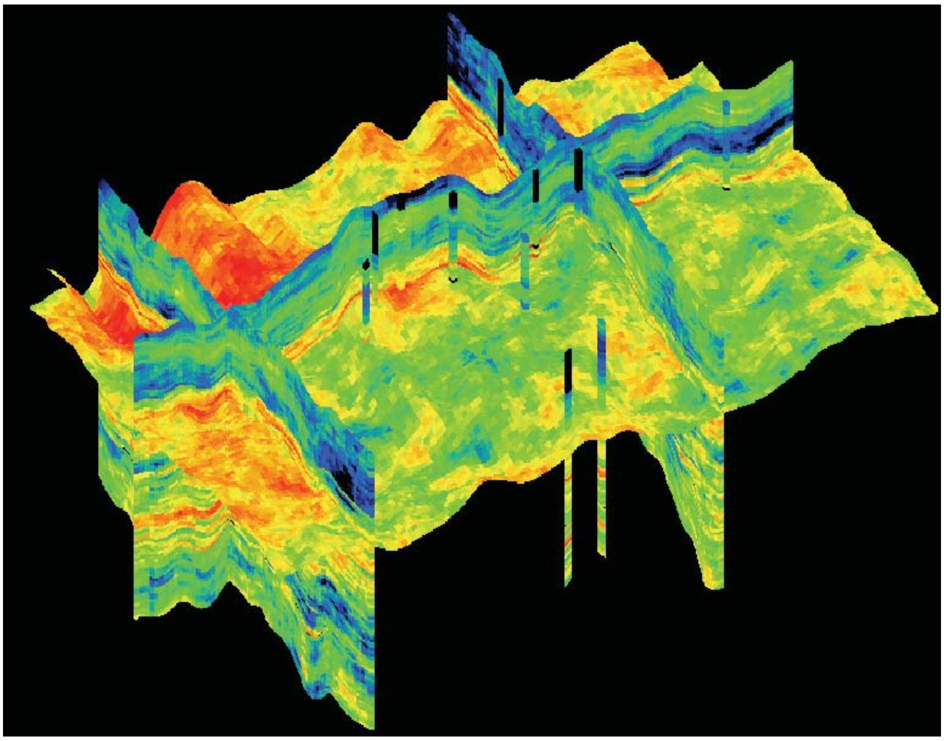
EGEE: sharing computing power for all sciences

The Enabling Grids for E-sciencE (EGEE) project is developing a Grid infrastructure to provide researchers in both academia and industry with access to major computing resources, independent of their loaction, 24 hours a day. The project was launched in April 2004, and one year later there were already applications from six different scientific disciplines running on the EGEE Grid infrastructure. CERN is the lead partner in EGEE, which involves a total of 70 institutional partners from Europe, the US and Russia. The LHC is the flagship application for the EGEE project, and LCG provides the bulk of the operations management for EGEE.

One example application is Geocluster, seismic processing software developed and marketed by the Compagnie Générale de Géophysique (CGG) for use in exploring the composition of the Earth's layers. CGG uses Geocluster to offer products and services to the worldwide oil, gas, mining and environmental industries. For a company like CGG, the benefit of EGEE is in part being able to link existing corporate data centres around the world together in a more effective way, using the functionality of the Grid middleware. Other applications running on the EGEE Grid infrastructure include drug discovery, cosmology and digital libraries.

EGEE is developing a new middleware package, called gLite, which incorporates in a modular way the best-of-breed solutions from a number of leading Grid projects, such as the European DataGrid project, EGEE's predecessor, the Virtual Data Toolkit (VDT), Globus and Condor, which are US initiatives. A team at CERN is leading this development of gLite, a first version of which was released in the spring of 2005.

3D visualisation of the Earth's layers using Geocluster software running on EGEE



THE STATUS
On track for completing the opencluster project

In January 2003, CERN openlab was officially launched as a new framework for multilateral projects between CERN and the IT industry. At that time HP, Intel and Enterasys were contributing key equipment to the openlab's first major three-year project, the CERN opencluster. IBM joined the partnership a few months later, and Oracle by the end of that year. These partners have brought state-of-the-art technologies – both hardware and software – to the collaboration, each primarily in a specific technological area: processors for Intel, servers for HP, storage management for IBM, switches and routers for Enterasys and databases for Oracle. At CERN a dedicated team of in-house experts and industry-funded research fellows have helped to integrate and test this advanced equipment and software, often working closely with technical teams from the partner companies.

This annual report summarises progress since the last annual meeting of the board of sponsors in June 2004. This represents a period of consolidation for the opencluster project, where initial investments in testing and validating the equipment and porting Grid and physics software to the opencluster have paid off in several ways. The opencluster has, for example, played a central role in many of the data and service challenges carried out during the last year for the LHC Computing Grid (LCG). Equipment from the opencluster has continued to produce record-breaking performance for data transfer between CERN and the US. IBM's Storage Tank technology has been extensively tested at CERN, with impressive results. HP has used the expertise developed through the opencluster project to connect the company's own data centres in Puerto Rico and Bristol to the LCG. And Oracle software is now being distributed to LCG Tier-1 sites, thanks to the efforts of Oracle-sponsored openlab fellows.

At the end of this year, the opencluster project comes officially to a close. While there remain several exciting challenges for the last six months of the project, the list of successes so far already amply justifies the efforts that CERN and its partners have put into this project. I would like to take this opportunity to congratulate everyone involved in achieving these successes, both in the partner organisations and amongst my staff here in CERN's IT Department.

Besides technical achievements, a major event for CERN openlab during the last year was the Computing in High Energy Physics (CHEP'04) conference, held in Interlaken from 27 September to 1 October. I wish to thank all partners for their support of this event – the level of sponsorship was unprecedented, and contributed directly to the high quality of the event, which hosted a record number of over 500 delegates. Also, a special session on the future of Scientific Computing, featuring speakers from the openlab partners, provided insight into where information technology is going and how this could impact the high-energy physics community.

CERN openlab partners also participated in other events during CERN's 50th anniversary celebrations, contributing to activities for the general public during the open-day event and taking part in the official ceremony to mark the 50th anniversary. In return, my colleagues and I have taken part in a variety of events hosted by industry partners, an activity which helps both to strengthen our professional relationship, and to inspire us to consider new areas of common interest.

In conclusion, I would like to thank all the industrial partners for their generous and unwavering support of the CERN opencluster project, and I look forward to developing new projects of similar scope and ambition in the openlab framework.

Wolfgang von Rüden
Head of the CERN openlab for DataGrid applications and Head of CERN's IT Department

The openlab team: a growing pool of talent

CERN openlab represents a significant investment in manpower for the IT Division. There are five CERN fellows (postdoctoral researchers) and one masters-level technical student working on the opencluster project, as well as contributions from 16 senior technical and administrative staff at CERN. There have also been significant technical contributions from technical liaisons in the partner companies. In addition 14 undergraduate summer students were active for periods of 2-3 months in the CERN openlab student programme during June-September 2004, with co-funding from HP and Enterasys.

A unique feature of CERN openlab is that it functions as a cross-organizational activity, rather than as a separate unit. Senior technical staff come from several of the IT Department's technical groups (Architecture and Data Challenges, Communication Systems, Database and Engineering Systems), and there is close collaboration with the major Grid projects LCG and EGEE, as well as with computing experts in the individual LHC experiments. This open structure ensures that the scientists and engineers forming the technical team can better react to practical operational concerns or user requirements when contributing to the openlab activities.

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Andreas Unterkircher	openlab fellow (HP)
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Industry Contributor Liaison with CERN

John Asher	Voltaire

CERN Technical Liaison with Industry Partners

Sverre Jarp	HP and Intel
Jean-Michel Jouanigot	Enterasys Networks
Rainer Többicke	IBM
Dirk Düllmann	Oracle

The openlab partners: a constellation of capabilities

CERN has teamed up with leading IT partners for five key technologies that support advanced clusters working on a Grid: processors, servers, high-speed switching, storage technologies and database software. The CERN opencluster combines 64-bit processor technology and 10Gb/s network cards from Intel, compute servers in a cluster from HP, and a 10Gb/s switching environment from Enterasys Networks. IBM provides 28TB of high-end storage to the project, as well as its Storage Tank data management technology, and Oracle contributes a wide variety of features to its Oracle9i Database and Oracle Database10g suites.

Enterasys Networks

Enterasys Networks is a leading worldwide provider of broadline intelligent data networking infrastructures for enterprise-class customers. Enterasys' networking hardware and software offerings deliver the innovative security, availability and mobility solutions required by Global 2000 organizations coupled with the industry's strongest service and support. For more information on Enterasys and its products, visit www.enterasys.com.

"The aggregate data throughput for LHC will exceed one terabit per second. Enterasys is confident that its 10-Gigabit Ethernet Technology will enable CERN to unlock the full potential of its DataGrid." John Roese, Chief Technology Officer for Enterasys Networks.

HP

HP is a leading global provider of products, technologies, solutions and services to consumers and businesses. The company's offerings span IT infrastructure, personal computing and access devices, global services and imaging and printing. HP completed its merger transaction involving Compaq Computer Corp. on 3 May 2002. More information about HP is available at www.hp.com.

"By participating in the CERN LCG, HP had the opportunity to connect to a real operational Grid in action and get a unique experience." Michel Benard, Director for Technology Programs, HP University Relations.

IBM

IBM is the world's largest information technology company, with 80 years of leadership in helping businesses innovate. Drawing on resources from across IBM and key Business Partners, IBM offers a wide range of services, solutions and technologies that enable customers, large and small, to take full advantage of the new era of e-business. Additional information about IBM is available at www.ibm.com/us/.

"This is the perfect environment for us to enhance our Storage Tank technology to meet the demanding requirements of large scale Grid computing systems." Jai Menon, IBM Fellow and co-director of IBM's Storage Systems Institute.

Intel

Intel, the world's largest chip maker, is also a leading manufacturer of computer, networking and communications products. Additional information about Intel is available at www.intel.com/go/hpc.

"CERN's DataGrid project is an ideal application for Intel's most powerful processor yet, the Itanium® 2 processor. The awesome computer power required will find a formidable engine in the Itanium." Steve Chase, Director, Business and Communication Solution Group of Intel.

Oracle

For 27 years, Oracle has been helping customers manage critical information. The company's goal is to make sure that customers spend less money on their systems while getting the most up-to-date and accurate information from them. Oracle does this by simplifying or outsourcing IT infrastructure to reduce costs, and by integrating disparate systems to create a single, global view of the customer's business. www.oracle.com.

"Leading-edge grid technologies developed at CERN will be road-tested as part of its Large Hadron Collider project. As these technologies then come into the commercial mainstream, both we and our customers will benefit even further." Sergio Giacoletto, Executive Vice President, Oracle Europe, Middle East and Africa.

The openlab facilities: at the heart of the Grid

CERN opencluster

The cluster now has just over 100 Intel Itanium® 2 dual processor HP rx2600 nodes, with 25 10-GbE Network Interface Cards (NICs) delivered by Intel. Enterasys Networks contributes four 10Gb/s Matrix N-7 switches with additional port capacity for 1 Gb/s (in total 20 10-GbE ports and 300 1-GbE ports). IBM is sponsoring 28TB of high-end storage, as well as the IBM TotalStorage SAN File System storage virtualization software.

In 2004-05, changes to the opencluster included the delivery by Enterasys of two of the latest high perfomance Matrix X-16 10Gb/s routers. Also, a 96-way Infiniband switch initially cabled to 40 systems was provided by Voltaire, a CERN openlab contributor. Next generation disk servers were connected to the opencluster during the last year (24 disks at 74GB per disk), using two 4-way RX4640 Itanium servers and three RAID controllers. The iSCSI cluster which implements the IBM TotalStorage system was expanded from 10 to 15 nodes.

The opencluster facility occupies a prominent position in the middle of CERN's Computer Centre, directly below the visitor gallery and frequently used as a backdrop for filmed interviews.

CERN openlab offices

The CERN openlab team has established offices alongside the CERN Computer Centre, along the corridor from the openlab openspace. Most of the core technical team and the openlab management unit is installed there.

CERN openlab openspace

This VIP meeting room, built with access directly to the Computer Centre, provides industrial partners and their clients with a prime location for technical and promotional meetings, where the partnership is prominently featured. It is also widely used by the IT Department and increasingly by CERN's Press and VIP services, for meetings with visiting dignitaries and journalists.

CERN openlab staff and 2004 openlab students next to the opencluster

CERN OPENCLUSTER RESULTS
Paving the way for 64-bit computing on the Grid

One of the most significant results from the CERN openlab partnership in 2004 was the decision of HP to allocate a substantial number of Intel Itanium® 2 64-bit processors to LCG from its Bristol and Puerto Rico computer centres. This move was based on experience gained with the CERN opencluster over the last two years, and the openlab technical team played an active part in helping the HP sites connect to LCG. The team has ported the complete LCG middleware, LCG-2, to 64-bit. Other packages that have been ported by their respective authors are ROOT, a data analysis framework, Geant4, a physics simulation framework, CLHEP, a C++ class library, CASTOR, the CERN hierarchical storage manager. Work is also under way to port common HEP libraries like SEAL and POOL to the 64-bit environment.

In early 2005, the Poznan Supercomputing and Networking Center in Poland became the third contributor of 64-bit nodes to LCG, and others are following suit. It is anticipated that 64-bit computing will be crucial to the future of scientific computing, and thanks to the CERN openlab initiative, the HEP community now has the chance to test its applications for 64-bit compatibility on the LCG infrastructure.

Of the four LHC experiments, ALICE is the first to be 64-bit compatible, and the CERN opencluster has contributed to several ALICE data challenges over the last two years. The current aim of the openlab team is to allow the other LHC experiments to work on Itanium, by checking that all their software packages are 64-bit clean, and ensuring that any required changes are retained in the software repositories.

CERN openlab fellows Andreas Hirstius and Andreas Unterkircher

Testing a spectrum of software

As well as porting Grid middleware and experimental software to the 64-bit environment, the CERN openlab team has launched two other software initiatives over the last year. The first, in collaboration with ALICE, involves testing a Grid auction software package from HP Labs, called Tycoon, which is a promising candidate for a future, more market-based approach to allocating resources on Grids such as LCG.

The second project concerns porting Xen, an open-source virtualization software, to Itanium. Xen allows a user to have multiple operating systems running at once and a thin kernel handling switching between them and managing device access. Work has focussed on extending the Itanium port after its initial release by HP Labs, in particular by adding multiple domain support.

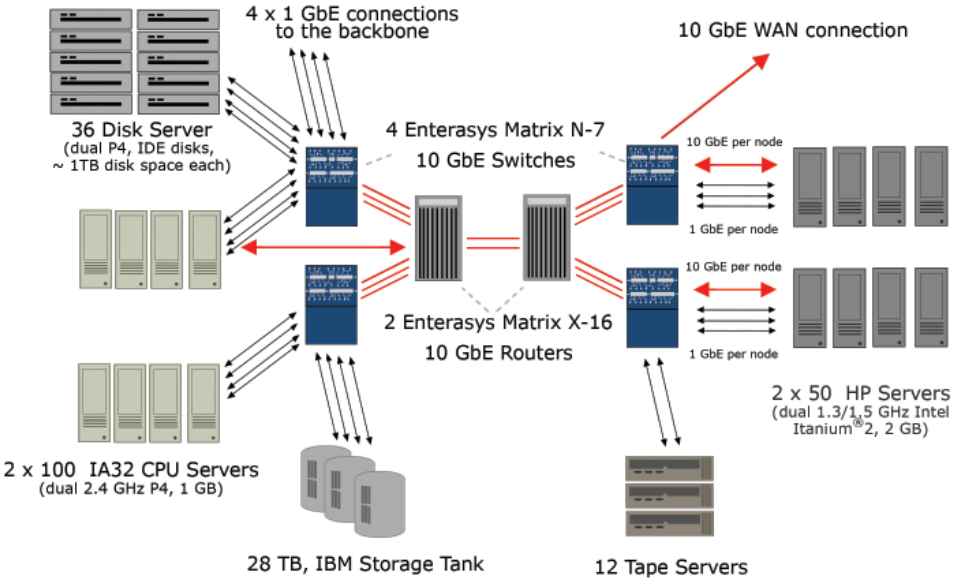
Following a request from CERN's Technical Support Department, the opencluster has been used to improve modeling of the airflow and cooling around the LHC detectors in their underground caverns. The computational fluid dynamics was performed using StarCD software, and excellent speed-up of the modeling was demonstrated thanks to the Itanium floating point performance and Infiniband interconnects of the opencluster.

In addition to these new initiatives, work continued in 2004-05 on compiler optimization. The focus has been C++ performance and the joint compiler project between CERN and Intel has dealt with 60 performance issues in two years. This collaboration also expanded during the last year to cover EM64T as well as the Itanium compilers. In EM64T mode, the compiler registers that all architectural extensions are available, giving a better basis for code generation. The openlab team proposed both Geant4 and ROOT as candidates for the SPEC2005 benchmarks, and Geant4 has been retained for consideration.

Snapshot of the opencluster

The illustration below shows a high-throughput cluster prototype which integrates the CERN opencluster with equipment from the LCG. This corresponds to the actual configuration in 2004-05. The box (bottom) gives a snapshot of the server allocation of the CERN opencluster, from April 2005, with the numbers in parentheses indicating the number of servers. The list attests to the central role of HP/Intel server cluster in supporting activities of the other three openlab partners, Enterasys, IBM and Oracle, as well as participation in the ALICE data challenge and the LCG service challenges.

CERN opencluster architecture



A snapshot of the opencluster server usage

- General use, 64-bit porting (4)
- CPU benchmarking (1)
- LCG service challenge (~20)
- LCG/EGEE middleware (12+2)
- Enterasys + 10 Gb LAN testing (10+6)
- 10 Gb WAN disk servers (2)
- Inifiniband testing (6)
- Alice data challenge (28)
- IBM StorageTank client (2)
- Oracle testing (2)

Pushing the storage envelope

In 2004-05, IBM's storage virtualization software achieved breakthrough performance results at CERN. Using Storage Tank, an IBM Research product for storage virtualization which is marketed under the name IBM TotalStorage SAN File System, the internal tests involved reading and writing data to disk at rates in excess of 1GB/s for a total I/O of over 1 Petabyte in a 13-day period.

Storage Tank is designed to provide scalable, high-performance and highly available management of large amounts of data using a single file namespace regardless of where or on what supported operating system the data reside. The Storage Tank tests involved writing and reading over 300,000 files – each 2GB in size – into and out of storage managed by Storage Tank. The storage consisted of 15 iSCSI servers. There were 12 IBM file system writer clients and 12 reader clients, with four reader threads and either four or six writer threads used per respective client. All clients and iSCSI storage were connected via a 1 Gb/s Ethernet network.

A significant goal of the tests was to monitor the IBM virtualization solution under a range of failure scenarios, such as disconnecting iSCSI servers. The results confirmed the strong performance of this data management solution. The collaborative nature of the openlab partnership was also reflected in the fact that these tests relied on the high-speed switching technology provided by Enterasys. IBM has involved several leading storage management experts from IBM's Almaden Research Center in California and Zurich Research Lab in Switzerland in the tests at CERN.

Furthermore, first tests of the integration of Storage Tank with CERN's storage management system for the LHC experiments, CASTOR, obtained good results, helping both the IBM software and CASTOR to be further developed. These tests were carried out in connection with the ALICE data challenge in spring 2005. These tests also provided CERN and IBM with valuable experience on how to handle traffic on limited resources.

New networking achievements

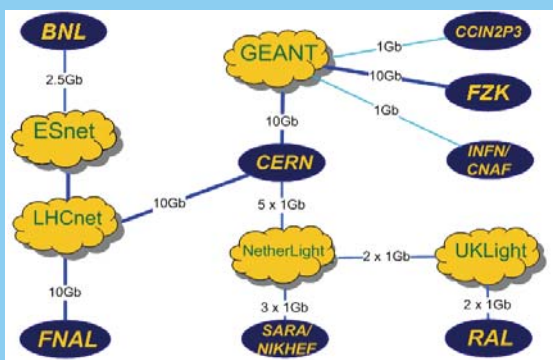
Testing of the Enterasys networking equipment was pursued during the last year. The Enterasys Matrix N-7 switches were interconnected with 10Gb/s Ethernet, to demonstrate the scalability of the technology. In 2004, two Enterasys Matrix X-16 high-performance 10Gb/s routers were delivered. These provided a nearly 5-fold increase in the number of 10Gb/s ports compared to the previous equipment. Comprehensive tests of the Enterasys Matrix X-16 demonstrated that the hardware is fully capable of providing the expected bandwidth for such a large cluster the size of the opencluster. In particular, Spirent 10Gb/s Ethernet Smartbits tests verified the 10Gb/s performance of the Enterasys Matrix X-16 at all frame sizes, and demonstrated that performance was unaffected by the number of flows.

Other bandwidth achievements during this period include a 4-way Itanium disk server reading at over 1GB/s and writing at 500MB/s, using three RAID controllers, and an array of 24 S-ATA disks. Over a WAN to Caltech, it was found that a read speed of 700MB/s could still be attained.

Performance benchmarks of Infiniband, provided by openlab contributor Voltaire and installed initially on 40 opencluster nodes, were carried out. A throughput of 750 MB/s was attained for block sizes in excess of 10k.

Supporting the service challenges

During the last year, the LCG project initiated a new set of challenges of its Grid infrastructure. In contrast to the data challenges, which are primarily designed to test the computing models of the individual LHC experiments over a limited period, the service challenges aim to stress test the underlying networking infrastructure of the Grid as a running service. The opencluster equipment has played a key role at various stages in these service challenges. For example, during the first service challenge in late 2004, the four Enterasys Matrix N-7 switches from Enterasys, which have successfully provided several hundred Gb/s connections for the interconnection of the opencluster, were interconnected to several Tier-1 sites of the LCG via the 10Gb/s LCG infrastructure, providing key connectivity for this service challenge. During this challenge, Itanium servers were used as data servers. In April 2005, the second service challenge achieved a significant milestone, by sustaining a continuous data flow of 600 MB/s on average for 10 days from CERN to seven Tier-1 sites in Europe and the US. The total amount of data transmitted during this challenge was 500 TB. The opencluster network infrastructure and Itanium servers played a key role in this service challenge, and in particular enabled 800MB/s peak performance to be attained. Typically, after launching each service challenge with the state-of-the-art opencluster equipment and achieving an acceptable level of stability, the service challenge aims to switch to using the sort of commodity equipment that the LCG must ultimately rely on.



Network connections between CERN and the international computing centres participating in the second service challenge, and the underlying high-speed networks that facilitated the challenge

Deploying databases on the Grid

While there are differences among the LHC experiments in their views of the role of databases and their deployment, there is relatively widespread agreement on a number of principles, namely that physics codes will need access to database-resident data, a single centralized database – whether at CERN or elsewhere – does not suffice, and a distributed deployment infrastructure should be open to the use of different technologies at each site.

Therefore, over the past year, one of the themes of database technology evaluation in the CERN openlab context has been to extend tests of specific technologies beyond CERN to some of the Tier-1 sites of LCG. For example, work on Oracle Streams, a technology to connect databases and ensure that data is replicated consistently, had initially focussed on data being sent between two databases at CERN. In the last year this effort has expanded to the propagation of physics data from databases at CERN to six LCG Tier-1 sites in Europe, the US and Taiwan.

Partly as a result of these successful tests, Oracle Streams is being integrated in the Distributed Database Deployment as a baseline replication technique for distributed database deployment. This will provide an application-independent replication in the core of future LCG software releases.

For the database services at CERN, the Tier-0 centre of LCG, work has focussed on using a mixture of Oracle DataGuard to ensure storage redundancy and another Oracle product, Real Application Clusters (RAC), for computing redundancy. Oracle DataGuard, which was originally devised for handling catastrophic failures in data centres, turns out to be effective in maintaining a hot backup of a catalogue, and keeping the Grid environment available while patches are applied. RAC is a cluster database with a shared cache architecture providing a highly scalable and available database. The combination of these two technologies, which are both part of Oracle Database 10g, is the baseline for future developments by the Oracle-sponsored research fellows in CERN openlab.

Other work during the last year includes: applying Oracle Dataguard to CERN's CASTOR mass-storage system to provide high-level availability; implementing Orion, an Oracle test facility, to benchmark I/O subsystems and validate their ability to handle large data flows; successfully testing Services, an Oracle Database 10g feature which enables prioritisation with large database clusters in a Grid environment, in order to select specific nodes for different applications; evaluating Grid Control, a distributed tool for administration and diagnostics of database servers. The latter product is a candidate for Tier-1 centres to use in order to gain an overview of how data is distributed. Discussions with database teams at the different sites are ongoing.

CERN openlab fellow
Rosa Maria Garcia Rioja

OTHER ACTIVITIES
The CHEP'04 Conference

CERN hosted CHEP'04, a major conference for Computing in High Energy and Nuclear Physics, at the Congress Centre in Interlaken from 27 September to 1 October 2004. The industrial partners of the CERN openlab were the prime sponsors of the conference.

For the over 500 physicists and computer scientists who gathered at the conference – a record number for the event – the progress of the LCG was one of the primary points of interest on the agenda. As well as Grid middleware, Grid deployment, Grid security and scientific applications for the Grid, CHEP'04 addressed wide area networking, computer fabrics, software tools, frameworks and libraries, information systems, event processing algorithms and online computing. An industrial exhibition offered a chance to learn about the latest advances from leading providers of hardware and software.

This edition of CHEP was particularly auspicious, falling in the week when CERN celebrated its 50th anniversary. On the day of the anniversary, 29 September, a special session on the future of Scientific Computing featured lead speakers from the IT industry, who discussed the future of information technology.

Andrew Sutherland, Vice President Technology Solutions Oracle EMEA, argued that the evolution of computing is not slowing down yet. Jai Menon, IBM Fellow and Director and Chief Technologist Storage Systems Architecture and Design, outlined the grand challenges facing storage systems. Stan Williams, Senior HP Fellow and Director of Quantum Science Research at HP, provided a perspective on the evolution and revolution in the design of computers based on nanoelectronics. John Roese, Chief Technology Officer at Enterasys Networks, addressed the future of high speed LANs. Dave McQueeney, Chief Technology Officer for IBM's US Federal team, reviewed the technological outlook for computing from IBM's perspective.

The same day, a special brainstorming session was held with the speakers and other representatives of the openlab partners and CERN, to discuss possible future directions for CERN openlab. This session was chaired by the Director General of CERN, Robert Aymar. Fabiola Gianotti, a leading scientist at CERN, summarised the computing challenges that the High Energy Physics community forsees on the 5-10 year horizon, which lead to a lively and inspiring discussion of how various emerging technologies, such as nanotechnology and game processors, could play a role on that timescale.

Conference

Robert Aymar, Director-General of CERN

Industrial exhibition

Banquet

CERN openlab dissemination

The openlab Technical Team ensures dissemination of CERN openlab results through traditional technical channels such as conference presentations, technical publications and thematic workshops. In addition, the cutting-edge nature of the CERN openlab activities result in frequent press releases and other non-technical publications, as well as requests for presentations about openlab to visiting VIPs and the general public.

A description of CERN openlab for the general public can be found on the external website at http://www.cern.ch/openlab. A detailed description of CERN openlab events and publications can be found on the operational website at http://openlab-mu-internal.web.cern.ch. This site includes an archive of all publicly available documents and presentations made by CERN openlab, as well as a dedicated sponsors area.

Publications and conference presentations

"The Grid gains new dimensions", CERN Courier, p17, (Sept. 04)
"The CERN openlab for DataGrid Applications", ERCIM News No. 59, (Oct. 04)
"Computing conference goes to the Swiss Alps", CERN Courier, p23-25, (Jan./Feb. 05)
"LHC Grid tackles multiple service challenges", CERN Courier, p15, (June 05)
"Software achieves breakthrough in data challenge", CERN Courier, p16, (June 05)
"HPC Virtualisation with Xen on Itanium", M.Sc. Thesis of H. Bjerke, NTNU Trondheim, (July 05)

External presentations, covering openlab activities, were made at:

- CHEP'04, "openlab technical overview", Interlaken (Sept. 04)
- Oracle Open World, London & Amsterdam, (Sept. 04)
- Gelato Fall meeting, "openlab – High Speed Data Transfers", Beijing (Oct. 04)
- Oracle Grid event, Moscow (Nov. 04)
- Oracle Open World, San Francisco (Dec. 04)
- HPC Round Table, "CERN and the LHC Computing Challenge", Munich (Dec. 04)
- Enterasys Secure Networks Event, "CERN and GRID computing – the next computing challenge" Bern (Jan. 05)
- Oracle Grid Network, CERN (June 05)
- HP Dutchworld, Amsterdam (Oct. 05)
- Gelato Spring meeting, "Computing for LHC", Cupertino (May 06)

Press releases

"CERN openlab adds a new dimension to Grid computing" (July 04)
"CHEP'04: Physicists and Industry Experts Meet in Interlaken to Discuss Future of Scientific Computing" (Sept. 04)
"IBM shatters data management challenge at CERN" (IBM release) (March 05)

Thematic workshops

As part of the CERN openlab activities, Thematic Technical Workshops are organized. These are open exclusively to representatives of openlab industrial partners as well as CERN staff. The standard format of Thematic Workshops is as follows: on day one, CERN experts present specific CERN requirements and the status of their technical development; on day two, CERN meets sponsors on a one-to-one basis. The themes of the Workshops are usually proposed by the industrial partners.

In the period June 2004-05, one Thematic Technical Workshops was organized:
• 5th thematic workshop on Industrialising the Grid (June 05)

This workshop, together with the brainstorming session held at CHEP'04 in September 2004, provided CERN and the openlab partners with opportunities to discuss future directions for collaboration.

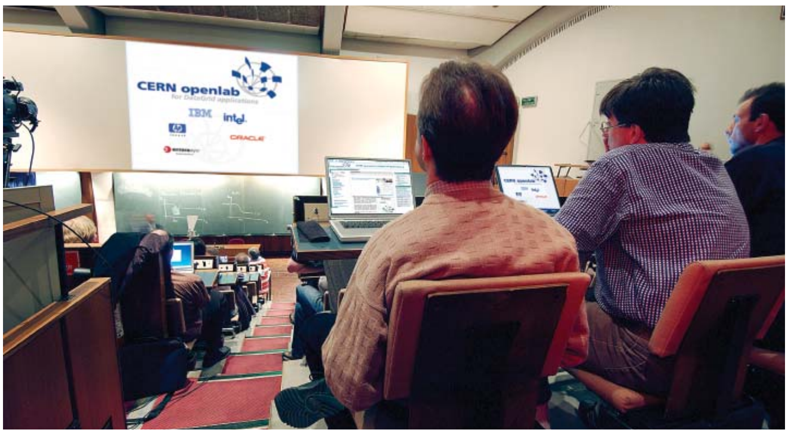
First Tuesday events

CERN openlab hosts regular First Tuesday events at CERN in collaboration with the organization "First Tuesday Suisse Romande". These public events attract typically 100 persons, and involve speakers from CERN, CERN openlab's industrial partners, as well as other guest speakers. The public is primarily from the regional business and investor communities. The events are also webcast live and the webcasts are archived. In the period June 2004-05, two events were held:
• 5th FT @ CERN: Digital Writing. With Eric Chaniot (HP), Olivier Martinet (HP) (6 Oct 2004)
• 6th FT @ CERN: Data Management in the 21st Century: the Petabyte Challenge with Robert Haas (IBM) (12 May 2005)

VIP and Industry Visits

CERN is regularly visited by prominent delegations from member state ministries and scientific organizations, as well as by companies interested to know more about CERN's technology activities. A presentation of CERN openlab's activities has become a feature of such visits, as it is viewed as an outstanding example of industrial involvement at CERN. Such delegations normally visit the openlab openspace for a briefing, prior to a tour of the computer centre.

In addition, visiting journalists from European and international newspapers and TV stations are regularly briefed about CERN openlab in the context of CERN's Grid activities.



Workshop at CERN

Student activities

Based on a pilot programme in 2002, the CERN openlab student programme was launched in summer 2003 with 11 students from seven European countries. The idea is to have the students work in international teams, on projects related to the applications of Grid technology. In summer 2004, there were 14 students, and HP and Enterasys co-sponsored the programme. Many students worked on issues related to the CERN opencluster, such as Linux virtualization, SmartFrog, compiler optimization and benchmarking of networking equipment. There was also a project to develop a digital logbook and digital guestbook for CERN's 50th anniversary, based on the HP digital pen, while another team worked on LHC@home, a screensaver program launched for the 50th anniversary. A GridCafé event for the 50th anniversary was prepared by one team, for the CERN openday on 16 October 2004.

An underlying objective of the openlab student programme is to encourage students and their home institutions to build longer-term relationships with CERN openlab, for example by arranging for the students to do their masters project at CERN. As a direct result of the 2004 programme, three openlab students returned to do further projects in the IT Department during the winter 2004-05, including one who has since been hired by EGEE. For 2005, 16 students are anticipated to take part in a similar programme, this time with EGEE and LCG-related projects, students from as far afield as Brazil and Pakistan, and co-sponsored by HP and Intel.

A related student activity is the CERN School of Computing, which offers a two week programme to some 80 students each year, and which obtained an important grant from the European Commission FP6 Marie Curie programme in 2003, to provide for grants to assist the students with living and travel allowance over the next four years. Grid computing was a core feature of this school in 2004, which attracted 77 students, and where the CERN openlab is given prominent coverage.

In 2003, CERN openlab was part of a successful application by CERN for EU funding from the Marie-Curie programme. As a result, CERN openlab was able to hire two Ph.D.-level students for two years each, from September 2004.

Outreach activities for the 50th anniversary

CERN openlab partner HP was co-sponsor of a GridCafé event during CERN's openday on 16 October 2004, which featured LCG, EGEE and openlab, as well as stands on Grid technology and Grid for society. Some 2000 persons managed to visit this event during the openday. This event will be reproduced in 2005 at the Fete de la Science in Lyons, France, and for the Science Museum in London.

The CERN official ceremony on 19 October 2004 was attended by Heads of State and VIP delegates from the scientific community, and CERN's Director General invited delegates from the CERN openlab partners to join this prestigious event. At the event, a digital guestbook, developed by the openlab student programme, was provided for the guests to write their wishes to CERN directly on the web.

CERN openlab partner representatives at CERN 50th official ceremony, from left: Richard Curran, Director, Intel Solution Services EMEA; Hans Ulrich Maerki, Chairman of the Board, IBM EMEA; Wolfgang von Rüden, CERN; Gerard Vivier, President EMEA, Enterasys Networks; Sergio Giacoletto, Oracle Executive Vice-President EMEA

THE FUTURE
New contributions on the horizon

New contributions on the horizon

The plans for the next 6 months of the opencluster project is to continue to participate in the LCG service challenges and proceed with the ongoing programme of software testing and validation. At the end of 2005, the opencluster project officially comes to an end, although Oracle, the last partner to join, will still have one year of partnership activities left.
During 2004, various potential successor projects to opencluster were reviewed by CERN and the openlab partners. The field of IT security in particular was assessed. As a result, a project on Grid and site security was successfully submitted as an EU FP6 proposal and a parallel project on security and mobility was initiated in collaboration with a Finnish consortium.

Planning the next phase

In June 2005, the Thematic Workshop on Industrialising the Grid provided an opportunity to review with the partners possible new project topics beyond 2005. There is a fortunate coincidence between the funding cycle of CERN openlab and the EGEE project, and so various opportunities to link these projects more closely together as of 2006 are being considered.

In a comparatively short time, CERN openlab has achieved a very high level of recognition for the quality of its technical results and the novelty of such a multilateral public-private partnership. There is clearly expressed interest from several of the partners to continue such a collaboration, even widening the scope beyond Grid technology to other domains of mutual interest. A Grid interoperability project and a 64-bit platform competence centre are concrete proposals now being pursued.

Looking beyond the 2007 time horizon, when the LCG and EGEE projects will surely have established Grids as a mainstream scientific infrastructure, there will be a need to provide technical leadership on a global scale to the Grid community. Such leadership must be based on expertise from the scientific and industrial communities. CERN is an obvious meeting place for the two communities, with CERN openlab as an example of the practical results that such public-private partnership can produce.

In conclusion, as long as information technology continues to evolve at breakneck speed, and the demands of CERN's users for advanced IT solutions grows apace, there will surely be a demand for the sort of close collaboration between CERN and leading IT solution providers that CERN openlab has pioneered.

This is the fourth annual report of the CERN openlab for DataGrid applications. It was presented to the Board of Sponsors at the Annual Sponsors meeting, 6 July 2005.

Participants in the Annual Sponsors Meeting, from left to right: François Fluckiger (CERN), Arnaud Pierson (HP), François Grey (CERN), Pierre-Alain Hinnen (Enterasys), Andrew Sutherland (Oracle), Russel R. Beutler (Intel), Michel Benard (HP), Stephan Gillich (Intel), Monica Marinucci (Oracle), Ben Bennett (Intel), Wolfgang von Rüden (CERN), Tom Hawk (IBM), Brian Carpenter (IBM), Pasquale Di Cesare (IBM), Sverre Jarp (CERN), Les Robertson (CERN), Markus Nispel (Enterasys)

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