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27 November 2005

LARGE HADRON COLLIDER COMMITTEE

Review of Computing Technical Design Reports for LCG

November 2005

Executive Summary

The LHC experiments and the LCG are assembling the computing infrastructure required to process the large amount of data expected in the years 2007-2010 and beyond. Each experiment has prepared a Computing Technical Design Report (TDR) for review by the LHCC. These Computing TDRs outline the requirements for the basic infrastructure that will be needed for LHC computing during the first few years of data taking. These computing models will most likely evolve over time as the detectors are commissioned and data analysis begins.

The review committee felt that the TDR documents from the experiments contained the conceptual designs of the computing systems. Technology is evolving rapidly, and while the overall goals are clearly defined, in many instances, choices of specific technology remain. In part, this is due to the pressure to delay decisions to be able to take advantage of technical advances and falling prices. In addition, the distributed computing model using the GRID is still undergoing intensive testing and commissioning.

The committee stresses that these computing models remain essentially untested. Some components were exercised during the data challenges and the recent service challenges. Other critical elements will be tested in the coming year. The lack of testing under battle conditions is particularly true for the distributed analysis portion of the models. The Tier-0 planning is the most advanced and the planned Tier-0 resource seemed well matched to the needs of the experiments.

The ongoing program of Service Challenges (SCs) forms the core of the conditioning tests for the Worldwide LHC Computing Grid (WLCG). SC-3 was underway at the time of the review. A list of the required WLCG baseline services and associated milestones has been established. Much work remains to be done to build and commission this global system of computers and have them operating 24 x 7. The committee applauds all the work that has been accomplished through the data challenges and the service challenges, but cautions that there are still very significant milestones to be met during the coming year.

The experiments have not yet fully determined their plans for alignment and calibration. The committee recommends that the experiments develop their calibration and alignment strategies as soon as possible - including the use of the CAF at CERN and the Tier-1 and Tier-2 centres. These plans should be developed in collaboration with the (W)LCG.

Large-scale data analysis tests are scheduled for the coming year that will use the WLCG baseline grid services. By September 2006, the major components of the computing systems will have been tested and the production system should be in operation. This is approximately the same timescale for initiating the large computing purchase required for the start of the LHC. The committee urges the computing management to proceed with caution in purchasing computing and to re-evaluate the resource planning regularly so that the computing resources are purchased only when needed. At the same time, we recognize the need to proceed with planned purchases for 2006 so that infrastructure is put in place and the large-scale system tests can advance.

A large quantity of common infrastructure software has been developed for the LHC. Much of this software development was done through external (non-CERN) funding. A plan is needed to support the computing and software infrastructure after the funding for EGEE and other GRID project funding comes to an end. This support plan should be included in the MoU process.

The computing resources at the Tier-1 and Tier-2 centres are identified through the MoU process. This process has already identified a large fraction of the required resources. It is important to keep in mind that there could still be large uncertainties in the resource requirement estimates. Moreover, the overall balance of resources amongst the experiments for resources outside of CERN seems difficult to achieve. There is an estimate of the pledged resources pledged for each experiment. At the time of the October review, ALICE had only identified about 50% of their required computing resources (CPU, disks, tapes). CMS was also lacking the required pledges to meet their resource needs. ATLAS and CMS have differing computing requirements for their Tier-1 sites. The committee finds that these differences are not fundamental but depend primarily on the details of their computing models.

The resource balance amongst the experiments is a major concern and must be resolved to ensure the physics output of all experiments. The current balancing scheme outlined in the MOU that involves descoping recommendation from the LHCC seems unworkable without some means for enforcement.

The review committee supports the first steps of the transition of the LCG organization towards management of the operation of a global LHC “computing centre”. The committee feels that the management of this global computing project still needs to be strengthened. Issues of balance of resources and global operations will require a strong organization and management team. We encourage a stronger connection between the computing planning process and the physics goals of the experiments. Therefore, we recommend that a “Computing Coordinator” be appointed to work together with CERN management, the LCG project and the four experiments.

The committee congratulates the collaborations and the LCG for their work presented in the Computing TDRs and recommends approval. More detailed comments and specific recommendations are outlined in the full document.

Introduction

Starting in 2007 the LHC is expected to produce proton-proton collisions at a center of mass energy of 14,000 GeV with an initial luminosity of approximately 2 x $10^{32}cm^{-2}s^{-1}$. The luminosity is expected to rise steadily until it reaches the design luminosity of 10 $^{34}cm^{-2}s^{-1}$ by 2010. It is expected that the trigger rates will not vary much with luminosity, which implies that the expected amount of data output rate will remain roughly constant.

Table 1 provides a comparison of the event size and trigger rate for the four experiments during p-p collisions. The event size, trigger rate and speed of the reconstruction and simulation codes are the fundamental parameters that are used to calculate the required production capacity. The capacity needed for analysis is more difficult to calculate and depends on the number of users, the number of analysis groups, and access patterns that are strongly analysis dependent. The AOD data will generally be available for analysis, but during commissioning access to the ESD and perhaps even the RAW data is anticipated.

p-p (HI)	**SIMU**	**Sim ESD**	**RAW**	**Trigger Rate**	**RAW Rate**	**RECO**	**AOD**	**TAG**
	MB	**MB**	**MB**	**Hz**	**MB/s**	**kB**	**kB**	**kB**
ALICE (HI)	300	2.1	12.5	100	1250	2500	250	10
ALICE (pp)	0.4	0.040	1.0	100	100	200	50	10
ATLAS (pp)	2	0.5	1.6	200	320	500	100	1
CMS (pp)	2	0.4	1.5	150	225	250	50	10
LHCb (pp)	--	0.4	0.025	2000	50	75	25	1

Table 1: The anticipated event size and raw data rates for the four experiments during proton-proton (pp) collisions at the LHC are presented in the Table. Also included are the estimates for Heavy Ion (HI) collisions at the ALICE experiment. SIMU: Simulated RAW data, RAW: data from the experiment to be recorded in mass storage, RECO (or ESD): output from the reconstruction code, AOD: reduced data format for analysis, TAG: summary for event selection.

There are large uncertainties on the estimates of processing times and how they scale with luminosity. These numbers will only be known when LHC data is available. Reprocessing of datasets primarily occurs at the Tier-1 centres. The experiments have estimated that this reprocessing could happen several times per year. It is anticipated that the number of passes be limited by the manpower available for validation and preparation of production software releases as well as by the overall compute capacity.

Planning for detector calibration and alignment is beginning for each of the experiments. In general, these schemes have not yet been worked out in detail and the impact on processing and reprocessing has not yet been fully evaluated.

The estimates for computing (cpu and disk) resources requirements for the LHC Computing system from 2007 to 2010 are presented in Figure 1 and Figure 2. These estimates include the requirements at CERN (Tier-0 and CAFs), the Tier-1 centres and the Tier-2 centres (or federations). The CPU resources are expected to grow from about 53 MSI2K in 2007 to over 330 MSI2k by 2010. At the moment 11 Tier-1 centres have been identified. The expected

disk requirement for the beginning of LHC operations 2007 is about 17 PB. This expands to about 135 PB in 2010. Mass storage (tape) requirements grow from about 14 PB in 2007 to almost 140 PB in 2010.

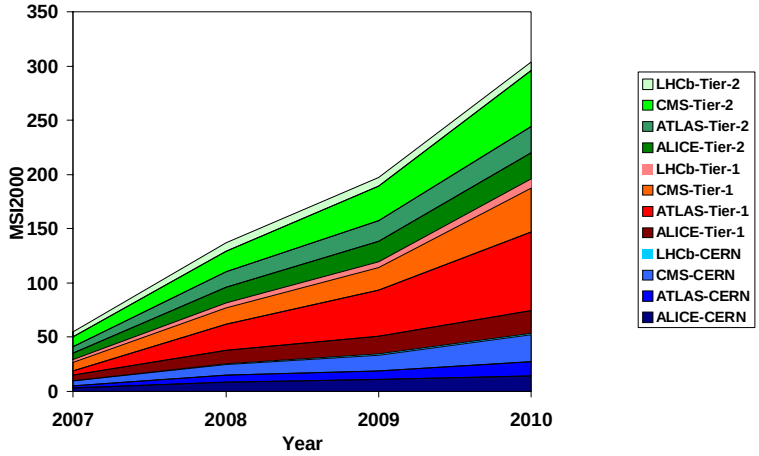

Figure 1 CPU requirements at the Tier-0, Tier-1 and Tier-2 centres for each of the four experiments. The time period is from 2007 to 2010.

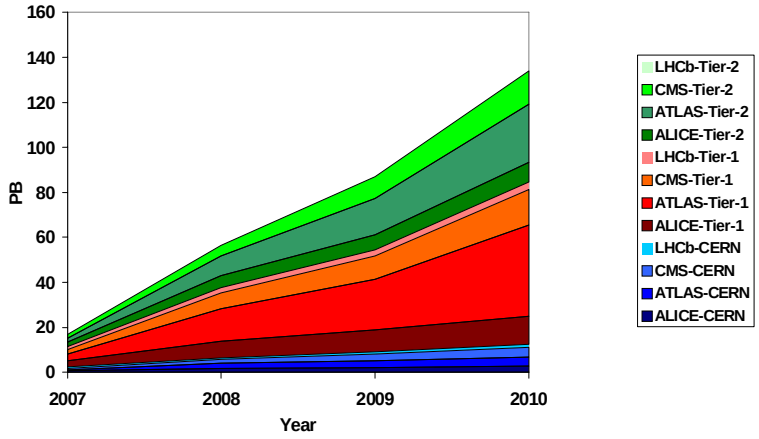

Figure 2 Disk requirements at the Tier-0, Tier-1 and Tier-2 centres for each of the four experiments. The time period is from 2007 to 2010. Note that LHCb plans to use the Tier-2 centres for MC production. Their analysis will primarily done at the Tier-1 centres.

For 2008 the total CPU requirements are 83 MSI2K and the disk requirements call for a total of 31 PB of disk at all centres. The exact amounts, of course, depend on the details of the LHC commissioning and run plan. More information on 2007- 2008 physics and calibration plans will be available during the coming year.

The Computing-Resource Review Board (C-RRB) has begun reviewing detailed MoUs regarding level of service and capacity at the Tier-1 and Tier-2 centres. The pledges collected at the time of the October meeting are presented in Table 2. While the overall level of the pledged resources for cpu, disk and tape at the centres was within about 20-30% at the time of this report, some experiments appear to have significant deficits in their identified resources at the Tier-1 and Tier-2 centres.

Tier-1 Planning for 2008		ALICE	ATLAS	CMS	LHCb	SUM 2008
CPU - MSI2K	**Offered**	6.7	22.7	12.5	4.4	46.3
	TDR Requirements	12.3	24.0	15.2	4.4	55.9
	Balance	**-46%**	**-5%**	**-18%**	**-0%**	**-17%**
Disk - PBytes	**Offered**	2.8	12.5	5.7	2.2	23.2
	TDR Requirements	7.4	14.4	7.0	2.4	31.2
	Balance	**-62%**	**-13%**	**-18%**	**-10%**	**-25%**
Tape - PBytes	**Offered**	3.2	9.1	8.1	1.9	22.3
	TDR Requirements	6.9	9.0	16.7	2.1	34.7
	Balance	**-54%**	**1%**	**-51%**	**-9%**	**-36%**

Includes current planning for all Tier-1 centres

Tier-2 Planning for 2008		ALICE	ATLAS	CMS	LHCb	SUM 2008
CPU - MSI2K	**Offered**	5.0	19.5	17.4	4.4	46.3
	TDR Requirements	14.4	19.9	19.3	7.7	61.3
	Balance	**-65%**	**-2%**	**-10%**	**-42%**	**-24%**
Disk - PBytes	**Offered**	1.4	5.9	4.5	0.8	12.6
	TDR Requirements	5.1	8.7	4.9	0.023	18.723
	Balance	**-72%**	**-33%**	**-8%**	**n/a**	**-33%**
# Tier-2 federations - included(expected)		12 (13)	20 (28)	17 (19)	11 (12)	28 (37)

Table 2 contains the Computing Resource Planning for 2008 from October 2005. This table was complied at the time of the October 2005 review and includes 28 Tier-2 centres or federations and all Tier-1 centres.

The Computing TDR Review Process

In early 2005 the LHCC reviewed the Computing Models of the four LHC experiments and released a report[1] containing an evaluation of the plans for data management and computing at the LHC. At that time, each of the four LHC experiments had produced estimates of their anticipated computing capacity requirements in terms of disks, tapes, CPUs and networks for the Tier-0, Tier-1 and Tier-2 centers. These numbers were documented in their Computing Model documents (ALICE[2], ATLAS[3], CMS[4], LHCb[5]) that were submitted to the LHCC in mid-December 2004 and reviewed in January 2005.

The review committee found that "*aside from issues of peak capacity, … the computing models presented are robust enough to handle the demands of LHC production computing during early running (through 2010.) There remains a concern about the validity of the data analysis components of the models.*" The committee did not consider costs in their evaluation, so there was not a comprehensive analysis of the scope of the computing requirements, except to say they should be sufficient to address the production requirements.

The four experiments and the LCG Collaboration submitted Technical Design Reports documents for the Computing Projects in June 2005 – ALICE[6], ATLAS[7], CMS[8], LHCb[9], LCG[10]. The LHCC received these materials and listened to a series of presentations from each of the four experiments and the LCG at the June 2005 LHCC meeting. The committee invited four external referees, one per experiment, to review the documents along with the LHCC members. In addition to the external referee, LHCC members helped to evaluate the Computing TDR of their "home" experiment. The LHCC LCG referees read and made comments on the TDR for the LCG.

The referees produced a set of questions concerning the individual TDRs. On October 7-8, 2005 the referees met together at CERN. During this two-day meeting, the leaders of the computing projects in the experiments and the LCG project were asked to supply answers to these sets of questions for the reviewers. All external referees and many LHCC members attended these sessions, which covered all five TDRs. The committee met in closed session on October 8 for discussions. This document contains a summary of these discussions and from the follow-up discussions at the October LHCC meeting. In addition to these general comments, specific comments and recommendations for each of the five TDRs are also given in this report.

The committee was impressed by the outline towards building global computing models that was outlined in the TDRs, but found that the documents contained conceptual designs or status reports rather than technical designs as in the case of the detector TDRs.

General Comments

The committee felt that the TDR documents from the experiments contained the conceptual designs of the computing systems. Technology is evolving rapidly, and while the overall goals are clear, in many instances, the technology choices have not yet been made. In part, this is due to the pressure to delay decisions to be able to take advantage of technical advances and falling prices. In addition, the distributed computing models using the GRID are still undergoing intensive testing and commissioning.

The committee stresses that the computing models remain essentially untested. Some of the components have been exercised during the experiments' data challenges and the recent service challenges. The agreement on the grid baseline service has been a good step toward global interoperability and much of this infrastructure will be tested within the upcoming year.

Testing under battle conditions – many users, chaotic access patterns - is a particular challenge before data taking begins. The distributed analysis portion of the computing models remains the least well tested. The outcome of these exercises could have an impact on Tier-1 and Tier-2 resources requirements.

Tier-0 planning is the most advanced and the resource requirements seemed well matched to the needs of the experiments.

The ongoing program of Service Challenges (SCs) forms the core of the conditioning and testing for the WLCG baseline services. SC-3 was underway though one month behind schedule at the time of the review. A list of required WLCG baseline services and associated milestones has been established and will be reviewed before SC-4. Much work remains to be done to build and commission this global system of computers and have them operating 24 x 7.

The committee applauds the work that has been done on the service challenges, but cautions that there are still significant milestones to be met in the coming year.

A CERN Analysis Facilities (CAF) is now foreseen for all experiments. The committee believes that these facilities are critical for commissioning and early calibration/alignment studies. In general, their usage should be defined better by the collaborations. The committee fears that the user community will migrate their analysis to these facilities rather than distribute their analysis to the Tier-1 or Tier-2 sites. This could create difficulties since the CERN and the CERN computing centre will not be able to house the computing power needed to accommodate this large user community.

The experiments still need to address their calibration and alignment schemes and the impact on computing resources and processing scenarios. The committee has several concerns: the CAF may be heavily loaded with analysis jobs from many users if not properly managed, and the Tier-2 centres may not be prepared to offer 24x7 coverage that may be required for these time critical tasks.

The committee recommends that the experiments develop their calibration and alignment strategies as soon as possible - including the use of the CAF at CERN and the Tier-1 and Tier-2 centres. These plans should be developed with close communication with the (W)LCG.

Large-scale data analysis tests are also scheduled for the coming year that will use the WLCG baseline grid services. By September 2006, the major components of the computing systems will have been tested and the production system should be in operation. It should be the right time to initiate large computing purchases that will put the required resources in place for the start of the LHC.

The committee urges the computing management to proceed with caution and to re-evaluate the resource planning regularly so that most computing resources are purchased only when needed. At the same time, we recognize the need to proceed with planned purchases for 2006 so that infrastructure is put in place and the large-scale system tests can advance.

A large body of software has been developed for the LHC by the LCG and by EGEE, OSG and other software collaborations and GRID projects. This software comes in many flavors. It could be middleware, an application, or an analysis tools. Many of these software products have become critical components of the infrastructure for the LHC computing systems.

A plan is needed to support the computing and software infrastructure after the funding for EGEE and other GRID project funding comes to an end. This support plan should be included in the MoU process.

Funding agencies and institutes from many parts of the globe are contributing to the LHC computing effort. There are 11 Tier-1 sites and more than 28 Tier-2 identified and many of these sites will provide services for more than one experiment. Overall, the promised resources seem reasonable.

The WLCG is a collaboration of institutes that are committed to providing LHC computing based on grid technologies. The true spirit of grid is "experiment blind", and if this were indeed true, there would be little concern regarding balance of resources amongst the experiments. Institutions and funding agencies, however, often prefer to support local interests when assigning resources and it seems doubtful that this will change. According to the Computing MOU, it is proposed that the C-RRB and the Resource Scrutiny Group (RSG) determine the availability of global computing resources. If these available resources are not sufficient, the LHCC will then be consulted to recommend the proper balance.

Overall balance of resources amongst the experiments for resources outside of CERN will be difficult to achieve. An estimate of the missing resources for each experiment was been made. At the time of the October review, ALICE could not identify approximately 50% of their required computing resources (CPU, disks, tapes) in the Tier-1 centres.

ATLAS and CMS have similar resource requirements at the Tier-0, however they have significantly different computing needs at their Tier-1 sites. The committee finds that this imbalance is not fundamental – meaning it does not originate from detector or physics effects, but that the differences depend mainly on the details of the computing model. One should note that there could still be large uncertainties in these resource numbers.

The resource balance issues are a major concern and must be resolved to ensure the physics output of all experiments. The current balancing scheme outlined in the MOU that involves descoping recommendation from the LHCC seems unworkable without some means for enforcement.

The role and mission of the LCG must refocus as LHC operations approaches. LHC computing depends on the success of the GRID and funding agencies (and other scientists) from all over the world are monitoring the HEP commitment to GRID computing. The LCG must have a strong commitment to operating large scale distributed computing on the grid.

The LCG can no longer be seen as a development or a deployment project. The LCG needs to become an organization focused on the operation of a global service. The review committee supports the first steps of the transition of the LCG towards a global LHC "computing centre". Daily management of WLCG service and operations remains a concern. It is not clear to us how conflicts will be managed and priorities will be established.

The committee feels that the management of this global computing project needs to be strengthened. Issues of balance of resources and global operations will require a strong organization and management team and this team has to operate on a global scale as well as be responsive to the physics goals of the experiments.

We encourage a stronger connection between the computing plans and to the physics goals of the experiments in the management. Therefore, we recommend that a "Computing Coordinator" be appointed to work together with CERN management, the LCG project and the four experiments

General Conclusions

The committee expresses its congratulations to the collaborations and the LCG for their Computing Technical Design reports. These documents form the foundation for the data production and physics analysis facilities and infrastructure at the LHC. While many of the concepts have been tested and validated, much remains to be done put achieve a distributed analysis structure based on GRID tools that can be used by a large number of LHC physicists. We advise a follow-up review of LHC Computing in Fall 2006. This could be done at the time of the LCG Comprehensive Review.

The committee finds that the Computing TDRs provide the necessary foundation for planning for data production and analysis. At this time, however, these models remain essentially untested. There remains a particular concern about the validity of the data analysis components of the models and recommends a follow-up review in Fall 2006.

Comments and Recommendations for the LCG

The LHC Computing Grid Technical Design Report provides an outline of the full GRID based computing plan for the LHC experiments. The computing requirements for the four experiments are compiled together and integrated into the LCG project plan. The common infrastructure, fabric and middleware, and the common applications have been identified and are outlined in the TDR. The status of planning, development or deployment has been evaluated in the TDR.

The plans for the LCG fabric seem to be well advanced. The requirements for the Tier-0 centre at CERN is well described in each of the Computing TDRs from the experiments and summarized in the LCG document. The experiments' Tier-0 requests seem well justified and reasonably well balanced. CERN and LCG have made plans to set up the Tier-0 centre (CPU, disk, tape, network) that matches their requests in a timely way - if budgets permit.

The requirements for the CERN Analysis Facility are not as well known. The experiments still need to provide complete calibration and alignment plans. These activities will be critical during commissioning and early running and the resources need to available in order to keep pace with data taking and first pass reconstruction.

Streamlining the purchasing process at CERN for computing equipment is essential. The current purchasing process takes too much time resulting in extra costs. It is well known that it is important not to invest too early in computing resources. Purchases should be timed to match experiments' testing and commissioning needs – at CERN and elsewhere. The LCG management should continue to work with the CERN management to speed up the purchasing process.

The experiments have agreed on a list of LCG/EGEE baseline services essential for grid operations. (See Table 3.) This compilation has permitted the WLCG collaboration to make a large step towards developing a global grid for HEP by helping them move closer to interoperability with other GRID projects. The services marked with an "A" in Table 3 have been designated "High Priority" by the experiments. The remaining baseline services are candidates for standard solutions, but the experiments have their own implementations.

These essential baseline services are to be exercised during SC3, though some without the full functionality that is required for a production service. The upgraded services are to be deployed in time for SC4 in late Spring 2006. There have already been delays in testing the services for SC3 and the throughput challenge scheduled for the Summer 2005 has been delayed. This is a concern and should be monitored closely during the coming year. Metrics are needed to assure that the critical services meet all the requirements.

It is important to ensure that all the required baseline services are ready and completely tested before the start of SC4. The experiments expect to begin distributed analysis tests with this service. The committee feels that the SC4 milestone is a key watch point for the project since there is not enough time

remaining to develop or deploy alternate solutions if the baseline services do not reach the required performance and reliability. The performance and reliability metrics for these services should be developed in collaboration with the experiments.

WLCG Baseline Services	ALICE	ATLAS	CMS	LHCb
Storage Element	A	A	A	A
Basic transfer tools	A	A	A	A
Reliable file transfer service	A	A	A / B	A
Catalogue services	B	B	B	B
Catalogue and data management tools	C	C	C	C
Compute Element	A	A	A	A
Workload Management	B	A	A	C
VO agents	A	A	A	A
VOMS	A	A	A	A
Database services	A	A	A	A
Posix-I/O	C	C	C	C
Application software installation	C	C	C	C
Job monitoring tools	C	C	C	C
Reliable messaging service	C	C	C	C
Information system	A	A	A	A

Table 3 shows the WLCG Baseline services and the requests from the experiments for these services. Services are divided into three categories. A: High priority; B: Standard solutions required, but experiments could have different implementations; C: Desirable to have common solution, but not essential.

Common applications needed by the experiments are developed through the application area. The Application Area phase II plan seems well matched to the experiments needs and to the available manpower. The ROOT – SEAL merge is welcome and should proceed without too much delay in order to avoid unnecessary duplication of effort.

EGEE provides middleware, known as glite, to be deployed on the EGEE grid infrastructure. The LCG TDR was written before glite was fully tested and certified. This middleware will be tested during the ongoing and upcoming service challenges. It was difficult for the committee to evaluate the current status of the glite components. The project is encouraged to develop performance more metrics for the middleware components and for the full system.

A new version of the CASTOR Mass Storage System is required to handle the demands of LHC computing. The deployment of the new system is behind schedule. Although much system testing has been done, the new system is not yet fully deployed. This remains a concern, since this is a required and critical component of the CERN Fabric.

Planning for distributed databases is discussed in the 3-D project. The infrastructure is in an early test phase. The infrastructure should be tested during the upcoming service challenge. This schedule seems tight and the hardware and service requirements at theTier-1 and Tier-2 centres are not well defined.

The Tier-1 and Tier-2 centres are integral parts of the LCG computing system. The service challenges have tested the operational capability of the centres and of the

network infrastructure that ties them together. There is still much work to be done to stabilize the full system. Communication with the centres is an issue that is being addressed in the new Management Board and the Grid Deployment Board. This communication has to be done on the technical and management levels. More contact between the centres and the experiments will be required as the project moves into the production phase.

The major milestones for the LCG have been described in the LCG TDR. Updated LCG phase 2 milestones are under internal discussion but are not yet available. However, the TDR milestones remain unchanged.

A set of draft milestones is available from the LCG planning page: http://lcg.web.cern.ch/LCG/planning/planning.html. These new milestones are expected to be approved by the LCG collaboration soon.

Service Challenge milestones

31 July 05	Service Challenge 3 Set-up
1 Sept 05	Service Challenge 3
31 Dec 05	Tier0/1 high-performance network operational
31 Dec 05	750 MB/s data recording demonstration at CERN
28 Feb 06	All required software for baseline services deployed
30 Apr 06	Service Challenge 4 Set-up
31 May 06	Service Challenge 4
30 Sept 06	1.6 GB/s data recording demonstration at CERN
30 Sept 06	Initial LHC Service in operation
1 Apr 07	LHC Service Commissioned

The committee was pleased to see that the project was moving towards an operations phase and has adopted a new management structure. However, there were concerns about the size of the management board. The committee recommends the formation of a smaller executive body within the management board.

The committee congratulates the LCG for their work in compiling a plan for the worldwide computing system required for LHC computing. In general, the overall plan seems sound, though there is much to be done to assemble and test the complete distributed system before the start of the LHC.

Appendix A

Committee Representation for October 7-8 review

Chair: P. McBride
Representatives from the LHCC: K. Borras, F. Forti, S. de Jong, M.Martinez-Perez, V. Kekelidze, B. Peyaud
External:
D. Boutigny (CC-IN2P3-Lyon; for ALICE C-TDR),
T. Haas (DESY; for ATLAS C-TDR),
C. Bozzi (INFN Ferrara; for CMS C-TDR),
Alan Campbell (DESY; for LHCb C-TDR)
LHCC Chairman and Secretary: S. Bertolucci, E. Tsesmelis

Also present at the review
PH Department: J.-J. Blaising, D. Schlatter
IT Department: J. Knobloch

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[1] Review of Computing Resources for the LHC Experiments CERN/LHCC/2005-006
http://committees.web.cern.ch/Committees/LHCC/lhcc-2005-006.pdf
[2] ALICE Computing Model CERN-LHCC-2004-038/G-086, draft:05-Jan-05, updated 04-Feb-05
[3] ATLAS Computing Model CERN-LHCC-2004-037/G-085
[4] CMS Computing Model CERN-LHCC-2004-035/G-083
[5] LHCb Computing Model CERN-LHCC-2004-036/G-084 (CERN-LHCb-2004-119)
[6] ALICE Computing Technical Design Report CERN-LHCC-2005-018, ALICE-TDR-012
[7] ATLAS Computing Technical Design Report CERN-LHCC-2005-022, ATLAS-TDR-017
[8] CMS Computing Technical Design Report CERN-LHCC-2005-023, CMS-TDR-007
[9] LHCb Computing Technical Design Report CERN-LHCC-2005-019, LHCb-TDR-011
[10] LCG Computing Technical Design Report CERN-LHCC-2005-024, LCG-TDR-001