

The LHC Computing Review

S. Bethke

Max-Planck-Institute of Physics

Munich

CERN/LHCC/2001-004

CERN/RRB-D 2001-3

Original: English

22 February 2001

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE

CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

REPORT OF THE STEERING GROUP*

OF THE LHC COMPUTING REVIEW

<http://lhc-computing-review-public.web.cern.ch>

MEMBERSHIP OF THE REVIEW

Steering Group

Members:	S. Bethke (MPI Munich) H.F. Hoffmann (CERN) D. Jacobs (CERN) M. Calvetti (INFN Florence) M. Kasemann (FNAL) D. Linglin (CC-IN2P3 / CNRS)	Chair CERN Director for Sc. Computing Secretary Chair of the Mgmt and Resources Panel Chair of the Software Project Panel Chair of the Computing Panel	
In Attendance:	IT Division ALICE ATLAS CMS LHCb	Representative M. Delfino (CERN) F. Carminati (CERN) N. McCubbin (RAL) M. Pimia (CERN) H. Newman (CALTECH) J. Harvey (CERN) M. Cattaneo (CERN) CERN Director for collider programmes LHCC Chairman	Alternate L. Robertson (CERN) K. Safarik (CERN) G. Poulard (CERN)
Observers:	R. Cashmore (CERN) J. Engelen (NIKHEF)		

Worldwide Analysis / Computing Model Panel

	D. Lenglin (CC-IN2P3 / CNRS) F. Gagliari (CERN)	Chair Secretary	
Expt. Reps.:	ALICE ATLAS CMS LHCb	Representative A. Masoni (INFN Rome) A. Putzer (U. Heidelberg) H. Newman (CALTECH) F. Harris (U. Oxford) C. Michau (UREC-STIC / CNRS)	Alternate A. Sandoval (GSI Darmstadt) L. Perini (U. Milan) W. Jank (CERN) M. Schmelling (MPI Heidelberg)
Experts:	Y. Morita (KEK)		

Software Project Panel

	M. Kasemann (FNAL) A. Pfeiffer (CERN)	Chair Secretary and CERN-IT representative	
Expt. Reps.:	ALICE ATLAS CMS LHCb	Representative R. Brun (CERN) D. Barberis (U. Genoa) L. Taylor (Northeastern U.) P. Mato (CERN)	Alternate A. Morsch (CERN) M. Bosman (U.A. Barcelona) T. Todorov (IN2P3 Strasbourg) O. Callot (LAL Orsay)
Experts:	V. White (FNAL)		

Management and Resources Panel

	M. Calvetti (INFN Florence) M. Lamanna (INFN Trieste and CERN)	Chair Secretary	
Expt. Reps.:	ALICE ATLAS CMS LHCb	Representative P. Vande Vyvre (CERN) J. Huth (Harvard) P. Capiluppi (INFN Bologna) J. Harvey (CERN) J. Gordon (RAL) T. Wenaus (BNL)	Alternate K. Safarik (CERN) H. Meinhard (CERN) I. Willers (CERN) J.P. Dufey (CERN) L. Robertson (CERN) K. Woller (DESY)
Experts:	F. Etienne (IN2P3 Marseille) F. Ruggieri (INFN Bari) G. Wormser (IN2P3 Paris)		

The LHC Computing Review

the challenge:

- 4 experiments; 50-200 Hz data taking rate
- raw event size: 0.12 / 1 / 1-25 MB (LHCb / ATLAS-CMS / ALICE)
- total raw data storage: 7 PB/a ($7 \cdot 10^{15}$ Bytes per year)
- total simulated Data storage: 3.2 PB/a
- world-wide* tape storage: 28.5 PB/a (40 million CD-Rom's)
- world-wide* disk storage: 10.4 PB/a (140k disks à 75 GB)
- world-wide* CPU capacity: 7350 k SI -95 (360k today's PCs)
- WAN bandwidth (Tier-0/-1): 1500 Mbps (1 experiment)
(5000 Mbps when serving all 4 exp.'s)

* all Tier-0, Tier-1 and Tier-2 computing centres, excl. Tier-3 and -4

The LHC Computing Review

(Executive Summary – the LHC computing model)

1. review **accepts scale of resource requirements** of exp.s
2. recommend **distributed, hierarchical model** à la MONARC
 - Tier-0: at CERN; raw data storage; reconstruction; ...
 - Tier-1: regional/supranational; analysis, MC generation, storage, ...
 - Tier-2: national/intranational;
 - Tier-3: institutional;
 - Tier-4: end-user workstations
3. **GRID technology** to be used (efficient resource usage, rapid turnaround)
4. need well-supported Research Networking of 1.5–3 Gbps (for each experiment), at **affordable costs**, by 2006.

Computing Resources¹³ planned by the four LHC Experiments in 2007 (*)

Parameter	Unit	ALICE		ATLAS	CMS	LHCb	TOTAL	ATLAS (**)
		p-p	Pb-Pb					
# assumed Tier1 not at CERN		4		6	5	5		6
# assumed Tier2 not at CERN***					25			
Event recording rate	Hz	100	50	100	100	200		270
RAW Event size	MB	1	25	1	1	0.125		2
REC/ESD Event size	MB	0.1	2.5	0.5	0.5	0.1		0.5
AOD Event size	kB	10	250	10	10	20		10
TAG Event size	kB	1	10	0.1	1	1		0.1
Running time per year	M seconds	10	1	10	10	10		10
Events/year	Giga	1	0.05	1	1	2		2.7
Storage for real data	PB	1.2	1.5	2.0	1.7	0.45	6.9	8.1
RAW SIM Event size	MB	0.5	600	2	2	0.2		2
REC/ESD SIM Event size	MB	0.1	5	0.5	0.4	0.1		0.5
Events SIM/year	Giga	0.1	0.0001	0.12	0.5	1.2		0.12
Number of reconst. passes	Nb	2		2-3	2	2-3		2-3
Storage for simul. data	PB	0.1	0.1	1.5	1.2	0.36	3.2	1.5
Storage for calibration	PB	0.0	0.0	0.4	0.01	0.01	0.4	0.4
Tape storage at CERN T0+T1	PB (10**15 B)	3.23		2.86	4.17	1.22	11.5	9.00
Tape storage at each Tier1 (Avg.)		}0.37		}1.26	1.02	}0.32	}3.0	}1.80
Tape storage at each Tier2 (Avg.)***					0.05			
Total tape storage / year		4.7		10.4	10.5	2.8	28.5	19.8
Disk storage at CERN T0+T1	PB	0.53		0.31	1.14	0.33	2.3	0.41
Disk storage at each Tier1 (Avg.)		}0.27		}0.26	0.44	}0.15	}1.1	}0.36
Disk storage at each Tier2 (Avg.)***					0.10			
Total disk storage		1.6		1.9	5.9	1.1	10.4	2.57
Time to reconstruct 1 event	k SI-95 sec	0.4	100	0.64	3	0.25		0.64
Time to simulate 1 event	k SI-95 sec	3	2250	3	5	1.5		3
CPU for 1 rec. pass/y (real data)	k SI-95	20	250	200	434	50		385
CPU for 1 SIM pass/y (sim+rec)	k SI-95	19	269	30	200	660		30
CPU reconstruction, calib.	k SI-95	65	525	251	1040	50	1931	435
CPU simulation		19	269	30	587	660	1564	30
CPU analysis		880		1479	1280	215	3854	1479
Total CPU at CERN T0+T1	k SI-95	824		506	820	225	2375	690
Total CPU each Tier1 (Avg.)		}234		}209	204	}140	}787	}209
Total CPU each Tier2 (Avg.)***					43			
Total CPU		1758		1760	2907	925	7349	1944
WAN, Bandwidths								
Tier0 - Tier1 link, 1 expt.	Mbps	1500		1500	1500	310	4810	1500
Tier1 - Tier2 link		622		622	622			622

(*) or the first full year with design luminosity

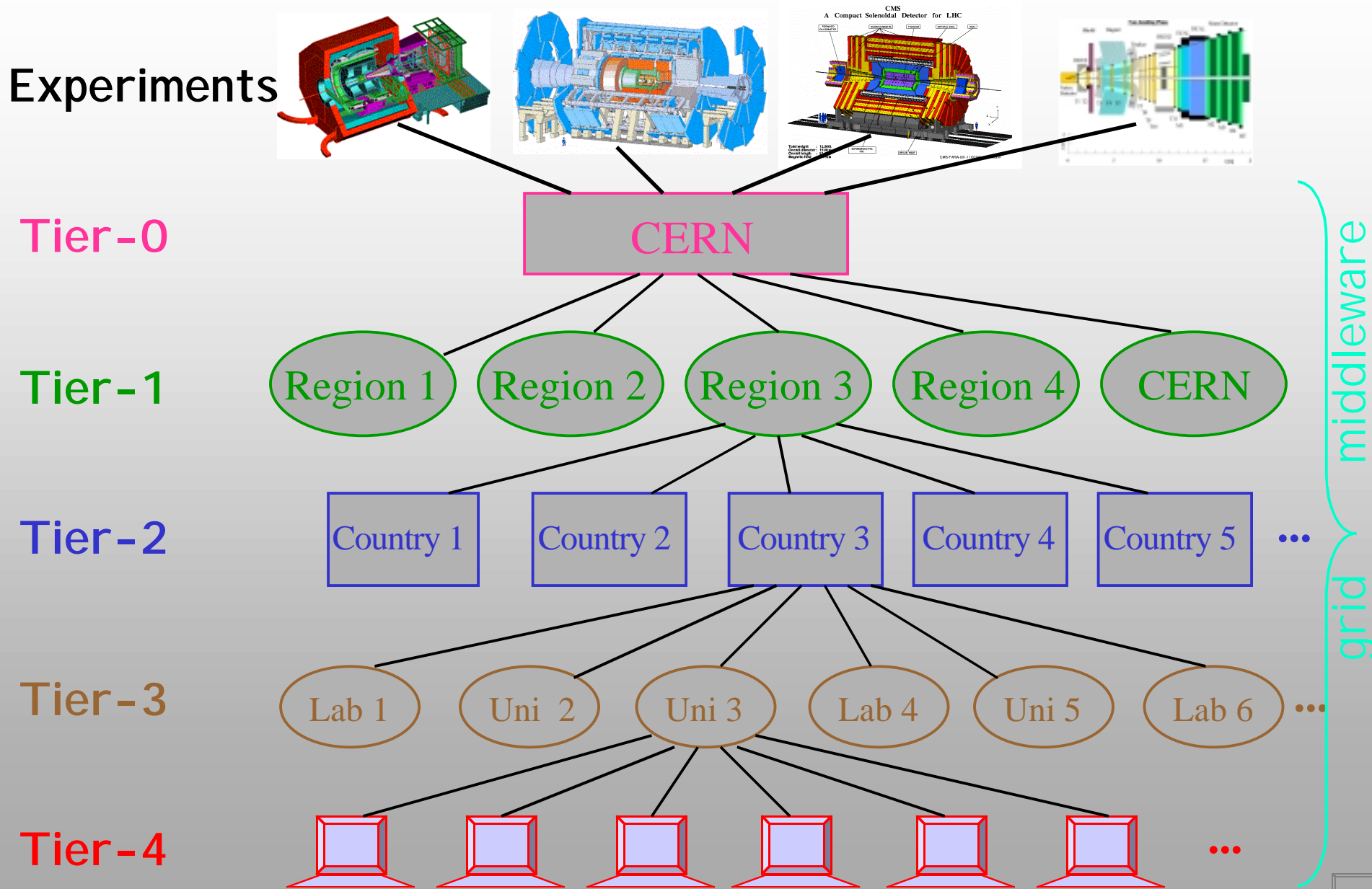
(**) further estimates envisaged by ATLAS, see Chapter 5.1.2.1 for details.

(***) for all except CMS, the Tier1 and Tier2 needs are merged together.

*(all numbers
include
realistic
usage
efficiency
factors)*





The LHC Computing Model



The LHC Computing Review

(Executive Summary – Software)

5. recommend **joint efforts and common projects** between experiments and CERN-IT; support for widely used products 
6. perform **data challenges** of increasing size and complexity
7. CERN should sponsor **transition to OO** programming
8. identified **areas of concern**:
 - limited maturity of current planning and resource estimates
 - insufficient development and support of simulation packages
 - insufficient support and future evolution of analysis tools

Examples
of

Common software products in use by LHC experiments

Project/Product		X=yes					IT	as	used by	
		ALICE	ATLAS	LHCb	CMS	HEP outside LHC			non-HEP	
GEANT4	Detector Simulation	X	X		X	X	developer	X	X	
	package written by GEANT collaboration		X	X	X	X	maintainer	X	X	
		X	X	X	X		user	X	X	
GEANT3	Detector Simulation						developer	X		
	package written in Fortran	X			X	X	maintainer	X		
		X	X	X	X		user	X		
FLUKA	MC for radiation studies						developer	X		
							maintainer	X		
		X	X	X	X		user	X		
Event Generators	Many - including Pythia, Herwig, QQ,etc.						developer	X		
							maintainer	X		
		X	X	X	X		user	X		
Objectivity DB + tools/knowledge	Commercial Object Database				X	X	"developer"	X	X	
	tools+knowledge		X		X	X	administrator	X	X	
					X	X	user	X	X	
ROOT persistency,CINT and file format	ROOT objects streamed to files for either data or conditions	X					developer	X	X	
		X					maintainer	X	X	
		X		X			user	X	X	
Mass Storage System	HPSS, Castor, other...					Castor	developer			
						X	administrator			
		X	X	X	X	X	user			
Relational DB for data handling	ORACLE or MySQL						developer	X	X	
						X	administrator	X	X	
		X		X			user	X	X	
ANAPHE	Replacement for CERNLIB				X	X	developer	X		
	several commercial and					X	maintainer	X		
	many HEP packages		X	X	X		user	X		



The LHC Computing Review

(Executive Summary – Management and Resources)

9. Current **cost estimates** based on forecast evolution of price and performance of computer hardware □

10. hardware costs of **initial set-up** of LHC distributed computer centres (Tier-0 to -2): **240 MCHF**
CERN-based Tier-0+1 centre: about 1/3 of total.

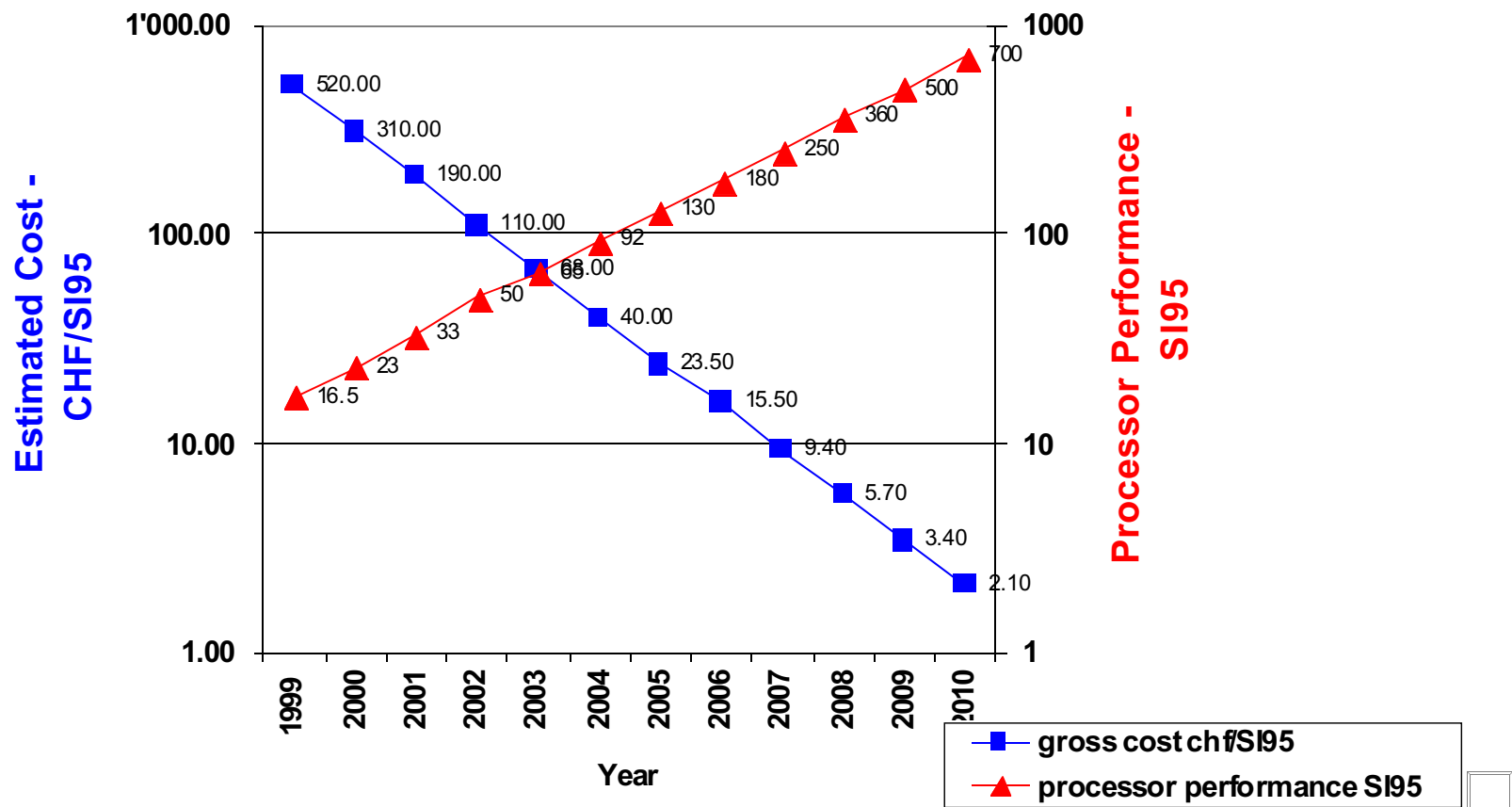
Significant uncertainties due to performance of LHC, detectors, triggers, backgrounds ...

11. investment for initial system to be spent in 2005, 2006 and 2007, in ~ equal portions (assuming LHC start-up in 2006 and reach of design luminosity in 2007)

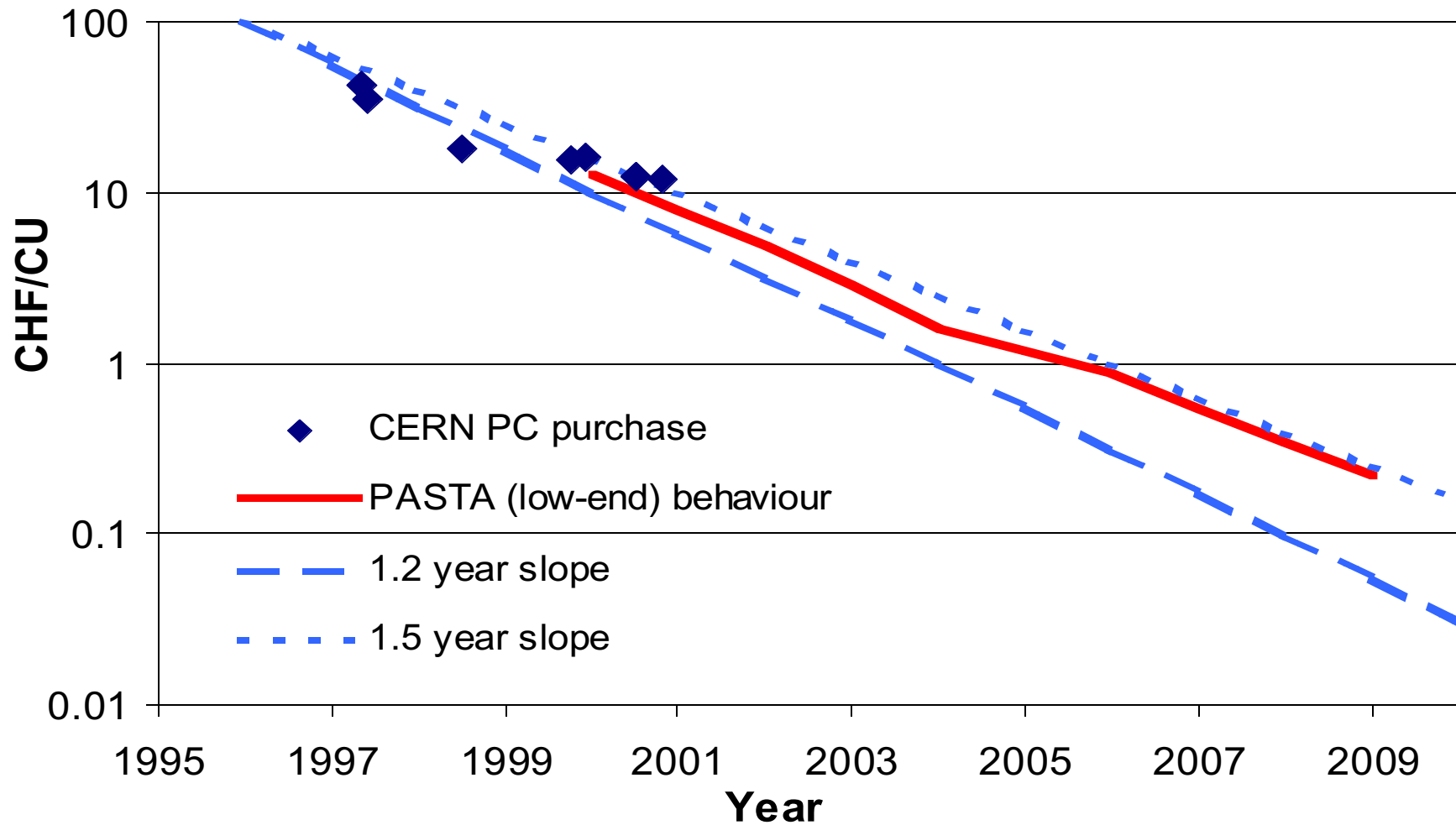
12. major concern: **core software teams severely understaffed**

CPU price evolution (PASTA report)

Projected Evolution of Processor Performance, Price/Performance

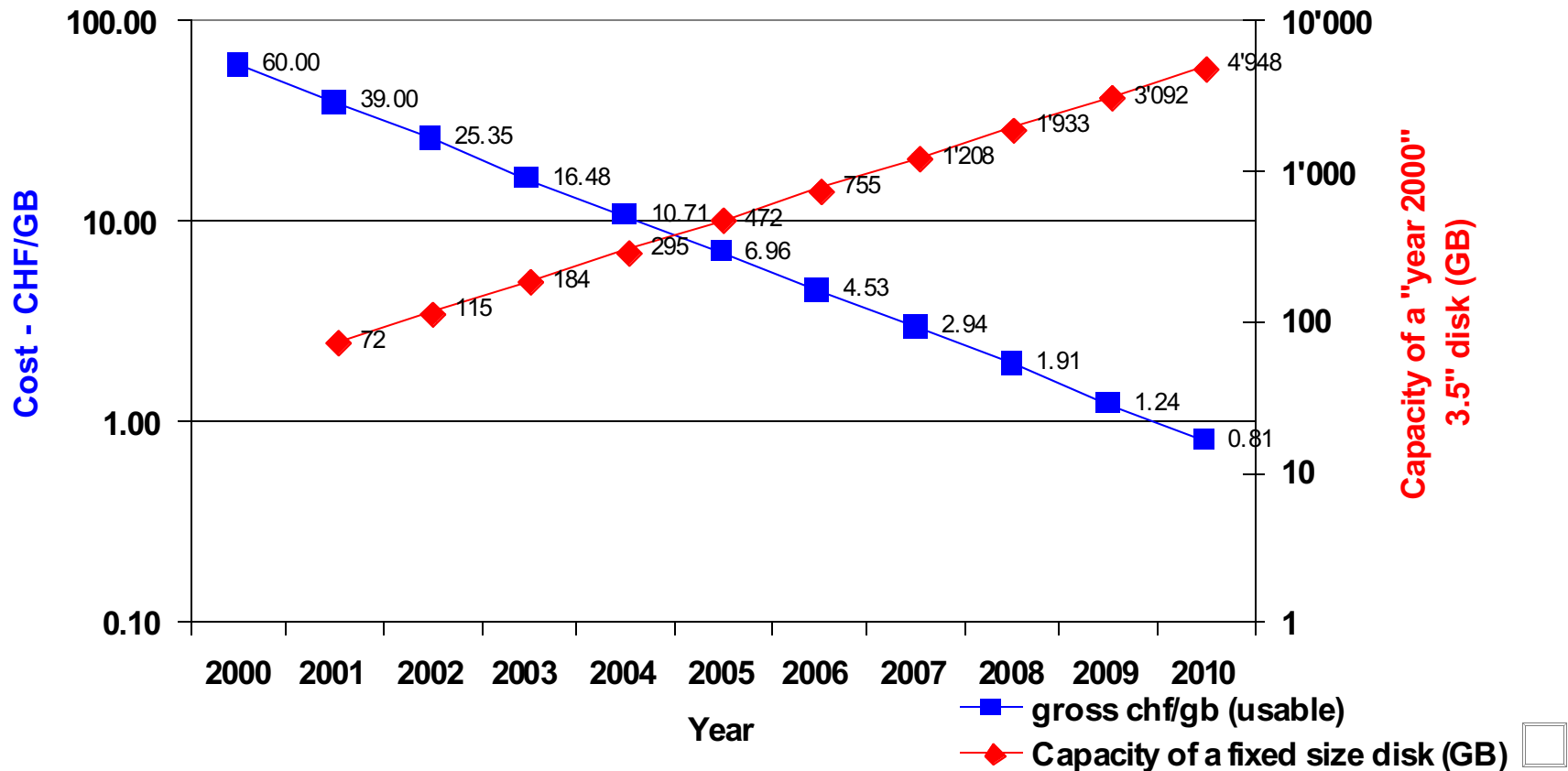


Comparison of recent CERN PC purchases with PASTA predictions



Disk price evolution (PASTA report)

Projected evolution of Cost of Disk Storage, Storage Density (mirrored IDE disk, usable capacity)



Required human resources (FTEs) to write the Core Software

Required human resources to write the Core Software							
	<i>available</i>	<i>----- resources required (person-years) -----</i>					
<i>year</i>	<i>2000</i>	<i>2000</i>	<i>2001</i>	<i>2002</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>
<i>collaboration</i>							
ALICE	12.0	17.0	17.5	16.5	17.0	17.5	16.5
ATLAS	23.0	31.0	36.0	35.0	30.0	28.0	29.0
CMS	15.0	25.0	27.0	31.0	33.0	33.0	33.0
LHCb	14.0	19.0	25.0	24.0	23.0	22.0	21.0
Totals	64.0	92.0	105.5	106.5	103	100.5	99.5
Additional resources		28.0	41.5	42.5	39.0	36.5	35.5

¹CORE software includes everything except the algorithmic part of the reconstruction software, the simulation and physics analysis. Human resources attributable to the GRID are not included.



The LHC Computing Review

(Executive Summary – Management and Resources)

13. planned **reduction of CERN-IT staff: incompatible** with CERN-based LHC computing system and software support
14. M&O of LHC computing system: **rolling replacement within constant budget**: requires ~ 1/3 of initial investment per year (~ 80 MCHF world-wide) - includes steady evolution of capacity
15. set-up of a **common prototype** as joint project (experiments, CERN-IT, major regional centres), reaching ~50% of overall computing complexity of 1 LHC experiment by ~2003/4
(estimated costs: ~ 18 MCHF - not included in initial invest.costs)
16. set up **agreement** about construction & cost sharing of prototype - **now!**

The LHC Computing Review

(Executive Summary – general recommendations)

17. Set up LHC Software and Computing Steering Committee (SC2) composed of highest level software and computing management in experiments, CERN-IT and regional centres to steer deployment of entire LHC hierarchical system
18. SC2 establishes Technical Assessment Groups (TAG's) to prepare and initiate certain tasks and projects
19. Each collaboration must prepare a MoU for LHC computing describing funding and responsibilities for hard- and software, human resources etc.
I MoU's or prototype/software agreements by end of 2001.

The LHC Computing Review: Summary

- emphasise utmost importance of proper funding, development, timely realisation and maintenance of computing for success of LHC !
- unprecedented challenge to international HEP and IT communities.
- follow distributed, hierarchical computing model à la MONARC.
- **initial hardware costs** of overall LHC Tier0-2 system: **~ 240 MCHF.**
(note: there are still sizeable uncertainties in these estimates)
- CERN-based Tier0+1 for all experiments: ca. 1/3 of total system.
- **maintenance and operation:** rolling replacements; **~ 80 MCHF / yr.**
- software development teams and CERN-IT **severely understaffed!**
- importance of support for commonly used software products.
- need for data challenges and common computing prototype.
- **setup & sign MoU's:** - prototype - software - LHC computing.
- setup SC2 committee to steer LHC computing project.

The End

of LHC Computing Review

The Start

of LHC Computing Project *funding*