Big Data and Storage Management at the Large Hadron Collider

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Accelerating Science and Innovation
CERN was founded 1954: 12 European States
“Science for Peace”
Today: 21 Member States

Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom
Candidate for Accession: Romania
Associate Members in Pre-Stage to Membership: Serbia
Applicant States for Membership or Associate Membership:
Brazil, Cyprus (awaiting ratification), Pakistan, Russia, Slovenia, Turkey, Ukraine
Observers to Council: India, Japan, Russia, Turkey, United States of America; European Commission and UNESCO

~ 2,300 staff
~ 1,000 other paid personnel
> 11,000 users
Budget (2013) ~1,000 MCHF
Global Science: 11000 scientists

Distribution of All CERN Users by Nation of Institute on 4 April 2012

MEMBER STATES
- Austria 102
- Belgium 138
- Bulgaria 53
- Czech Republic 202
- Denmark 75
- Finland 101
- France 908
- Germany 1318
- Greece 105
- Hungary 57
- Italy 1417
- Netherlands 186
- Norway 90
- Poland 206
- Portugal 133
- Slovakia 61
- Spain 363
- Sweden 88
- Switzerland 397
- United Kingdom 784

6784

CANDIDATE FOR
- Accession
  - Romania 78

ASSOCIATE MEMBER
IN THE PRE-STAGE TO MEMBERSHIP
- Israel 67
- Serbia 26

OTHERS
- China 115
- China (Taipei) 70
- Colombia 10
- Croatia 21
- Cuba 4
- Cyprus 9
- Egypt 7
- Ethiopia 17
- Georgia 10
- Iceland 3
- Iran 16
- Ireland 10
- Israel 20
- Korea 91
- Lebanon 1
- Libya 13
- Malta 1
- Mexico 43
- Montenegro 1
- Morocco 6
- New Zealand 11
- Oman 1
- Pakistan 22
- Peru 2
- Qatar 9
- Saudi Arabia 3
- Slovenia 38
- South Africa 21
- Thailand 5
- T.F.Y.R.O.M. 2
- Tunisia 1

934

3050

OBSERVERS
- India 134
- Japan 225
- Russia 859
- Turkey 83
- USA 1749
Stars and Planets only account for a small percentage of the universe!
Collisions at the LHC: summary

Proton - Proton: 2808 bunch/beam
Protons/bunch: $10^{11}$
Beam energy: 7 TeV (7x$10^{12}$ eV)
Luminosity: $10^{34}$ cm$^{-2}$s$^{-1}$
Crossing rate: 40 MHz
Collision rate: $10^7$-$10^9$

New physics rate: $0.00001$ Hz

Event selection: 1 in $10,000,000,000,000,000$
The 27 km long ring is sensitive to <1mm changes.
The Worldwide LHC Computing Grid

7000 tons, 150 million sensors generating data 40 millions times per second, i.e. a petabyte/s

The ATLAS experiment
A collision at LHC
The Data Acquisition for one Detector

~ 300.000 MB/s from all sub-detectors

~ 300MB/s Raw Data
Tier 0 at CERN: Acquisition, First reconstruction, Storage & Distribution

Tier 0 at CERN:
Acquisition, First reconstruction, Storage & Distribution

2011: 4-6 GB/sec

2011: 400-500 MB/sec

1.25 GB/sec (ions)
The LHC Data Challenge

- The accelerator will run for 20 years
- Experiments are producing about **25 Million Gigabytes** of data each year (about 3 million DVDs – 850 years of movies!)
- LHC data analysis requires a computing power equivalent to ~100,000 of today's fastest PC processors
- Requires many cooperating computer centres, as CERN can only provide ~20% of the capacity
WLCG – what and why?

A distributed computing infrastructure to provide the production and analysis environments for the LHC experiments

Managed and operated by a worldwide collaboration between the experiments and the participating computer centres

The resources are distributed – for funding and sociological reasons

Our task was to make use of the resources available to us – no matter where they are located

Tier-0 (CERN):
- Data recording
- Initial data reconstruction
- Data distribution

Tier-1 (12 centres + Russia):
- Permanent storage
- Re-processing
- Analysis

Tier-2 (~140 centres):
- Simulation
- End-user analysis

- ~ 160 sites, 35 countries
- 300000 cores
- 200 PB of storage
- 2 Million jobs/day
- 10 Gbps links
Data 2008-2013

CERN Tape Writes
27 PB
23 PB
15 PB

Tape Usage Breakdown

CERN Tape Archive

CERN Tape Verification

Data Loss: ~65 GB over 69 tapes
Duration: ~2.5 years

March 2014
Data transfers

- Global transfer rates are always significant (12-15 GB/s) – permanent on-going workloads

- CERN export rates driven (mostly) by LHC data export
No stop for the computing!

Activity on 1 January 2014
Running Jobs: 223509
Transfer rate: ~2.5 GiB/s
Processing on the Grid

1.4 $10^9$ HEPSPEC06/Month (210 K CPU continuous use)

Close to full capacity
Broader Impact of the LHC Computing Grid

- WLCG has been leveraged on both sides of the Atlantic, to benefit the wider scientific community
  - Europe:
    - Enabling Grids for E-sciencE (EGEE) 2004-2010
    - European Grid Infrastructure (EGI) 2010--
  - USA:
    - Open Science Grid (OSG) 2006-2012 (+ extension?)

- Many scientific applications ➔

Archeology
Astronomy
Astrophysics
Civil Protection
Comp. Chemistry
Earth Sciences
Finance
Fusion
Geophysics
High Energy Physics
Life Sciences
Multimedia
Material Sciences
...
A public-private partnership between the research community and industry
CERN openlab in a nutshell

- A science – industry partnership to drive R&D and innovation with over a decade of success
- Evaluate state-of-the-art technologies in a challenging environment and improve them
- Test in a research environment today what will be used in many business sectors tomorrow
- Train next generation of engineers/employees
- Disseminate results and outreach to new audiences
The CERN Data Centre in Numbers

- Data Centre Operations (Tier 0)
  - 24x7 operator support and System Administration services to support 24x7 operation of all IT services.
  - Hardware installation & retirement
    - ~7,000 hardware movements/year; ~1800 disk failures/year
  - Management and Automation framework for large scale Linux clusters

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<table>
<thead>
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<tbody>
<tr>
<td><strong>Racks</strong></td>
<td>1127</td>
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<td><strong>Servers</strong></td>
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<td><strong>Processors</strong></td>
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<td><strong>HEPSpec06</strong></td>
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<td><strong>Disks</strong></td>
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<td><strong>Raw disk capacity (TiB)</strong></td>
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<td><strong>Memory modules</strong></td>
<td>64035</td>
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<td><strong>Memory capacity (TiB)</strong></td>
<td>312</td>
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<td><strong>RAID controllers</strong></td>
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<tr>
<td><strong>Tape Drives</strong></td>
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<td><strong>Tape Cartridges</strong></td>
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<td><strong>Tape slots</strong></td>
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<td><strong>Data on Tape (PiB)</strong></td>
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<td><strong>High Speed Routers</strong></td>
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<td><strong>Ethernet Switches</strong></td>
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<td><strong>10 Gbps/100Gbps ports</strong></td>
<td>1396/74</td>
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<td><strong>Switching Capacity</strong></td>
<td>6 Tbps</td>
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<td><strong>1 Gbps ports</strong></td>
<td>27984</td>
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<td><strong>10 Gbps ports</strong></td>
<td>5664</td>
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<tr>
<td><strong>IT Power Consumption</strong></td>
<td>2392 KW</td>
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<tr>
<td><strong>Total Power Consumption</strong></td>
<td>3929 KW</td>
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March 2014
Thank You!