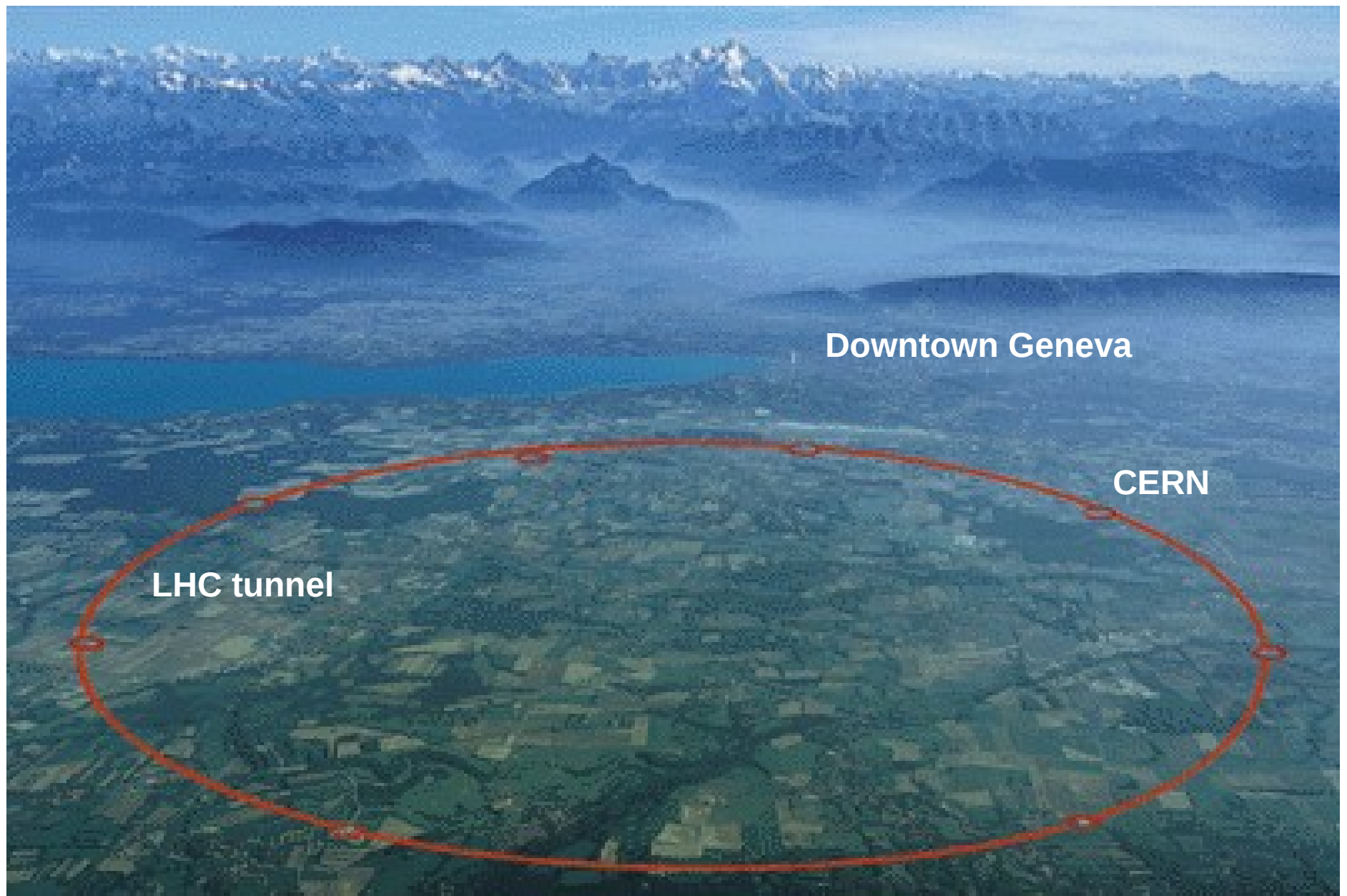




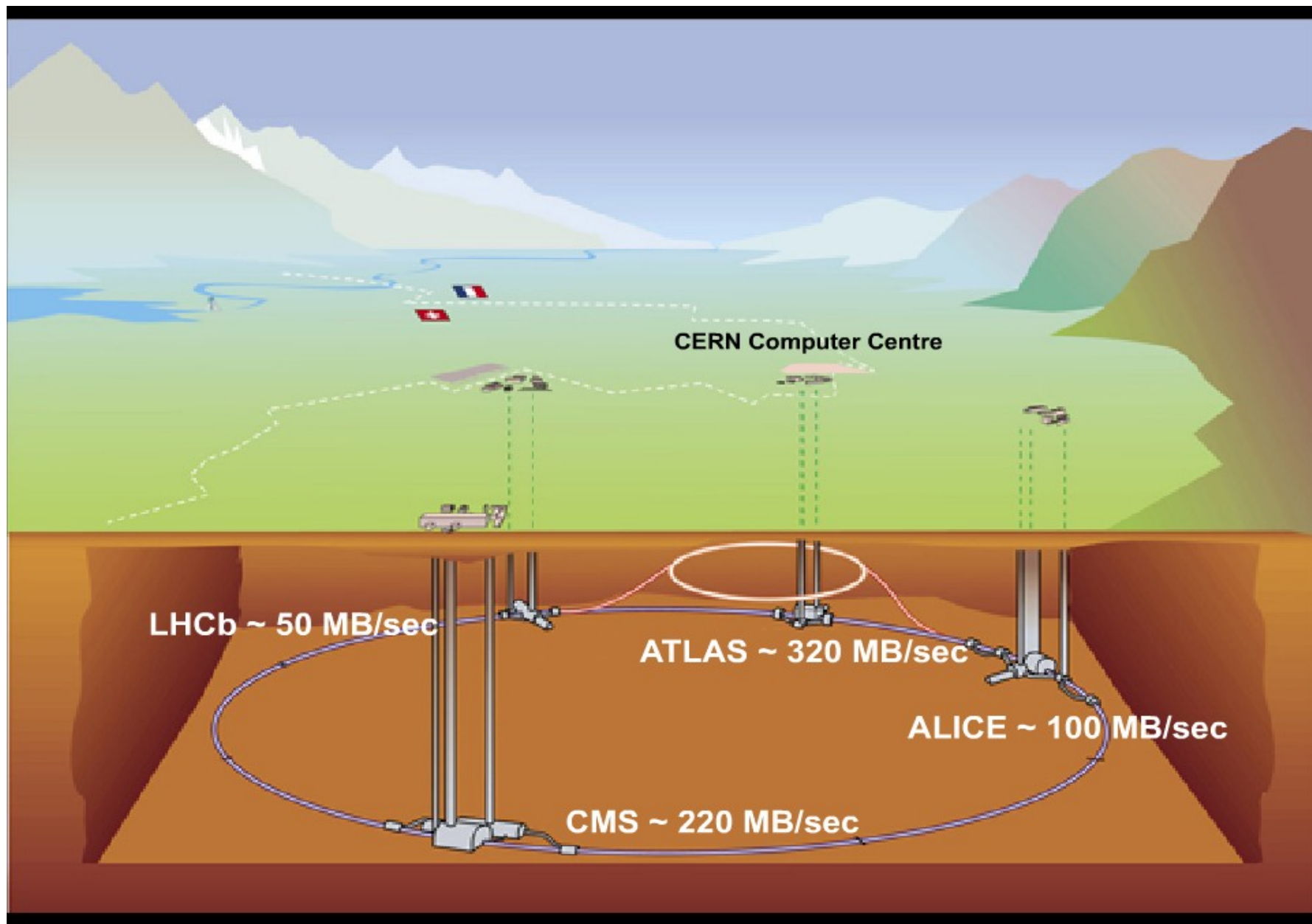
# LHC Computing and the GRID

Georgian Teachers Programme  
CERN, 27-Jan-2011

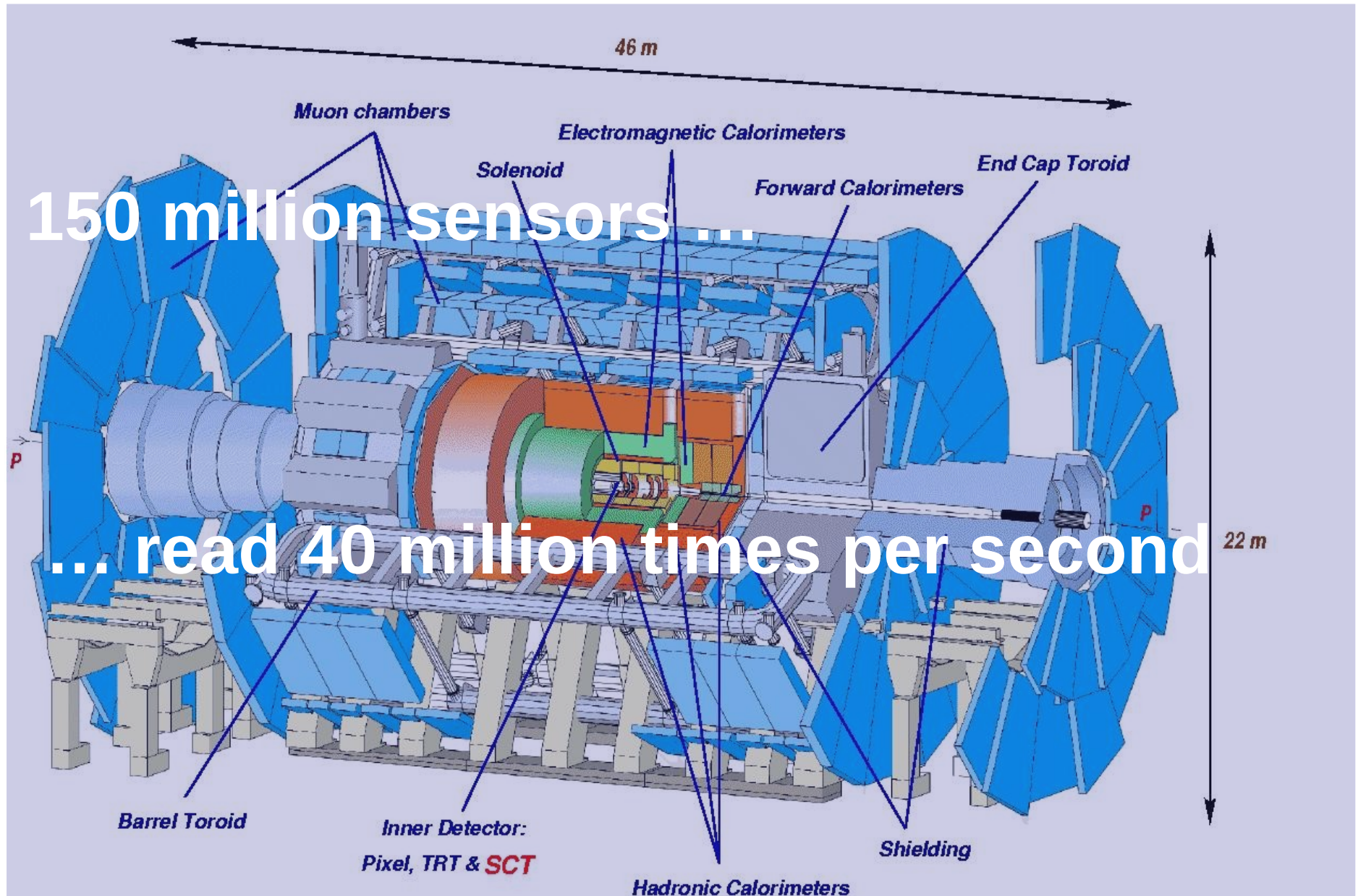
# The Large Hadron Collider (LHC) ...



## ... and The Experiments



# The ATLAS detector



150 million sensors ...

... read 40 million times per second

# The LHC Computing Challenge

- A particle collision = an event
- Pattern recognition problem working backwards from
  - Electronic signals in detectors
  - To mass, charge, momentum of decay products
  - To mass, charge, momentum of short-lived collision product
- Example: The Higgs boson
  - Look for characteristic decay pattern producing 4 muons
  - Record over 8 million events per day
  - On average only one event per day will be a Higgs boson

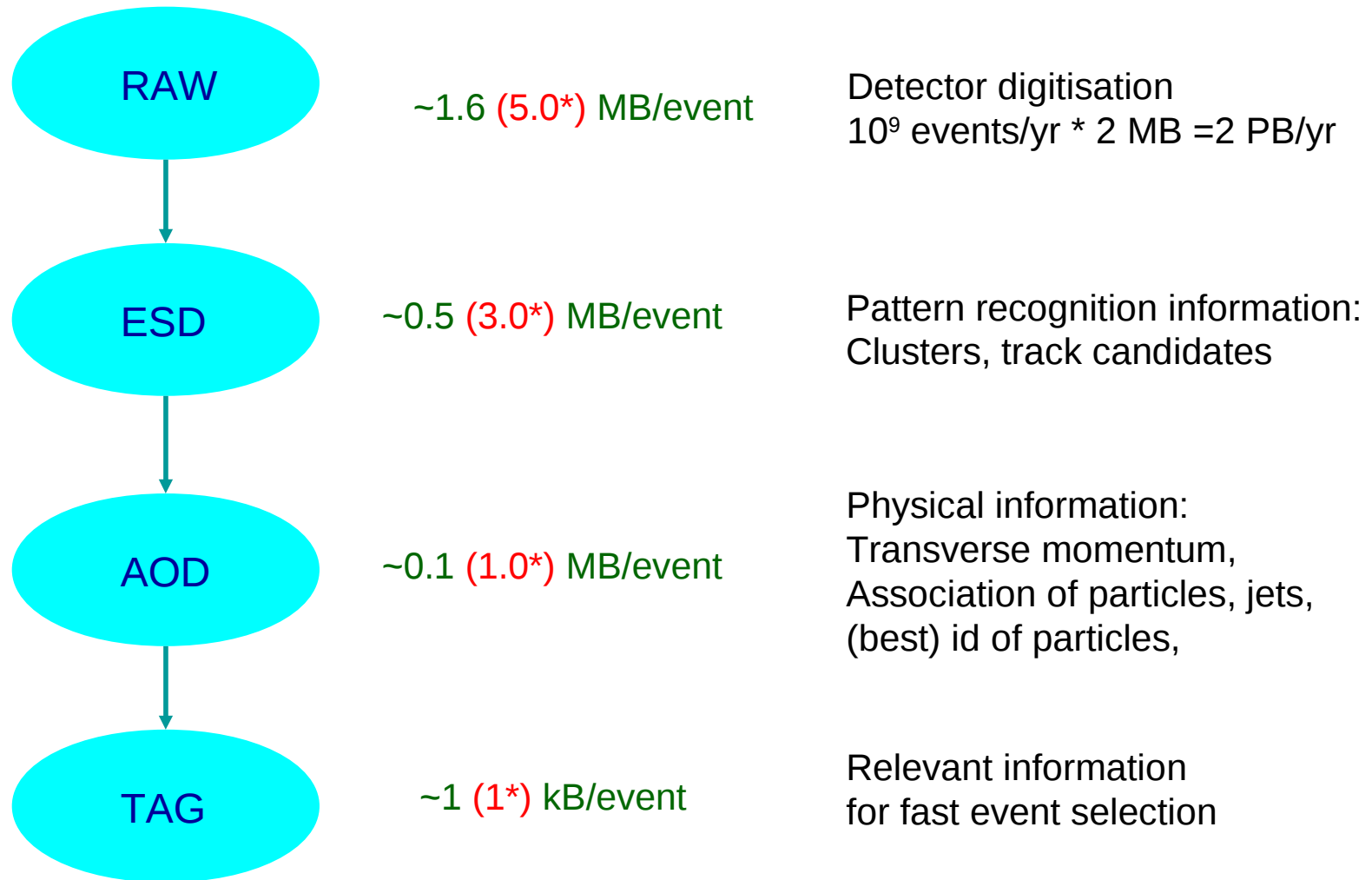
# The LHC Computing Challenge

- 40 million bunch collisions per second
- After filtering,  $\sim 100$  collisions of interest per second per detector
- $>1$ MB of data per collision, recording rate  $>1$  GB/sec
- $10^{10}$  collisions recorded each year, stored data  $\sim 15$  PB/year ...
- ... for over 10 years

# Types of Data

<i>Type</i>	<i>Description</i>
<b>RAW</b>	Real Raw Data, as recorded after the HLT
<b>SIM</b>	Simulated Data (HIT, RDO)
<b>DRD</b>	Derived Reconstruction Data
<b>ESD</b>	Event Summary Data (after reconstruction)
<b>AOD</b>	Physics Analysis Object Data
<b>DPD</b>	Derived Physics Data (analogous with n-tuples)
<b>TAG</b>	Short event summaries primarily for event selection

# Event size (ATLAS)



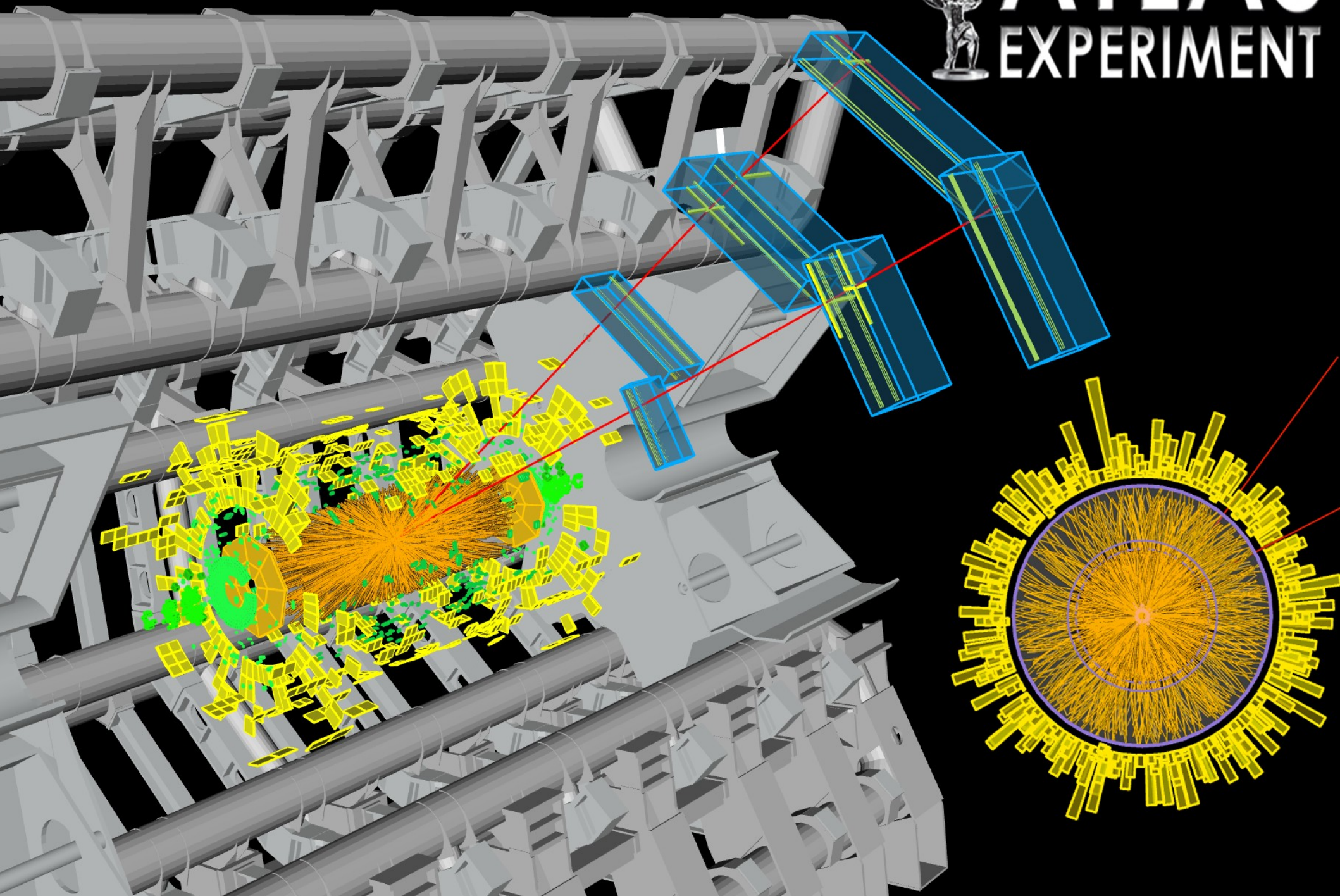
\* Heavy Ions



Run 169226, Event 379791  
Time 2010-11-16 02:53:54 CET



# ATLAS EXPERIMENT



# Data Storage and Data Processing

- Experiments producing ~15 Million Gigabytes of data each year
  - **Where will we store all of this data?**
- LHC data analysis requires a computing power equivalent to ~100,000 of PC processors
  - **Where will we find such a computing power?**
- Requires many cooperating computer centers as CERN can provide only ~20% of the capacity

# CERN Computing Center

- Number of machines (includes CPU servers, disk servers and infrastructure servers)
  - **8,500** machines with **54,000** cores
- Networking:
  - Connected to T1 centers using **10 Gbits/s** dark fiber connections and the GEANT network
- Data Storage:
  - Tape: **~40,000 TB**
  - Disk: **49,900 TB** on 58,500 disk drives
- Misc:
  - Major clean out took place in 2005 where more than **100km of cables** were removed
  - CERN Mail servers: 99% of the mail that reaches CERN is SPAM

# Computing for LHC

- **Problem:** Even with the Computing Center upgrade, CERN can provide only a fraction of the necessary resources
- **Solution:** CERN has over 250 partner institutes in Europe and over 200 the rest of the world. Many of them have significant computing resources
  - Build a **GRID** that **unites these computing resources**



# What is the GRID?



The **World Wide Web** provides seamless access to information that is stored in many millions computers of different geographical locations

The **Grid** is an infrastructure that provides seamless access to computing power and data storage capacity distributed over the globe

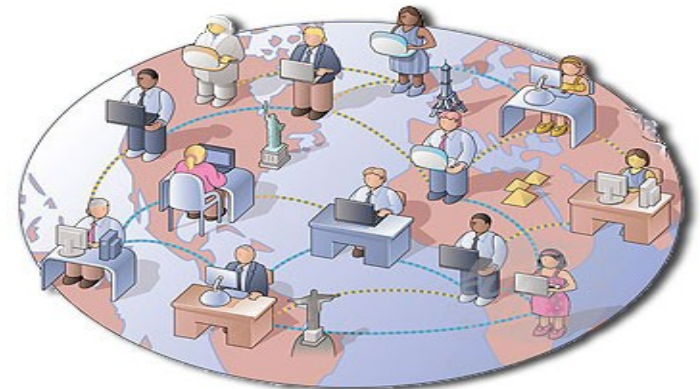
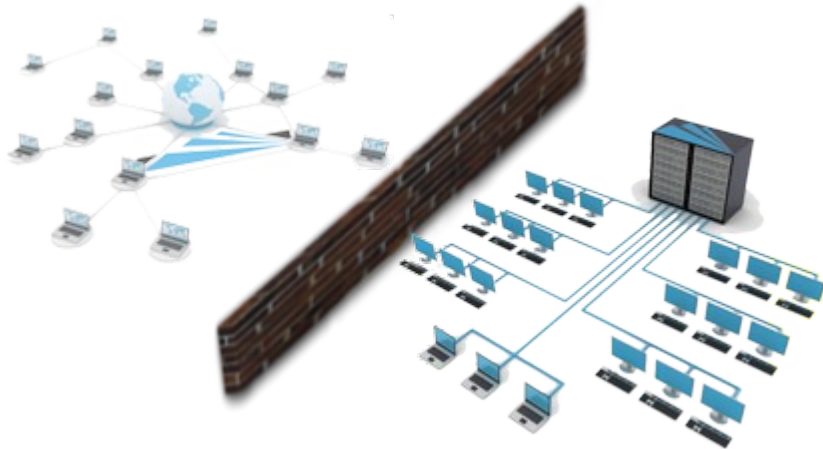
# GRID History

- Name “Grid” chosen by analogy with **electric power grid**
- **Vision:** plug-in computer for processing power just like plugging in toaster for electricity
- Concept has been around for decades (metacomputing, distributed computing)
- Distributed computing grid originally conceived at CERN in 1999
- Key difference with the Grid is to realize vision on a **global scale**



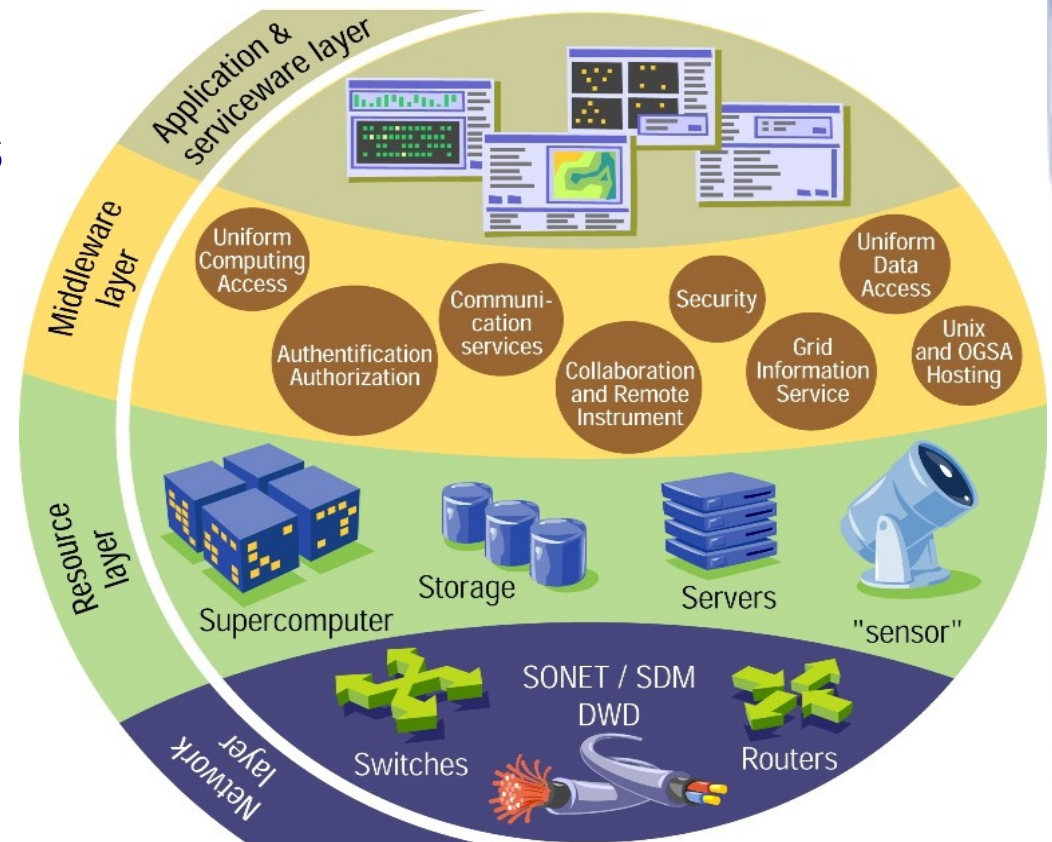
# Different Grids for different needs

- There is as yet no unified Grid, like there is a single Web. Rather there are many Grids for many applications:
  - **Enterprise Grids** link together PCs within single company
  - **Volunteer computing** links together public computers
  - **Scientific grids** link together major computing centers
  - **National Grids** are federated into **global** Grid infrastructure
  - High Energy Physics is a driving force for this



# How does the Grid work?

- It relies on advanced software called **middleware**
- Middleware automatically finds the needed **data** and the **computing power** to analyze it
- Middleware balances the load on different resources. It also handles **security, accounting, monitoring** and much more





# Virtual Organization

High Energy Physics, Earth Observation and Biology are examples of communities made up of several institutions and individuals sharing the same interests and the same scientific goals. They greatly benefit from putting together their computing resources, data and scientific instruments.

Such distributed communities are called *Virtual Organisations*.

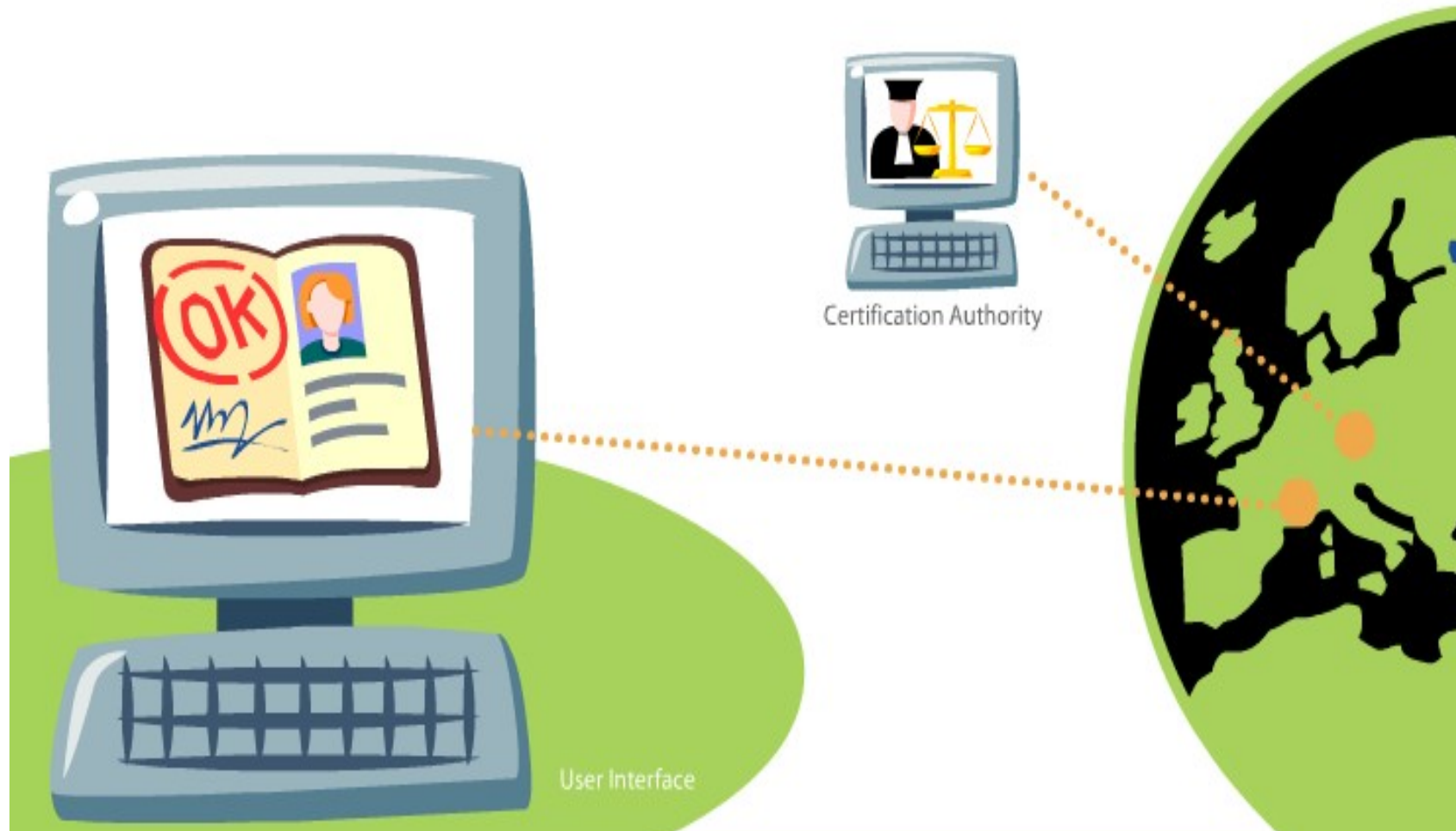


# Step 1: Join Virtual Organization

To have access to the Grid facility, you need to join a *Virtual Organisation*.



## Step 2: Get a permission



## Step 3: Write a file describing your job

To run a job on the LCG/EGEE Grid Facility, you have to describe it in the *Job Description Language (JDL)*.

**JDL** specifies job characteristics such as the application to use, the input data, the required resources, etc.



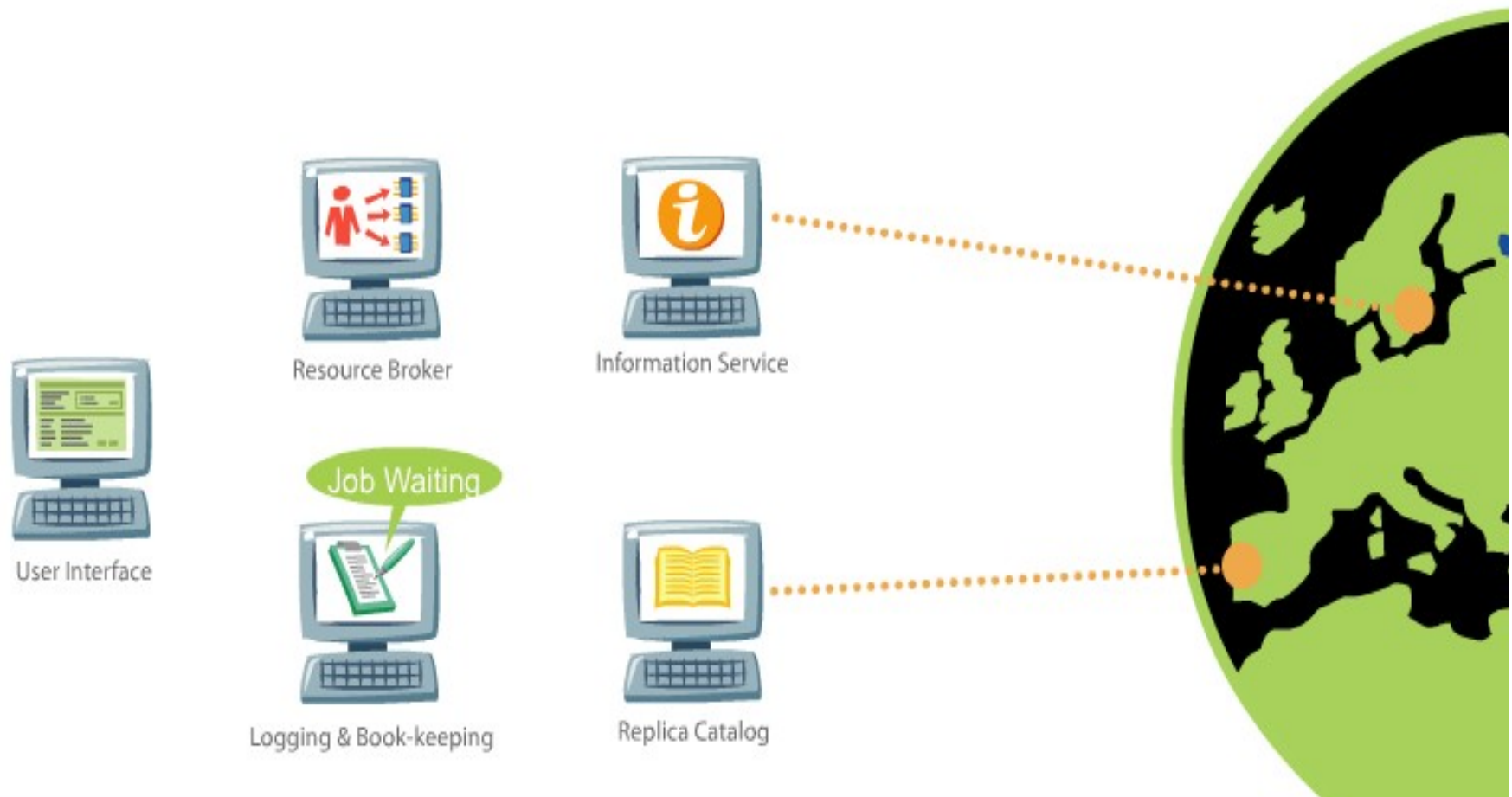
## Step 4: Submit your job to the resource broker

Once you have the jdl file for your job, you can submit it to the *Resource Broker*.



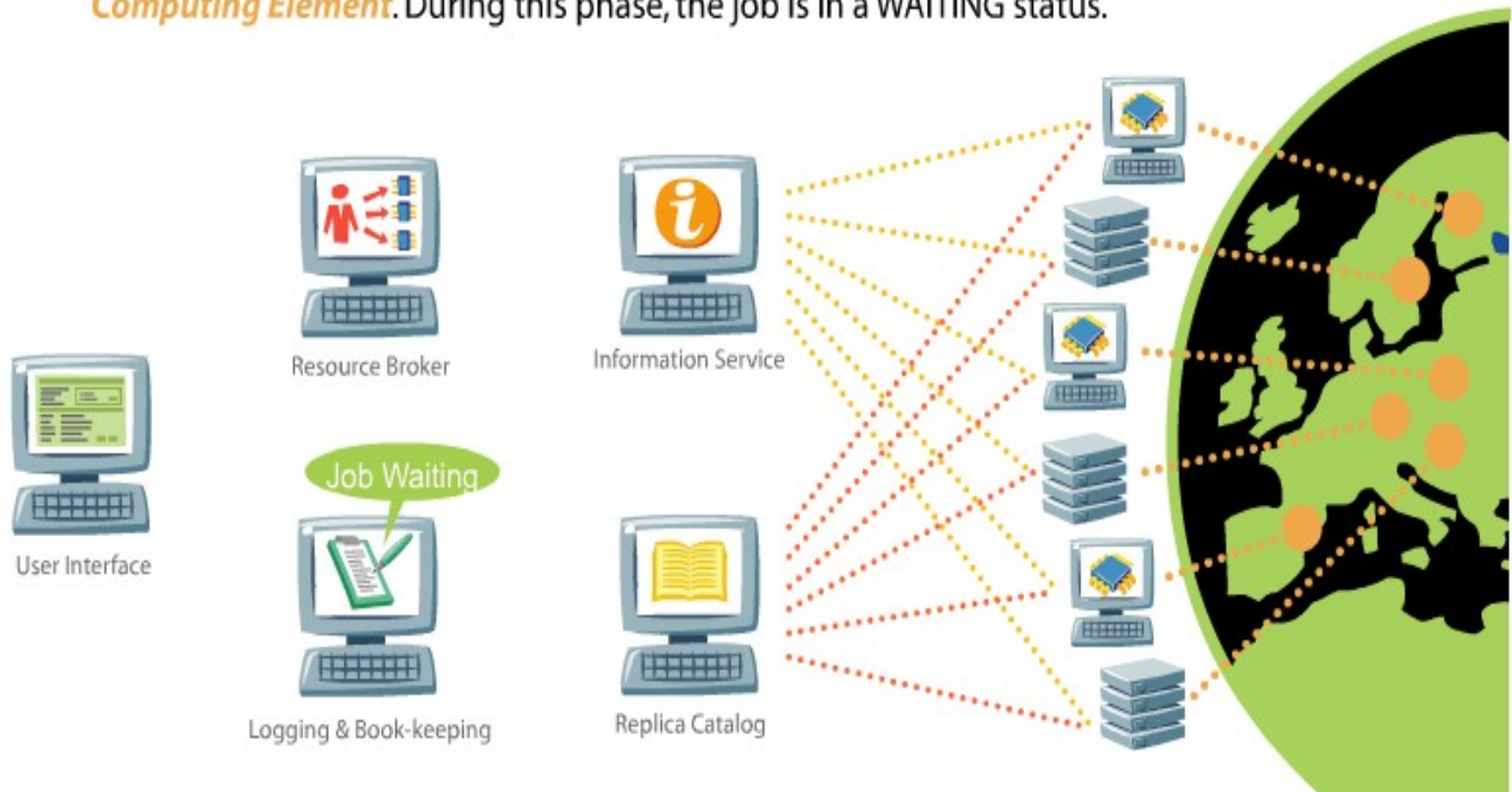
# Step 4: Submit your job to the resource broker

Based on the information given in the JDL file, the *Resource Broker* queries the *Information Service* and the *Replica Catalog* to check resources.



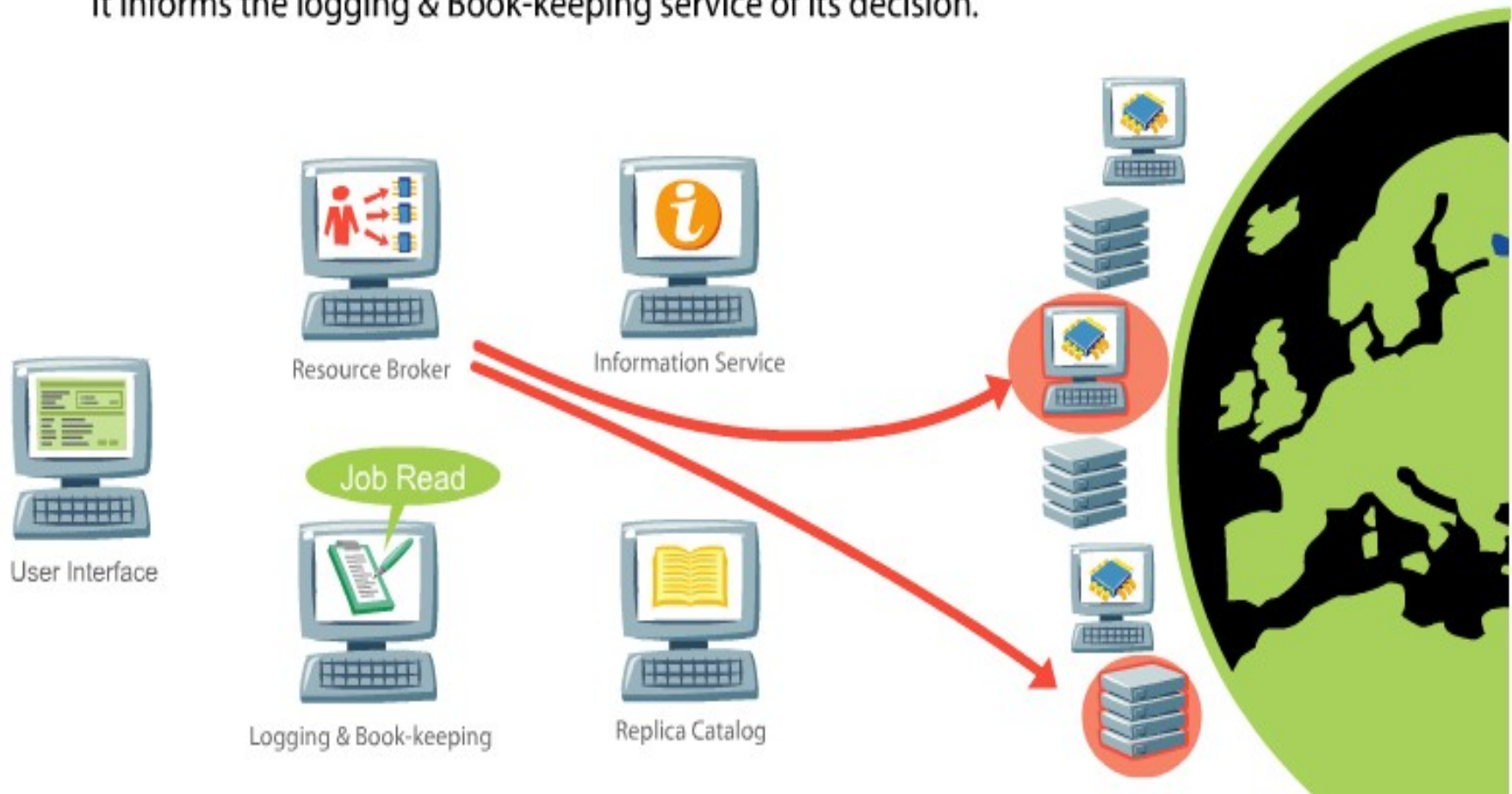
## Step 4: Submit your job to the resource broker

The *Replica Catalog* and the *Information Service* hold information on the current status of all the sites. The Resource Broker uses this info to match the job to a suitable *Computing Element*. During this phase, the job is in a *WAITING* status.



## Step 4: Submit your job to the resource broker

The Resource Broker *makes its choice*. It has found a suitable Computing Element and the Storage Element with the necessary data. It informs the logging & Book-keeping service of its decision.





# Step 5: Check the status of your job

During all this process, you can check the status of your job by contacting the *Logging & Book-keeping Service*.



User Interface



Resource Broker



Information Service



Logging & Book-keeping



Replica Catalog



## Step 5: Check the status of your job

The execution of the job has completed on the Computing Element.  
The *Computing Element transfers the output to the Resource Broker*.



## Step 6: Get the results

You can now retrieve your Output from the Resource Broker.  
When finished, book-keeping *information is purged*.



User Interface



Resource Broker



Information Service



Logging & Book-keeping



Replica Catalog



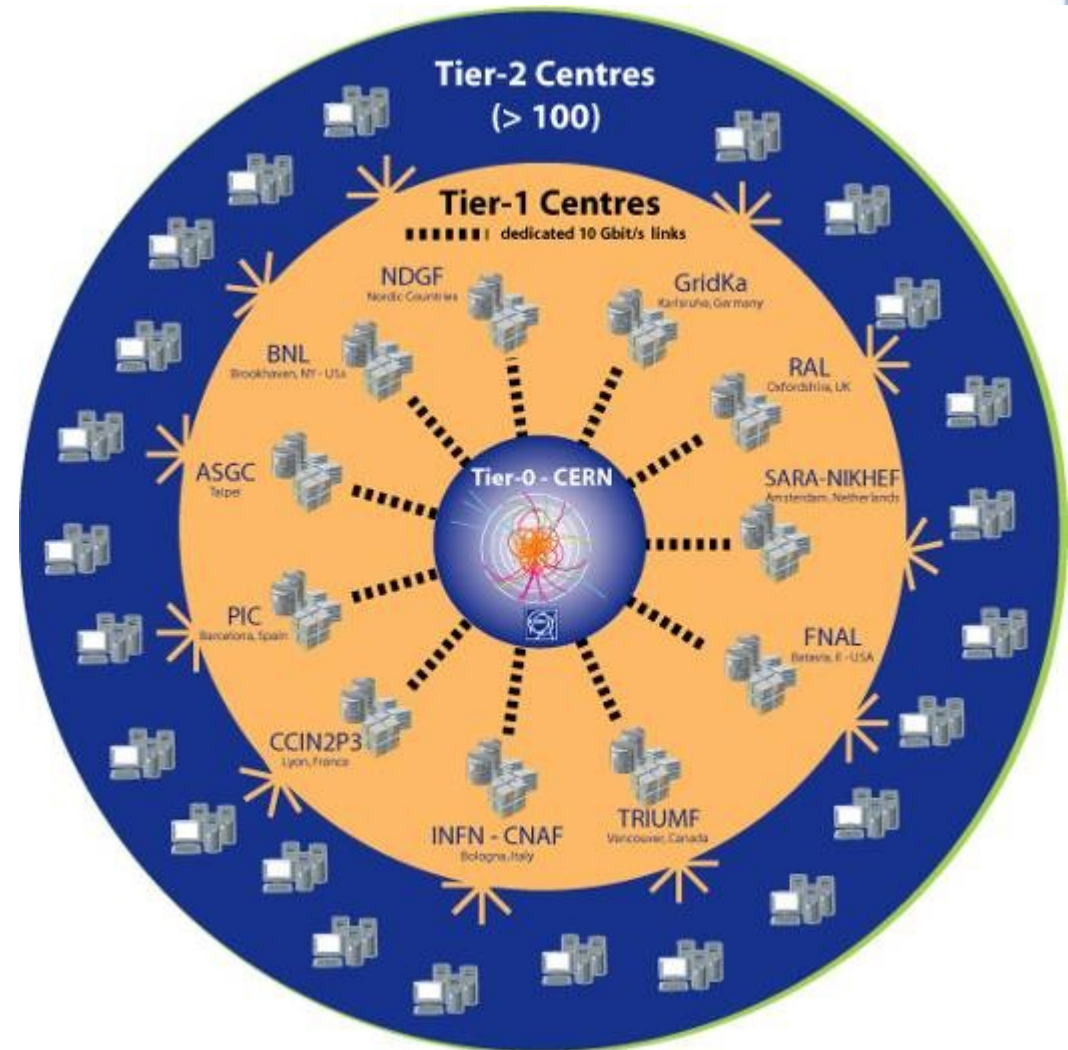
# Grid @ CERN

- CERN projects:
  - **LCG**. LHC Computing Grid
- EU-funded projects led by CERN:
  - **EGEE**. Enabling Grids for E-Science
- Industry funded projects:
  - CERN **Openlab** for DataGrid applications



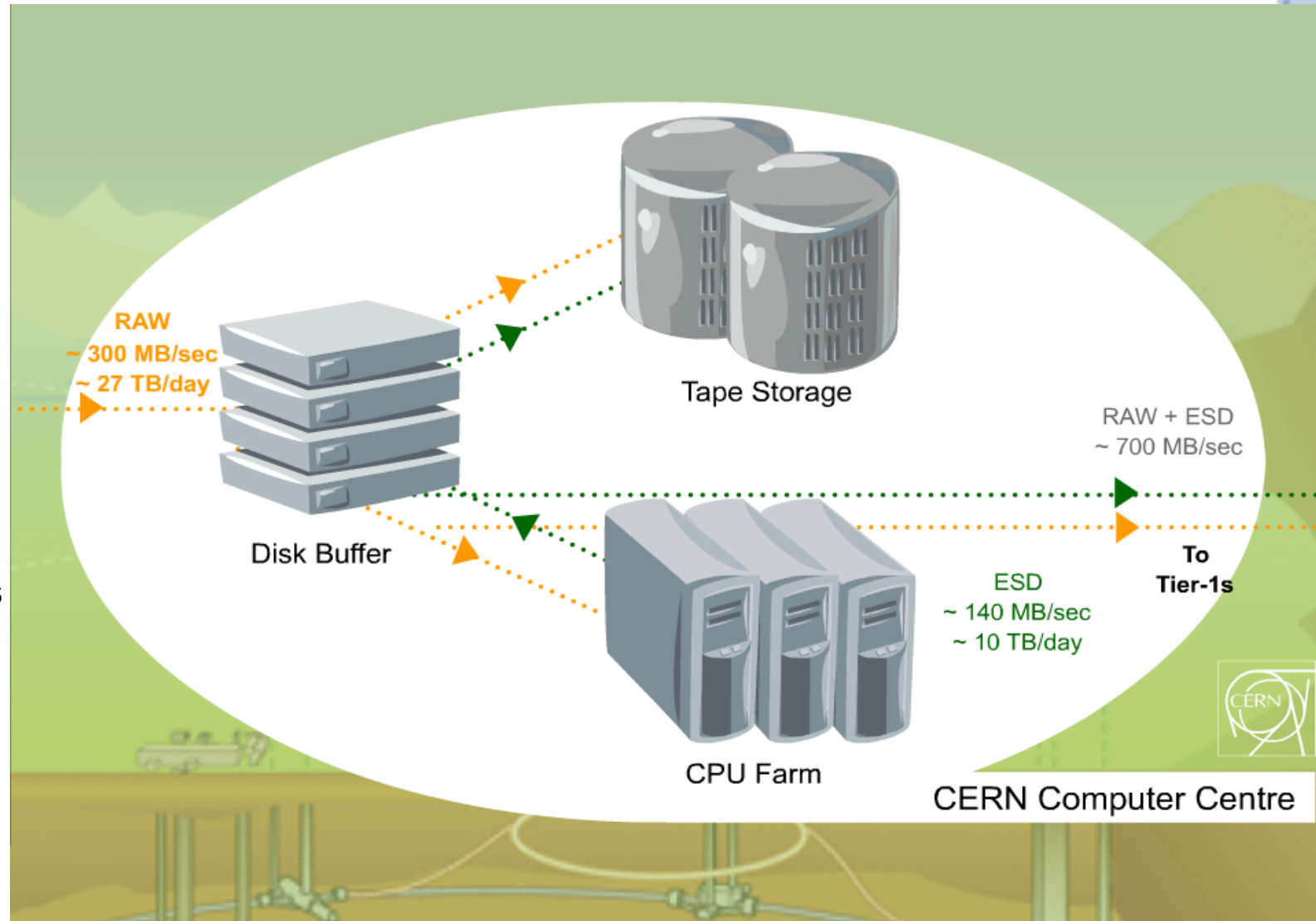
# LHC Computing Grid Project (LCG)

- Launched in 2002
- More than 150 computing centers
- 12 large centers for primary data management:
  - Tier-0 (CERN)
  - 11 Tier-1s
- 38 federations of smaller Tier-2 centers
- 35 countries involved



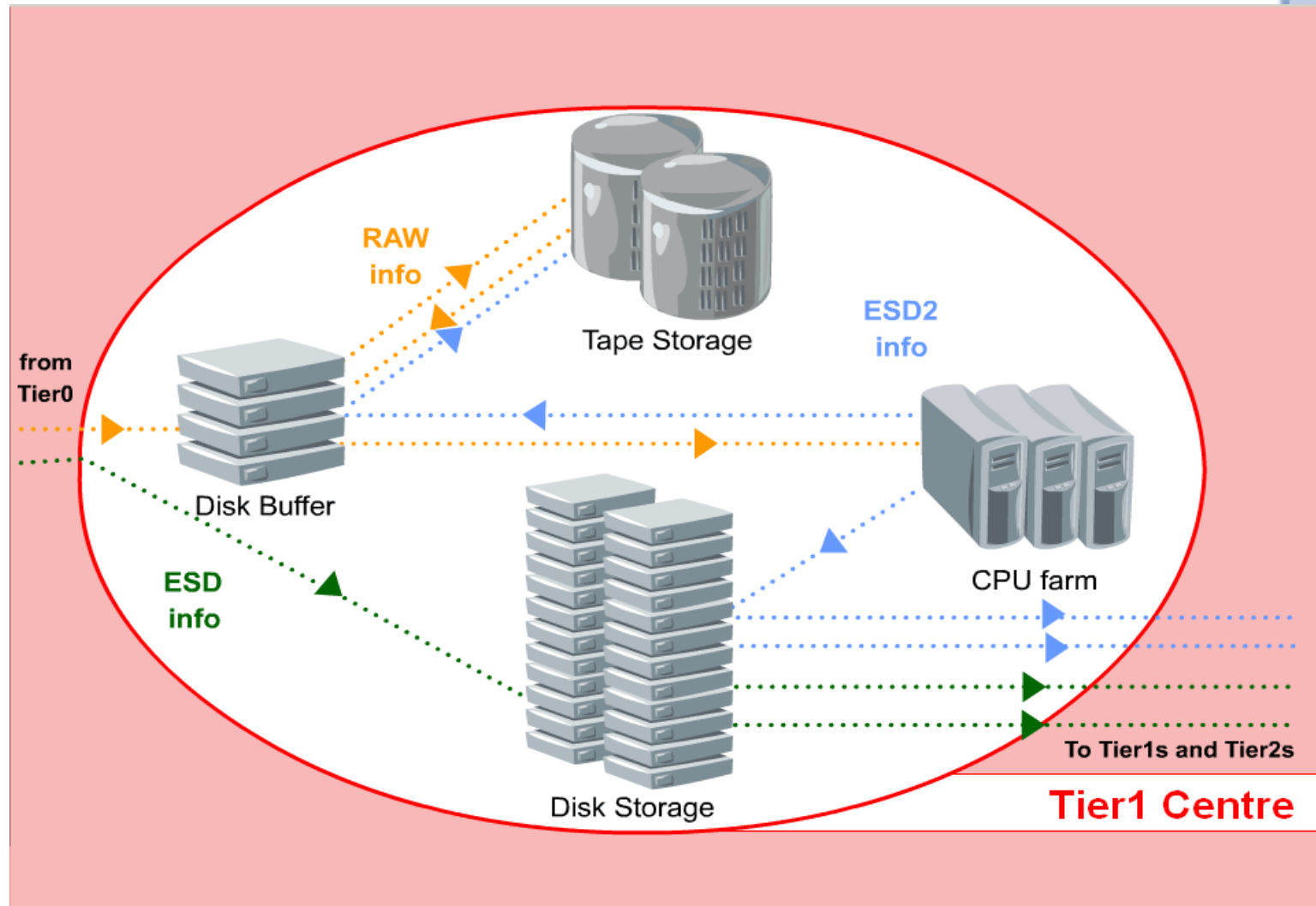
# Tier-0

- Full reconstruction on all events
- Calibration and alignment processes
- Monitoring tasks
- RAW and ESD
  - Save to tape
  - Export to Tier-1s



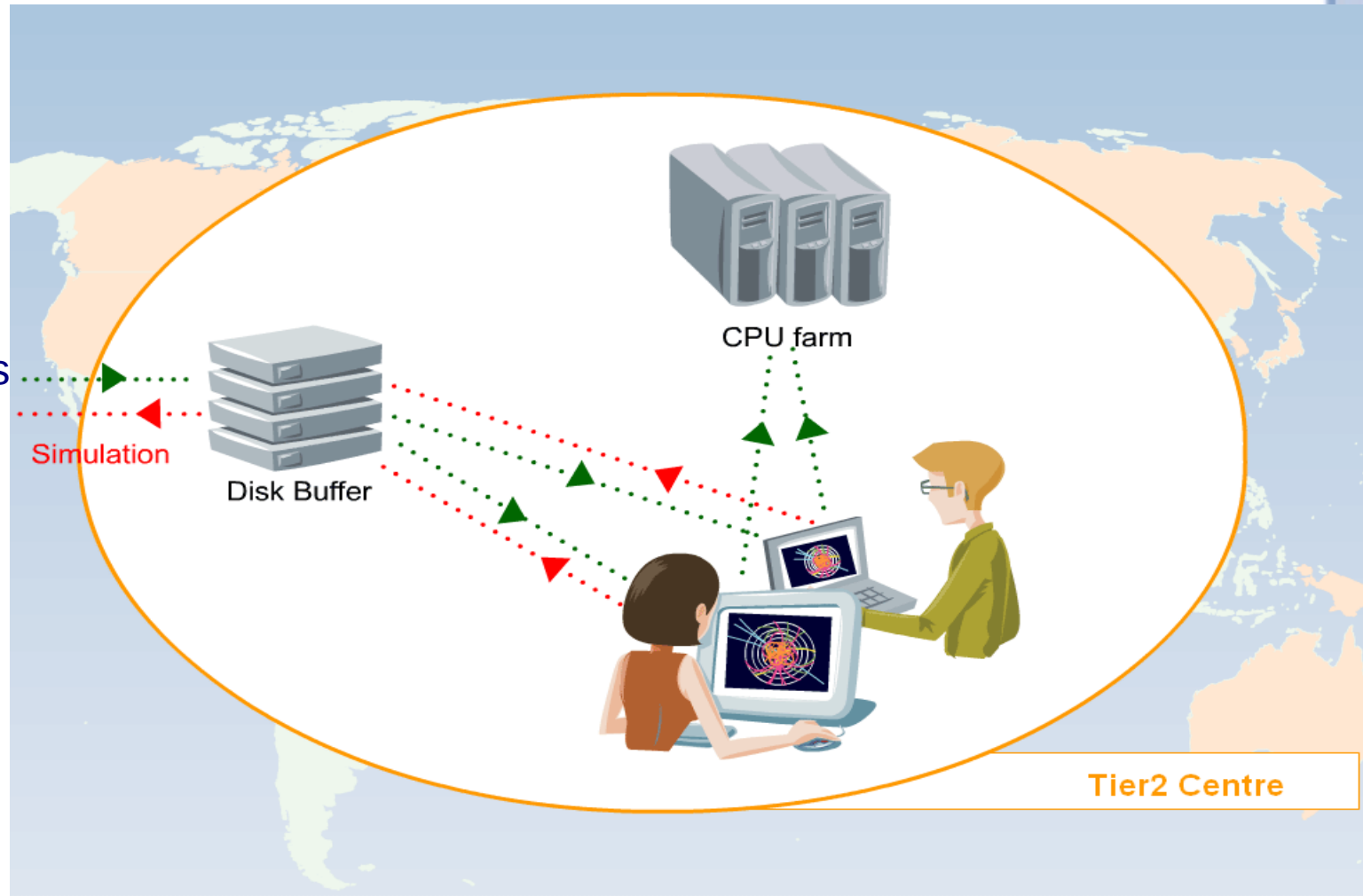
# Tier-1

- Long term storage and reprocessing of RAW data
- Scheduled access to large quantities of data
- Provide services for a cloud of associated Tier-2s
- Can provide also part of experiments' simulation capacities



# Tier-2

- CPU capacity for Simulation tasks
- Disk storage for their data fractions
- CPU capacity for group and user access to the data they keep on disk
- Disk storage for group and user derived data



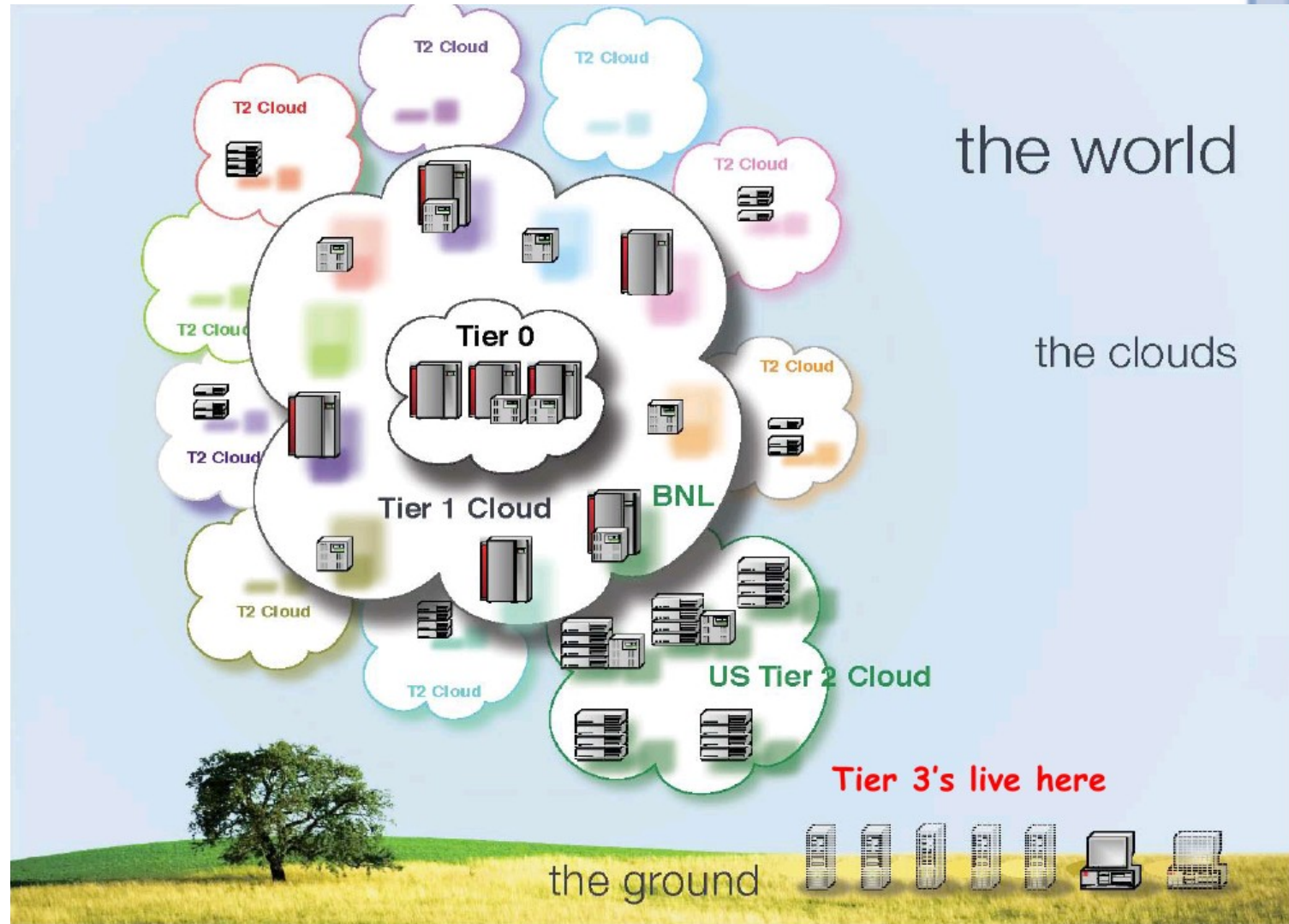


# Tier-3

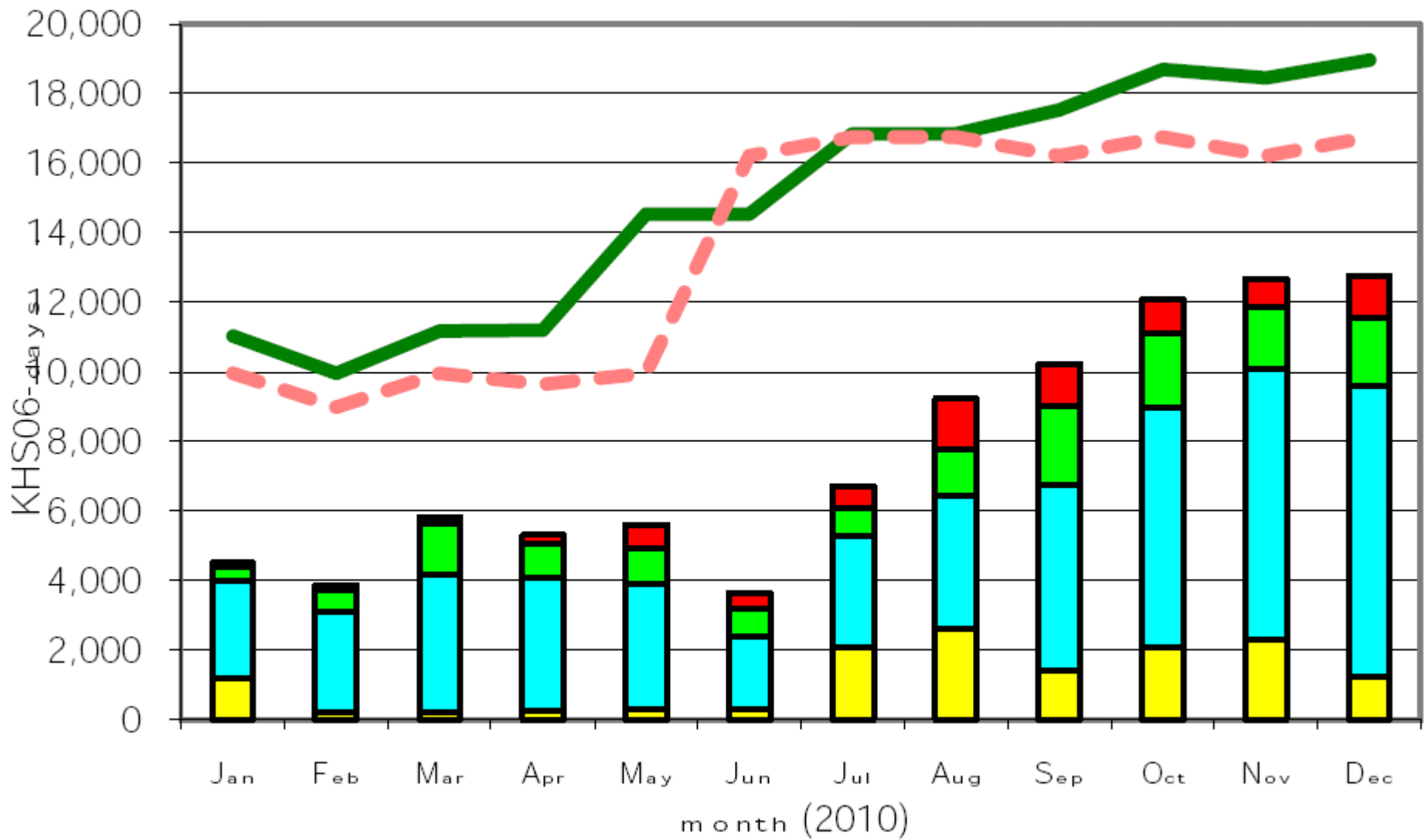
- “Analysis facilities” at your University, Institute ...

- “No pledged resources” (no WLCG MoU)

- Can consist of local clusters or even just an individual PC



# CPU Time delivered 2010



ALICE  
ATLAS

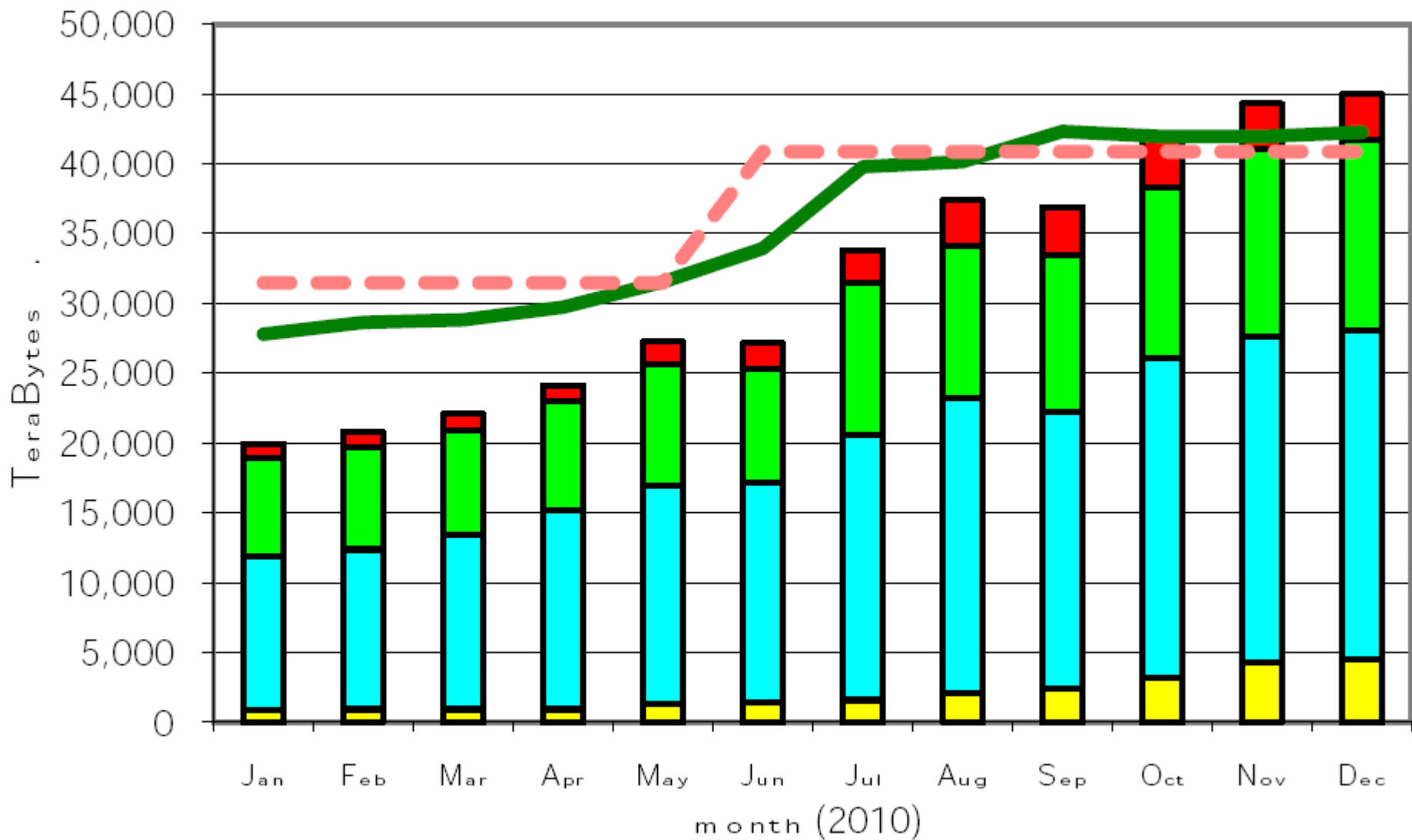
CMS  
LHC<sub>b</sub>

installed capacity (inc. efficiency factor)  
MoU commitment (inc. efficiency factor)

—  
- - -



# Disk Storage used 2010



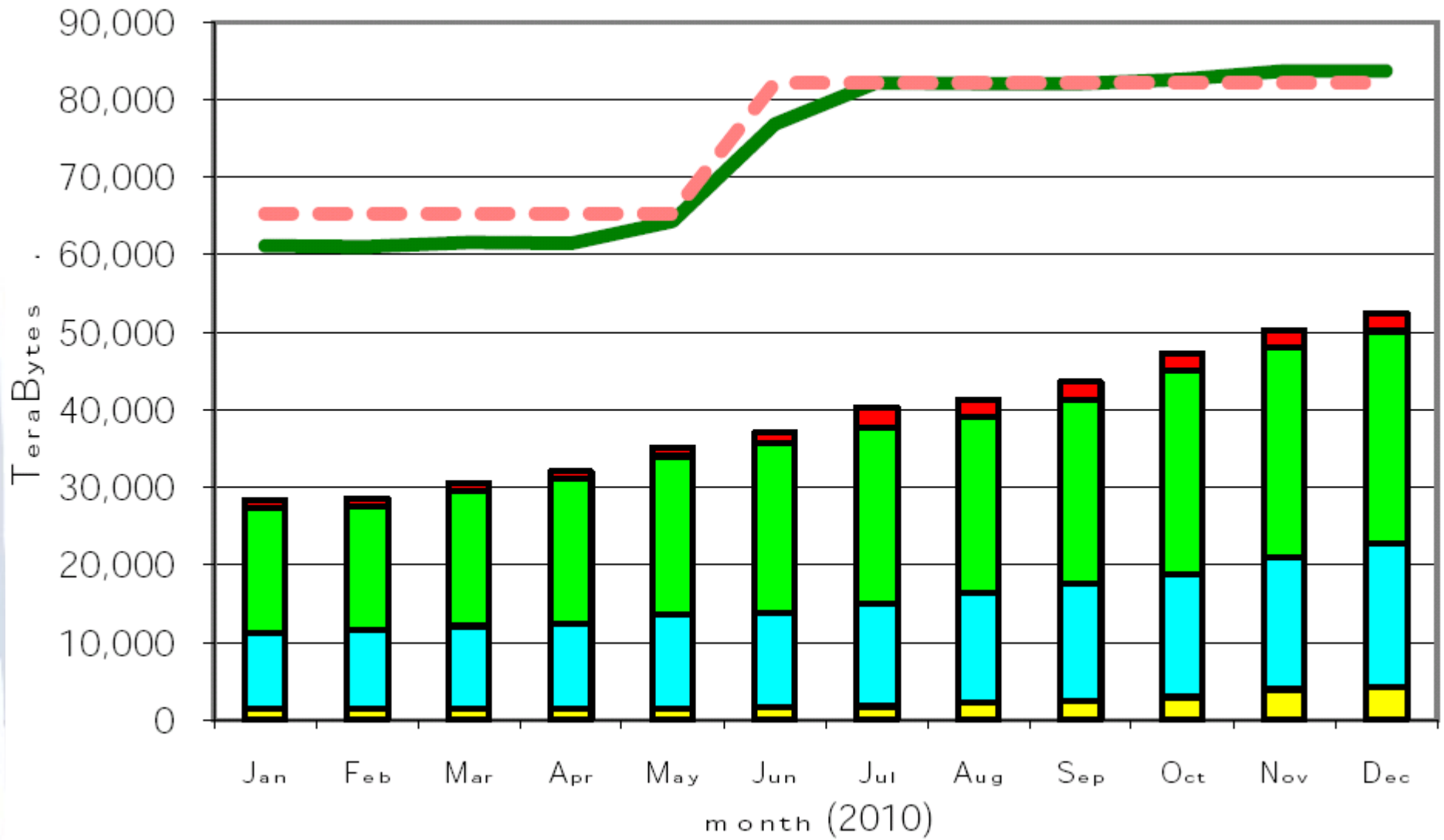
ALICE  
ATLAS

CMS  
LHC<sub>b</sub>

installed capacity (inc. efficiency factor)  
MoU commitment (inc. efficiency factor)



# Tape Storage Used 2010



ALICE  
ATLAS

CMS  
LHC<sub>b</sub>

installed capacity (inc. efficiency factor)  
MoU commitment (inc. efficiency factor)

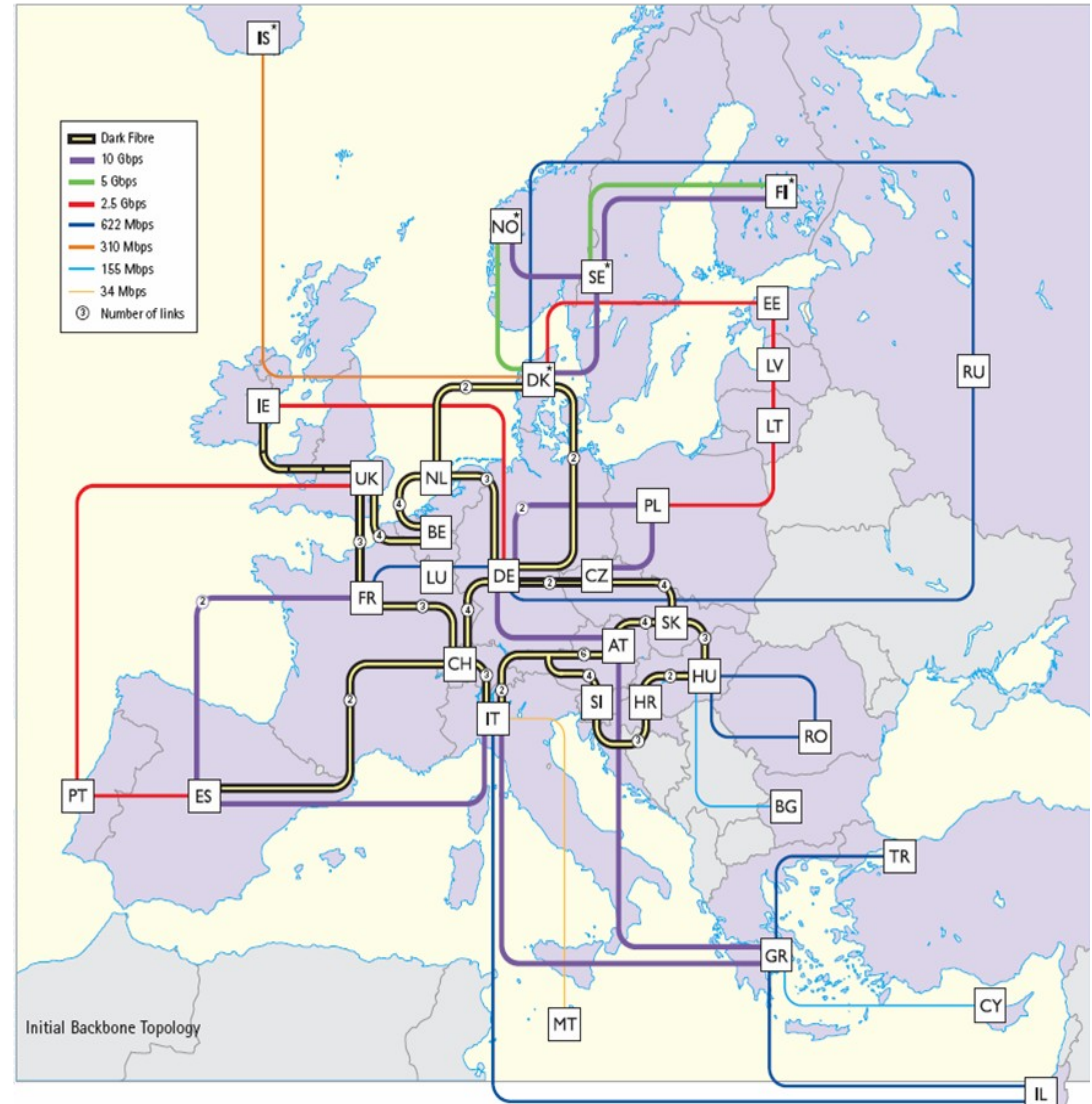
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- - -

# WLCG – the world's largest computing grid

- WLCG computing centers are based on the two main global grids
  - **EGI** (**E**uropean **G**rid **I**nfrastructure) in Europe
  - **OSG** (**O**pen **S**cience **G**rid) in the US
- Grids in Asia also contribute to the WLCG
  - **Taiwan Grid** and **EU-IndiaGrid**
- WLCG has benefited from investments made by European Commission via series of grid-related projects
  - **EGEE**, **E**uropean **D**ata**G**rid

# The Géant Research Network

- General purpose network connecting national research and educational nets (NREN)
- For the LHC in addition: Optical Private Network (LHCOPN) with 10GB/sec link over dark fibers

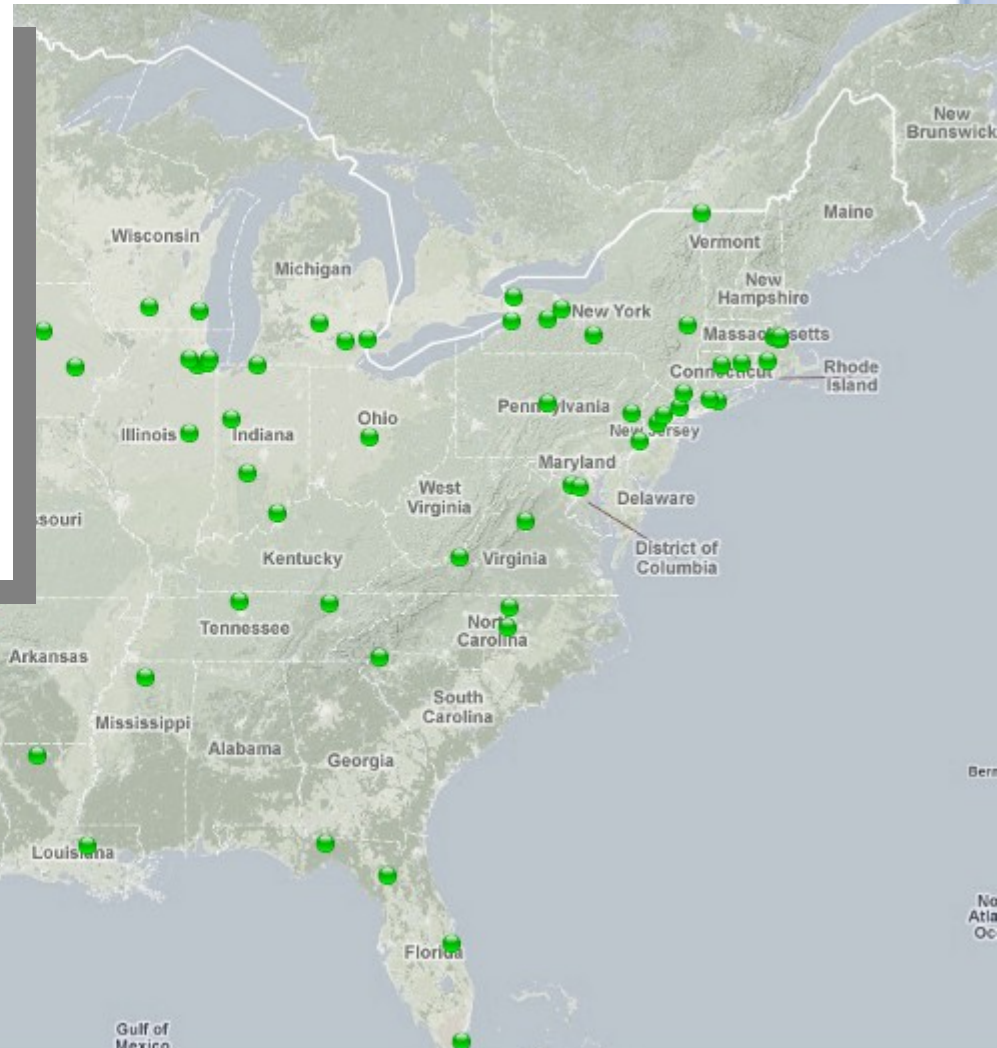
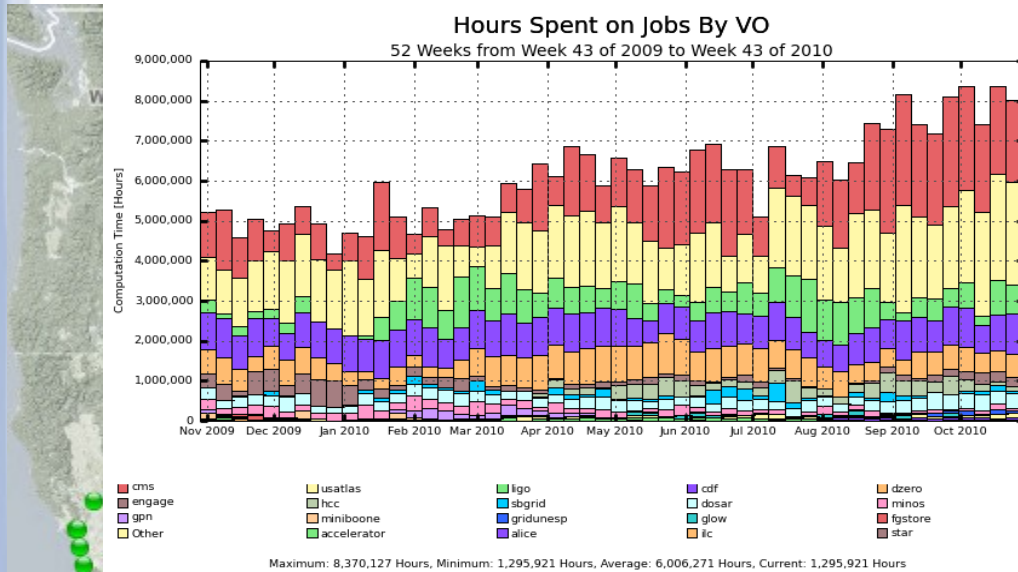


GÉANT2 is operated by DANTE on behalf of Europe's NRENs.



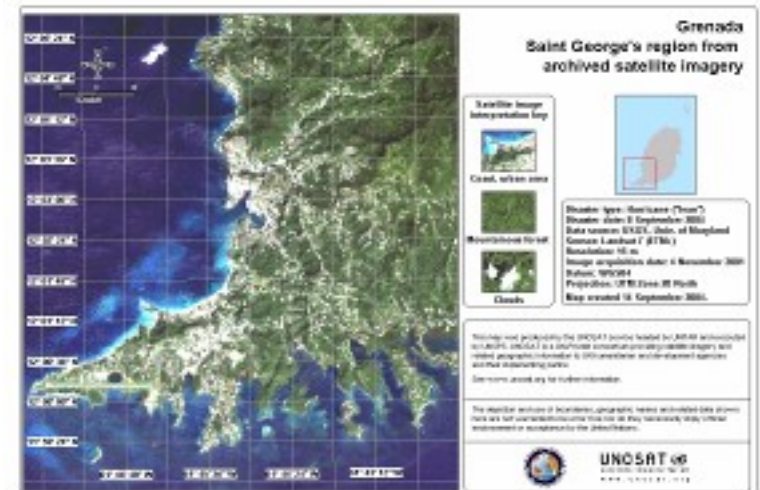
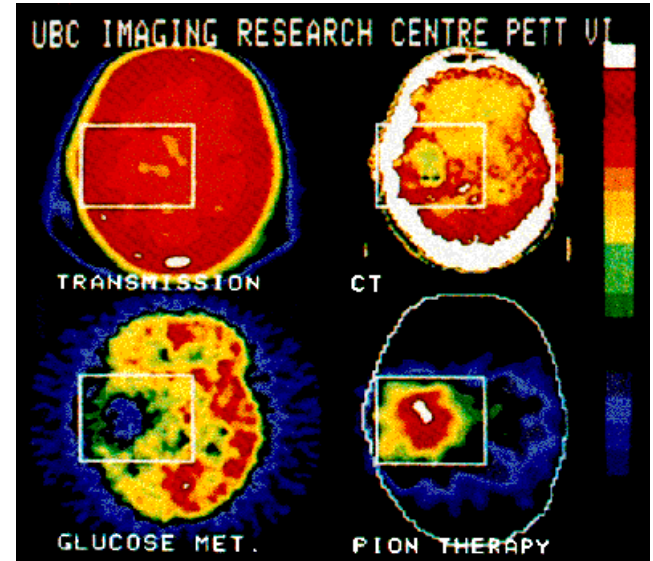
Open Science Grid

# OSG – A national, distributed grid for data-intensive research



# Grid Applications for Science

- **Medical/Health-care** *imaging, diagnosis and treatment*
- **Bioinformatics** *study of the human genome*
- **Nanotechnology** *design of new materials from the molecular scale*
- **Engineering** *design optimization, simulation, failure analysis*
- **Natural resources and the Environment** *climate modeling, Earth observation*





## More info about the Grid?



**GridCafé**  
[www.gridcafe.org](http://www.gridcafe.org)

# GRID in South Caucasus

- 2009 academic network links established between the South Caucasus countries and the European Geant2 network infrastructure
- Networking and Grid infrastructure being developed in all three countries
- October 2010 “First ATLAS-South Caucasus Software & Computing Workshop & Tutorial” in Tbilisi
  - Organized jointly by CERN and a number of Georgian institutions
  - Meeting platform for ATLAS Computing experts with local scientists and Networking/Grid experts
  - Presentations, tutorials, round table discussions, in particular about the possibility of developing Tier-3 centers in local research institutes

გმადლობთ ყურადღებისთვის!

