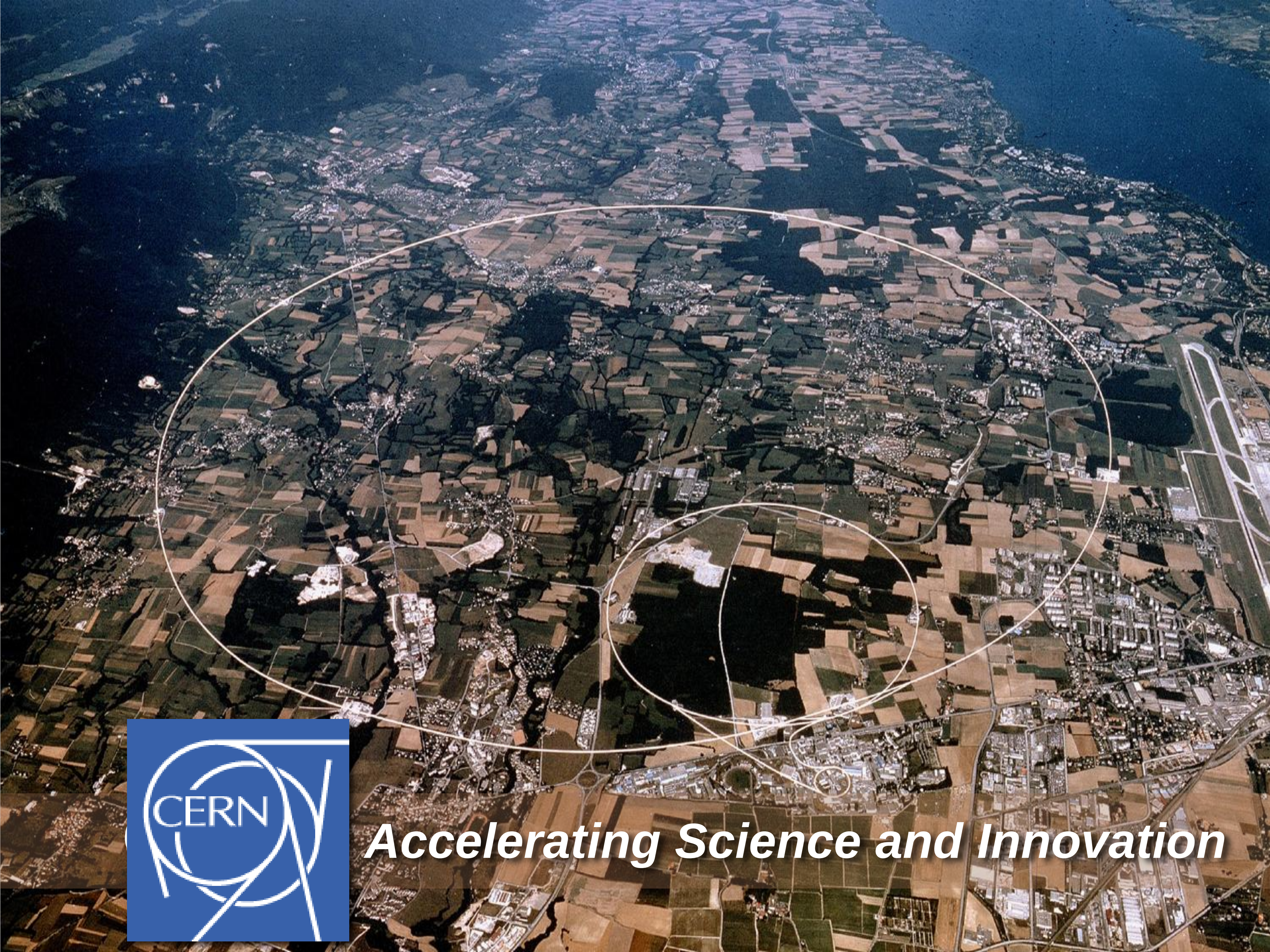
E-Health: Opportunities and Challenges of a Paradigmatic Convergence Field

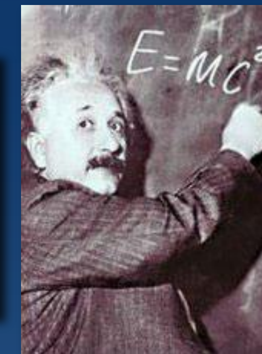
Erice Int. School of Scientific Journalism and Communication

Sergio Bertolucci
CERN, Geneva
Erice, May 2010


CERN
Accelerating Science and Innovation

Innovation
Education
CERN
uniting people
Research

The Mission of CERN



- Push back the frontiers of knowledge

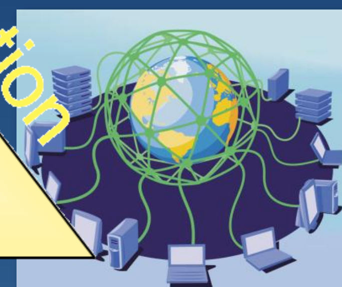
  E.g. the secrets of the Big Bang …wh[illegible]s the matter like within the first moments of the Univ[illegible]stence?

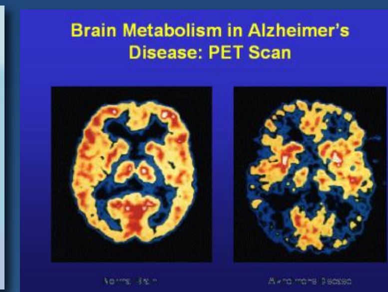
- Develop new techn[illegible] accelerators and d[illegible]

  Information technology [illegible]

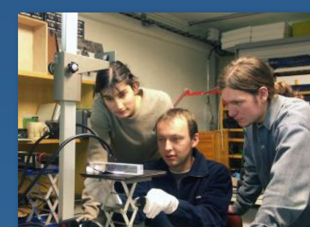
  Medicine - diagnosis and therapy

Innovation
Education
CERN
uniting people
Research



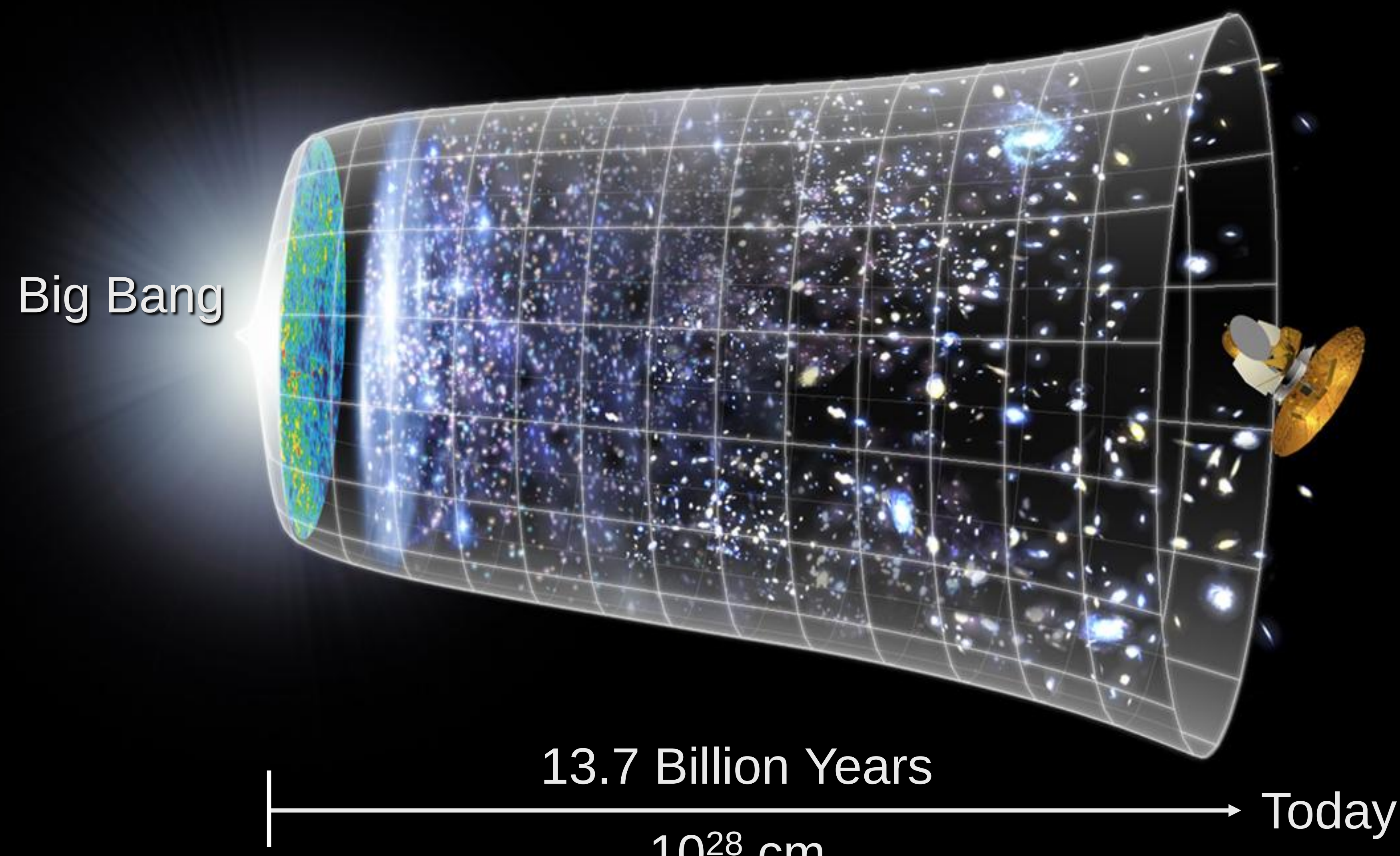


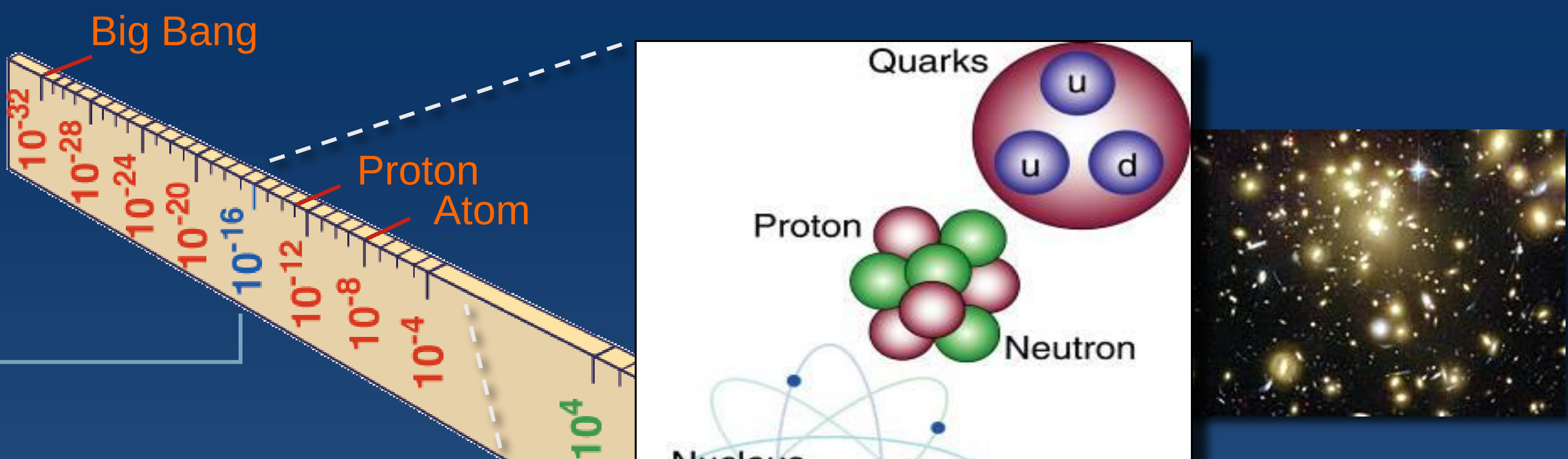
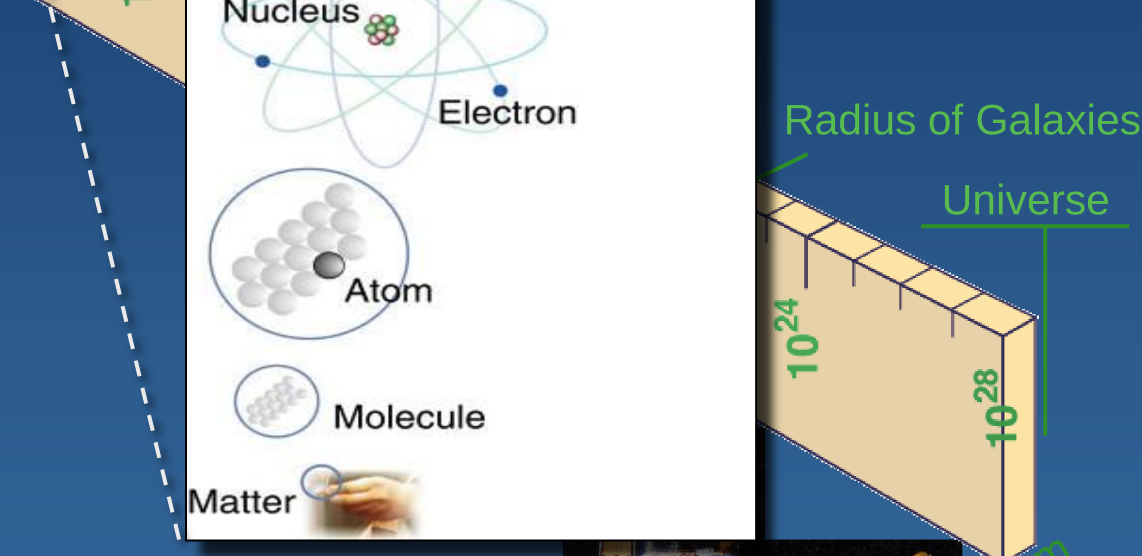
- Train scientists and engineers of tomorrow

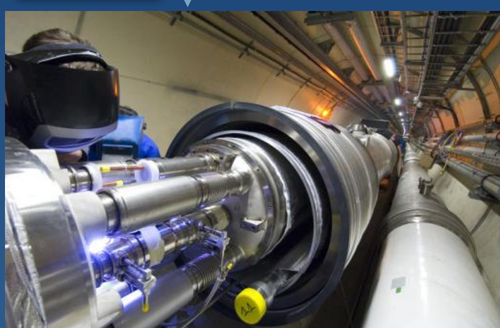


- Unite people from different countries and cultures

Evolution of the Universe





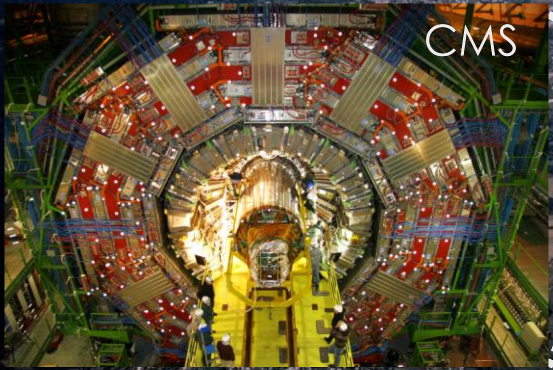
LHC

Super-Microscope

Study physics laws of first moments after Big Bang increasing Symbiosis between Particle Physics, Astrophysics and Cosmology

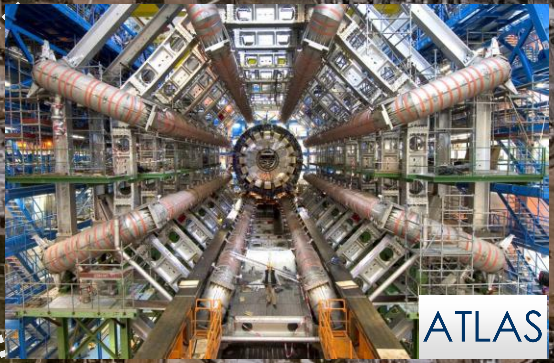
Enter a New Era in Fundamental Science

Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.



Exploration of a new energy frontier

Proton-proton collisions at E_{CM} = 14 TeV

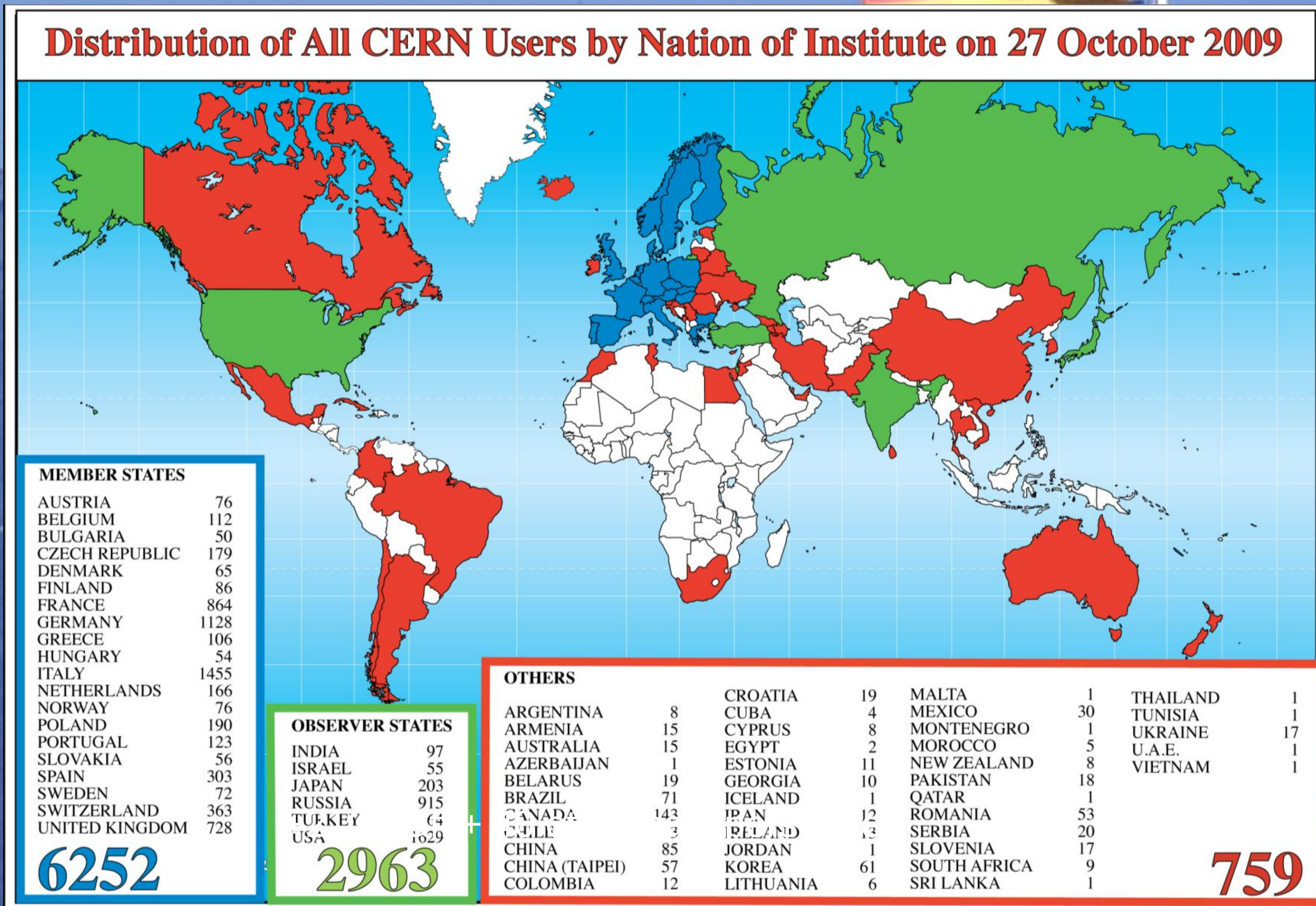


CERN was founded 1954: 12 European States
Today: 20 Member States

- ~ 2300 staff
- ~ 790 other paid personnel
- ~ 10000 users
- Budget (2009) 1100 MCHF

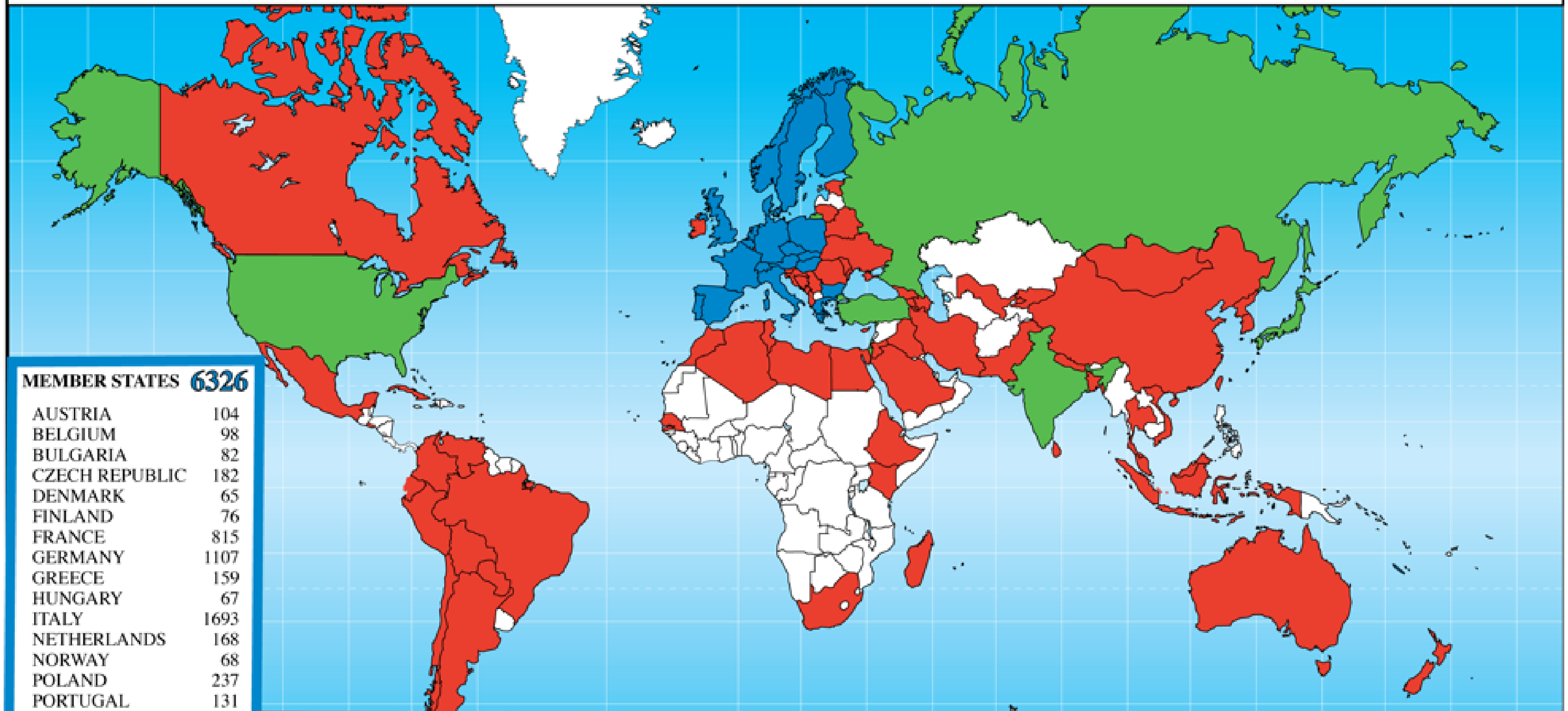
- **20 Member States:** Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.
- **1 Candidate for Accession to Membership of CERN:** Romania
- **8 Observers to Council:** India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and Unesco

CERN in Numbers



CERN in Numbers

Distribution of All CERN Users by Nationality on 27 October 2009



MEMBER STATES 6326

AUSTRIA	104
BELGIUM	98
BULGARIA	82
CZECH REPUBLIC	182
DENMARK	65
FINLAND	76
FRANCE	815
GERMANY	1107
GREECE	159
HUNGARY	67
ITALY	1693
NETHERLANDS	168
NORWAY	68
POLAND	237
PORTUGAL	131
SLOVAKIA	79
SPAIN	323
SWEDEN	70
SWITZERLAND	203
UNITED KINGDOM	599

OBSERVER STATES 2496

INDIA	167
ISRAEL	54
JAPAN	227
RUSSIA	1048
TURKEY	89
USA	911

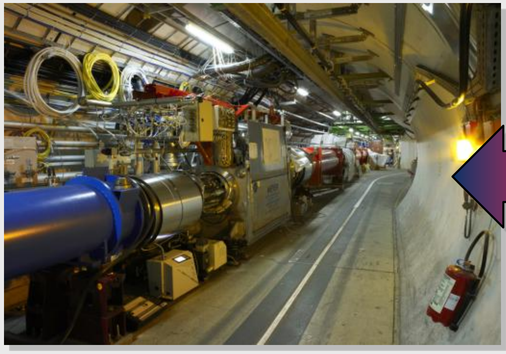
OTHERS 1190

ALBANIA	2
ALGERIA	8
ARGENTINA	12
ARMENIA	24
AUSTRALIA	18
AZERBAIJAN	5
BANGLADESH	3
BELARUS	37
BOLIVIA	2
BOSNIA AND HERZEGOVINA	1
BRAZIL	72
CANADA	135
CHILE	3
CHINA	200
CHINA (TAIPEI)	44
COLOMBIA	19
CROATIA	25
CUBA	4
CYPRUS	11
ECUADOR	3
EGYPT	4
EL SALVADOR	1
ESTONIA	11
ETHIOPIA	1
GEORGIA	32
GIBRALTAR	2
HONG KONG	2
INDONESIA	1
IRAN	19
IRAQ	1
IRELAND	23
JORDAN	1
KENYA	1
KOREA, D.P.R.	4
KOREA REP.	82
KYRGYZSTAN	2
LEBANON	7
LITHUANIA	10
LUXEMBOURG	4
LIBYA	1
MADAGASCAR	3
MALAYSIA	7
MALTA	1
MAURITIUS	1
MEXICO	43
MOLDOVA	1
MONGOLIA	1
MONTENEGRO	1
MOROCCO	15
NEPAL	3
NEW ZEALAND	10
PAKISTAN	36
PALESTININE (O.T.)	1
PARAGUAY	1
PERU	1
ROMANIA	96
SAN MARINO	1
SAUDI ARABIA	2
SENEGAL	1
SERBIA	33
SINGAPORE	1
SLOVENIA	20
SOUTH AFRICA	8
SRI LANKA	6
SYRIA	2
THAILAND	2
TUNISIA	5
UKRAINE	39
UZBEKISTAN	1
VENEZUELA	5
VIET NAM	6

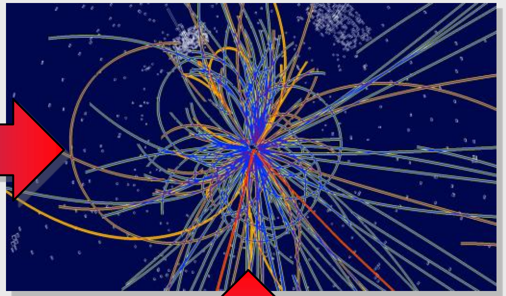
CERN Technologies - Innovation

Three key technology areas at CERN

Accelerating particle beams



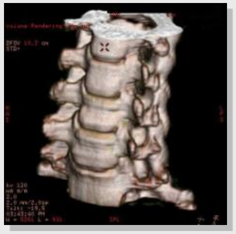
Detecting particles



Large-scale **computing** (Grid)

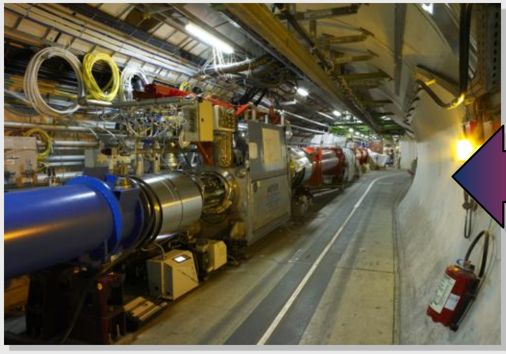
CERN Technologies - Innovation

Medical imaging

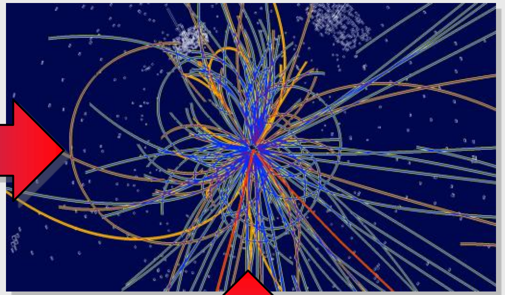


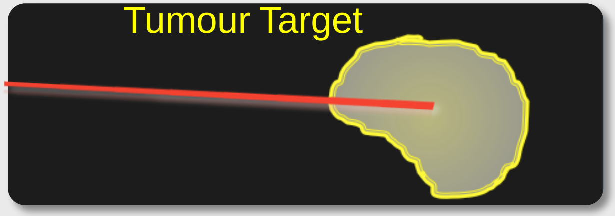
Example: medical application

Accelerating particle beams



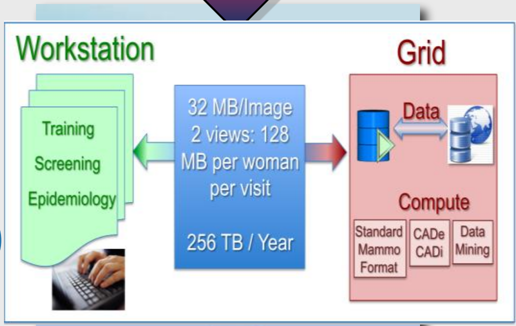
Detecting particles



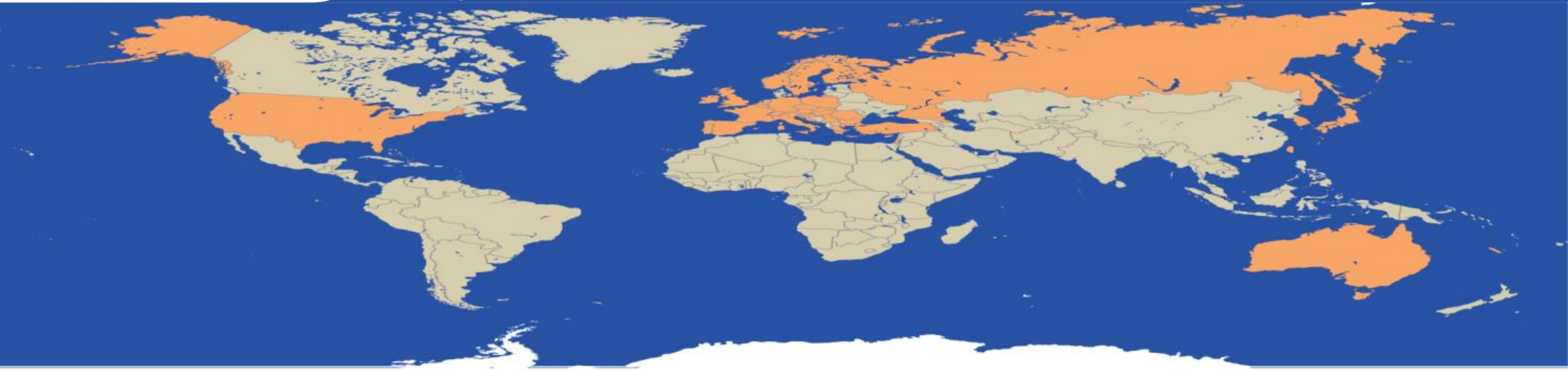


Charged hadron beam that loses energy in matter

Large-scale **computing** (Grid)



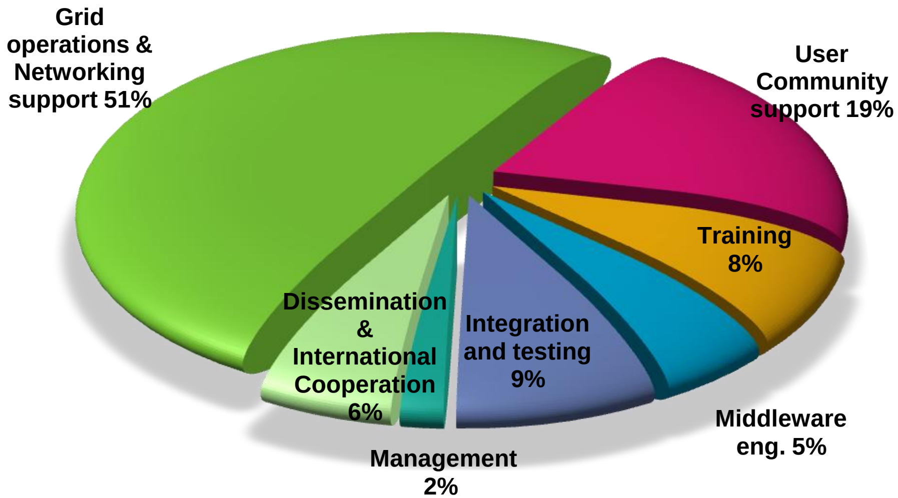
Grid computing for medical data management and analysis



Flagship Grid infrastructure project co-funded by the European Commission

Main Objectives

- Expand/optimise existing EGEE infrastructure, include more resources and user communities
- Prepare migration from a project-based model to a sustainable federated infrastructure based on National Grid Initiatives



Duration: 2 years
Consortium: ~140 organisations across 33 countries
EC co-funding: 32Million €

EGEE – What do we deliver?

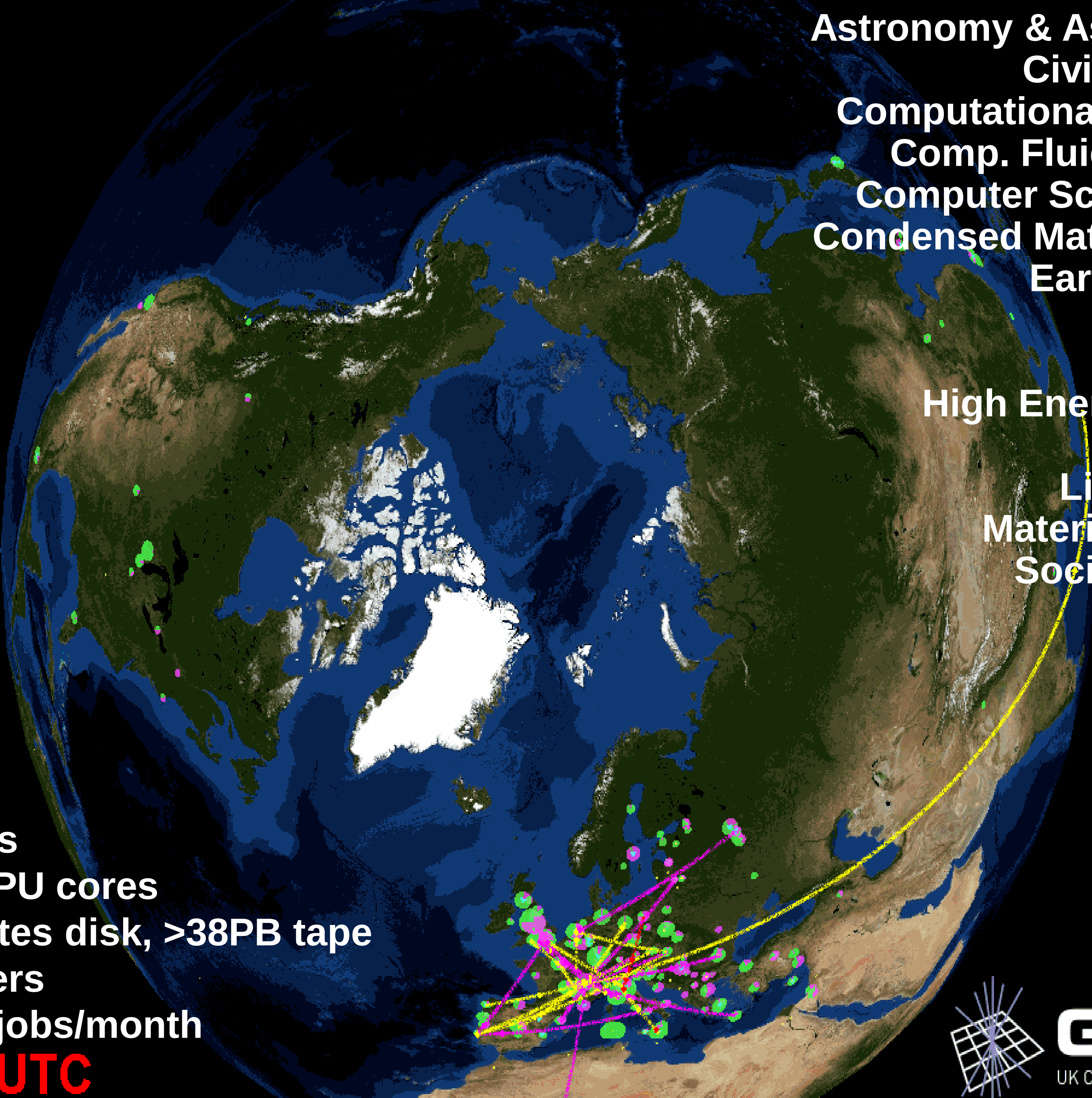
- **Infrastructure operation -** ***Sites distributed across many countries***
    - Large quantity of CPUs and storage
    - Continuous monitoring of grid services & automated site configuration/management
    - Support multiple Virtual Organisations from diverse research disciplines

- **Middleware -** ***Production quality software distributed under business friendly open source licence***
    - Implements a service-oriented architecture that virtualises resources
    - Adheres to recommendations on web service inter-operability and evolving towards emerging standards

- **User Support -** ***Managed process from first contact through to production usage***
    - Training
    - Expertise in grid-enabling applications
    - Online helpdesk
    - Dedicated support for specific disciplines
    - Networking events (User Forum, Conferences etc.) for cross-discipline interaction

Enabling Grids for E-sciencE

Astronomy & Astrophysics
Civil Protection
Computational Chemistry
Comp. Fluid Dynamics
Computer Science/Tools
Condensed Matter Physics
Earth Sciences
Finance
Fusion
High Energy Physics
Humanities
Life Sciences
Material Sciences
Social Sciences



~285 sites
48 countries
>140,000 CPU cores
>20 PetaBytes disk, >38PB tape
>13,000 users
>12 Million jobs/month

21:13:50 UTC

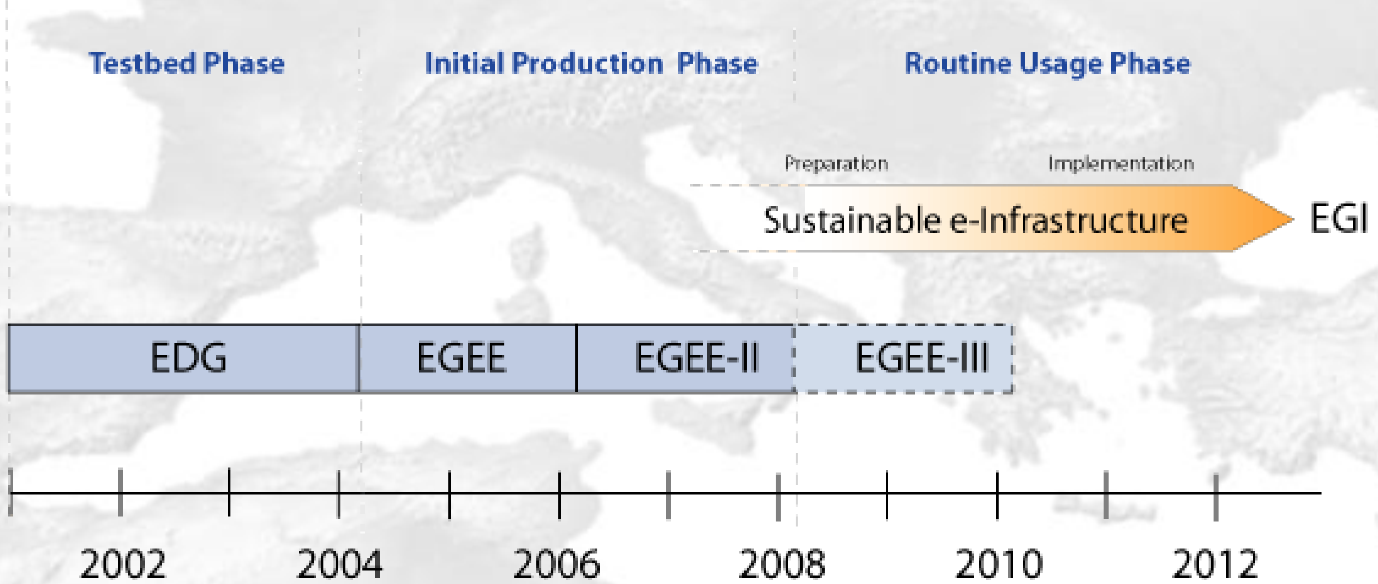
GridPP
UK Computing for Particle Physics

Goal: Long-term sustainability of grid infrastructures in Europe

Approach: Establish a federated model bringing together National Grid Infrastructures (NGIs) to build the European Grid Infrastructure (EGI)

EGI Organisation: Coordination and operation of a common multi-national, multi-disciplinary Grid infrastructure

- To enable and support international Grid-based collaboration
- To provide support and added value to NGIs
- To liaise with corresponding infrastructures outside Europe



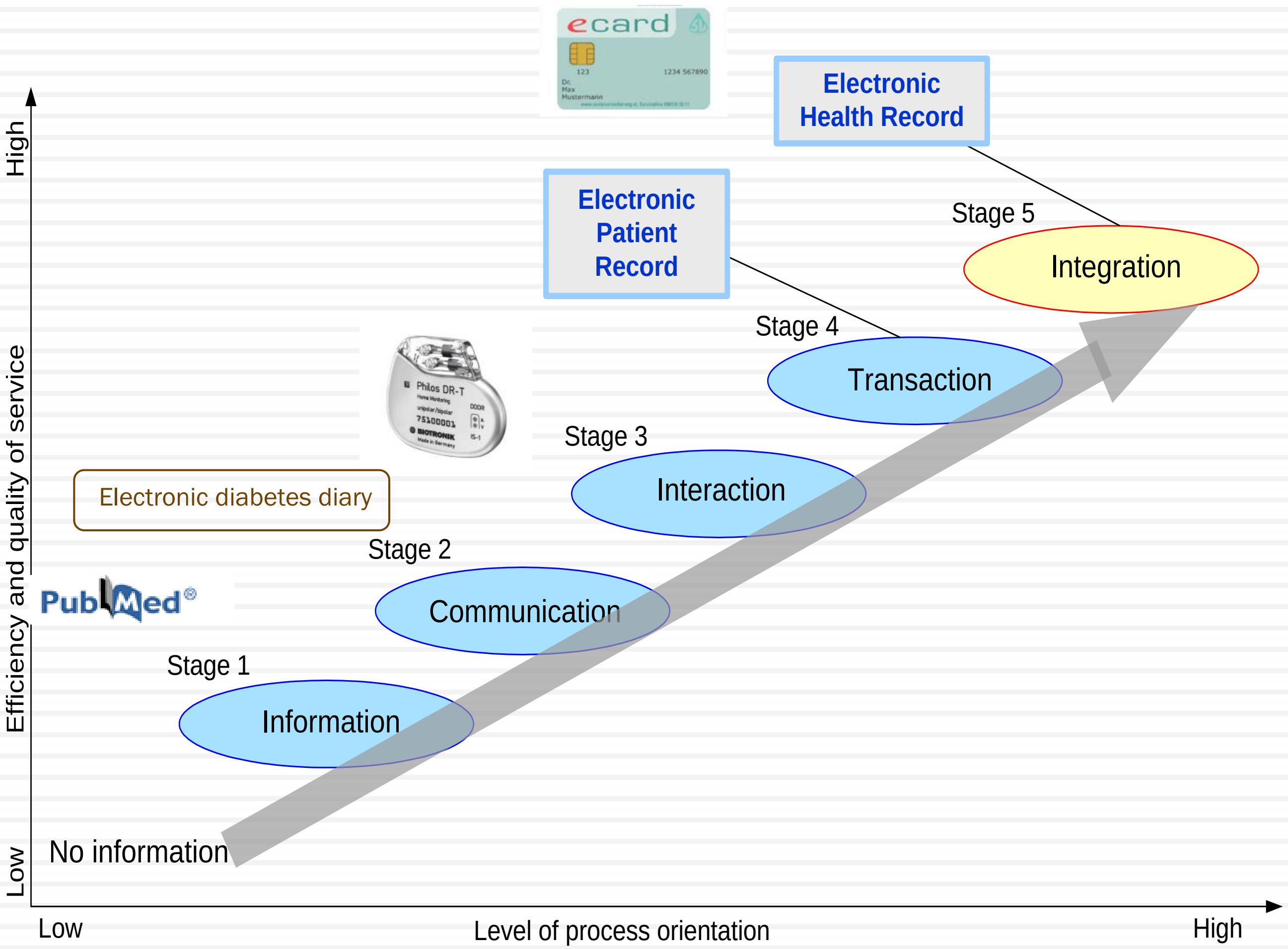
WHO definition of <u>**eHealth**</u>

"eHealth is the cost-effective and secure use of information and communications technologies in support of health and health-related fields,

- including health-care services
- health surveillance
- health literature
- health education, knowledge and research"

(World Health Organization , Ninth plenary meeting, 25 May 2005 - Committee A, seventh report)

5 Steps of eHealth



Steps of eHealth…

- **Step 1 - Information**
  - Providing information for patients, carers, doctors e.g. via the web, television, radio etc (information in one direction)-passive
- **Step 2 - Communication** (action)
  - The exchange of information between two people involved (patient - doctor, doctor - doctor...) without direct reaction of the communication partner (e.g. on-line diabetes diary)
- **Step 3 - Interaction** (action + reaction)
  - Exchange of information/data between people involved with immediate reaction from the communicating partner (e.g. telemonitoring, telesurgery…)

Steps of eHealth…

- **Step 4 - Transaction**
  - Electronic handling of a complete (treatment)process ("All or nothing")
- **Step 5 - Integration** (e.g. Electronic health record - EHR)
  - Electronic health biography – central documentation for all health relevant data from birth to death

Health on the Web

A real success….

- Estimated ~ 20,000 health websites
- Used by 98 million adults
  - 75% of people who have web access
  - Average of 3.3 times per month
- More than consult doctors each day
- Second most searched topic

Health on the Web

And a big responsibility…

- Correct communication
- Wrong directives
  - Miracle Medicine
  - Frauds
- Mix-up of test results and established procedures
- Tools for allowing information filtering

Grid usage for eHealth EGEE "Life Sciences" activity

Vincent Breton, LPC laboratory, Clermont-Ferrand

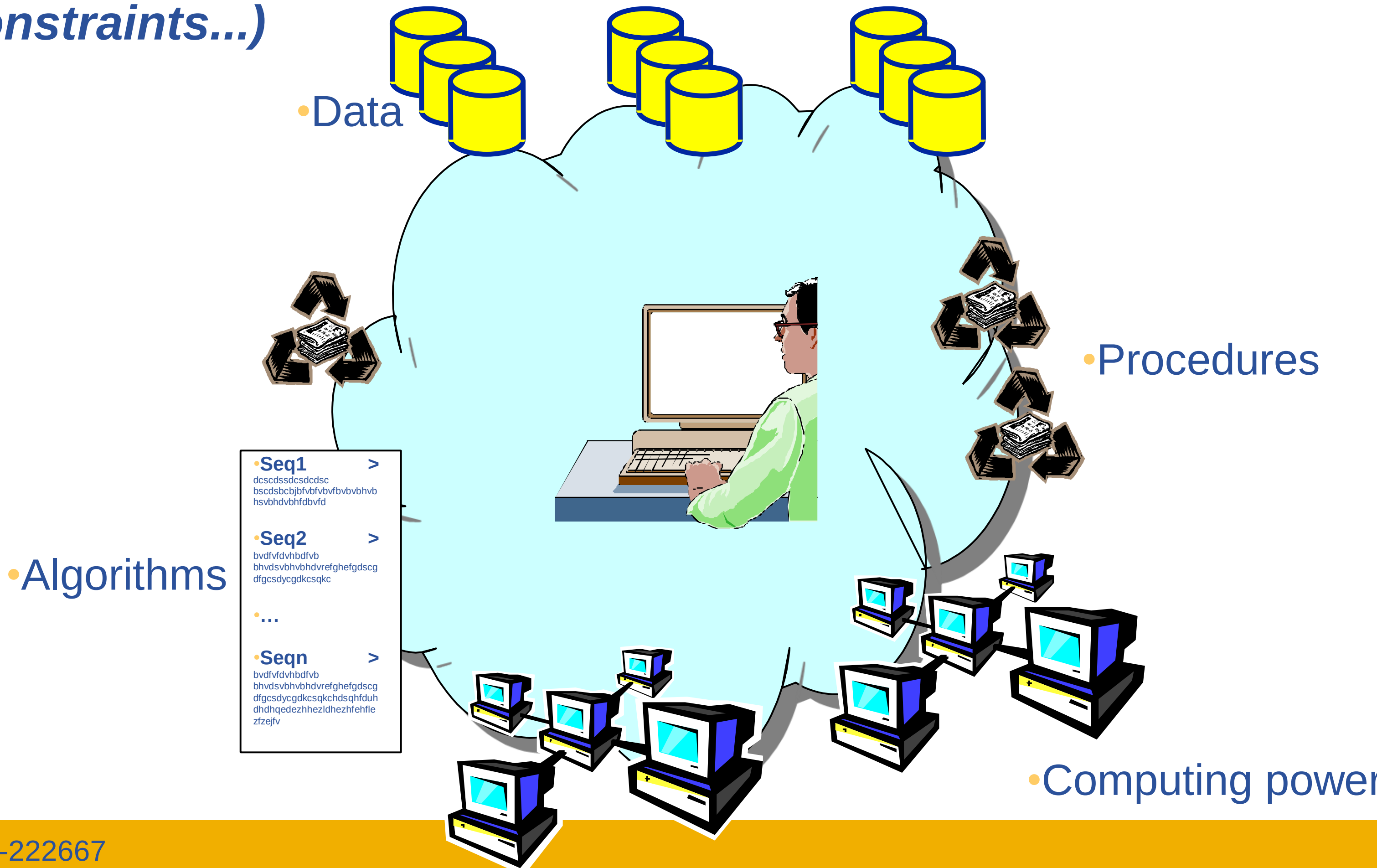
Johan Montagnat, I3S laboratory, Sophia Antipolis

CNRS, France

January 2010

Why grids for e-Health?

- ***Sharing computing resources and algorithms***
  - ***Research (populations studies, models design, validation, statistics)***
  - ***Complex analysis (compute intensive image processing, time constraints...)***

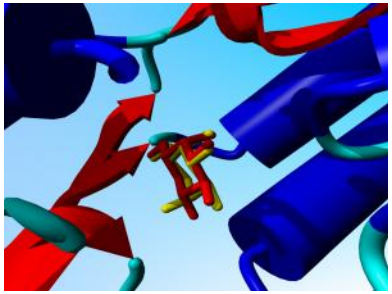


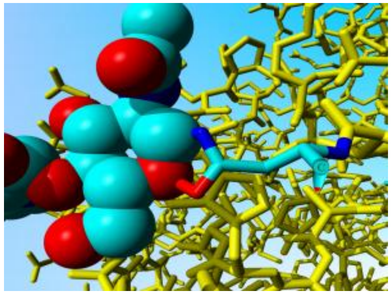
Genome Wide Haplotype analyses of human complex diseases with the EGEE grid

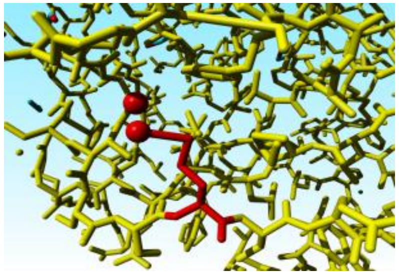
- **Goal: study the impact of DNA mutations on human coronary diseases**
- **Very CPU demanding analysis to study the impact of correlated (double, triple) DNA mutations**
- **Deployment on EGEE Grid**
  - 1926 CAD (Coronary Artery Diseases) patients & 2938 healthy controls
  - 378,000 SNPs (Single Nucleon Polymorphisms = local DNA mutations)
  - 8.1 millions of combinations tested in less than 45 days (instead of more than 10 years on a single Pentium 4)
- **Results published in *Nature Genetics March 2009* (D. Tregouet et al)**
  - Major role of mutations on chromosome 6 was confirmed

Application: recalculating protein 3D structures in PDB

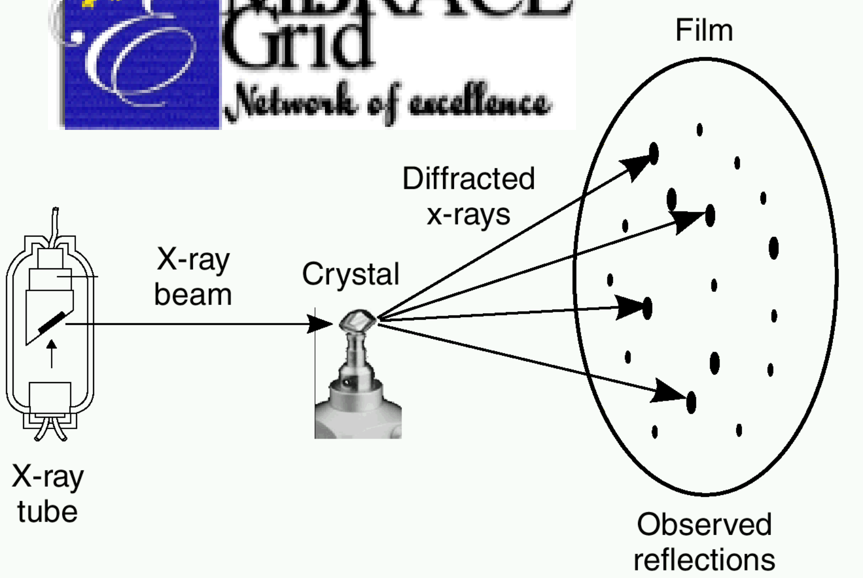
- **The PDB data base gathers publicly available 3D protein structures**
  - Full of bugs
- **Goal: redo the structures by recalculating the diffraction patterns**







EMBRACE Grid
Network of excellence



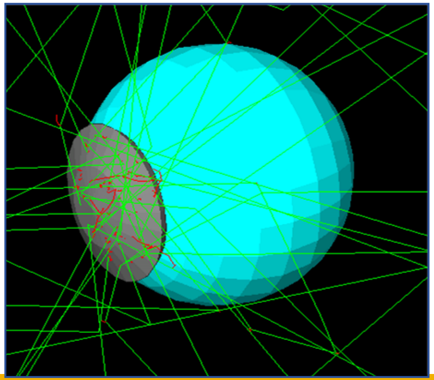
PDB-files	**42.752**
X-ray structures	**36.124**
Successfully recalculated	**~36.000**
Improved R-free	**12.500/17000**
CPU time estimate	**21.7 CPU years**
Real time estimate	**1 month on Embrace VO on EGEE**

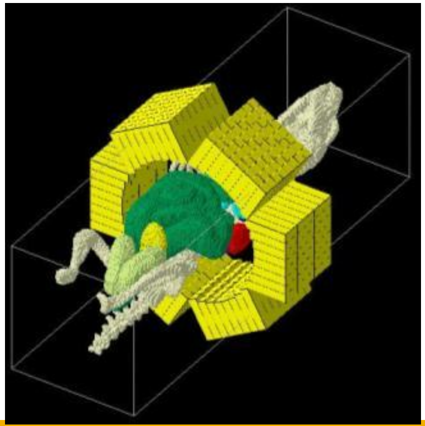
R.P Joosten et al, Journal of Applied Cristallography, (2009) 42, 1-9

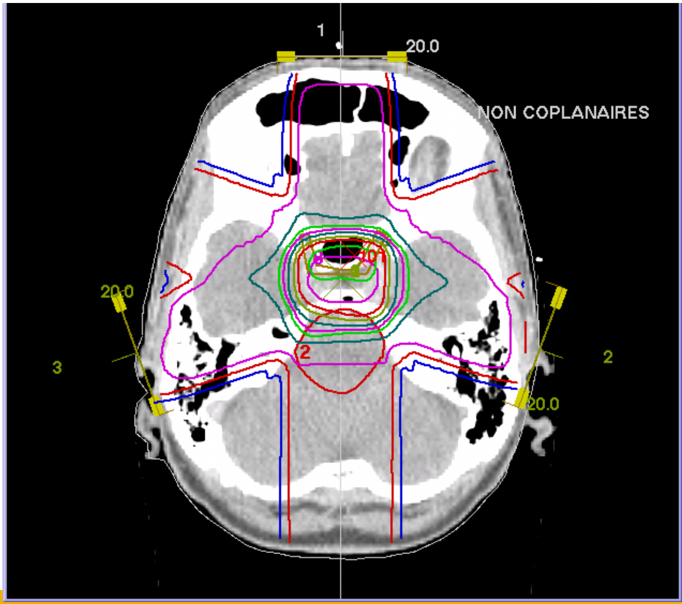
GATE application to radiotherapy

- **Scientific objectives**
  Geant4 Application for Tomographic Emission
  Medical physics applications: PET camera simulation, radiotherapy, occular brachytherapy treatment
  http://www.opengatecollaboration.org
- **Method**

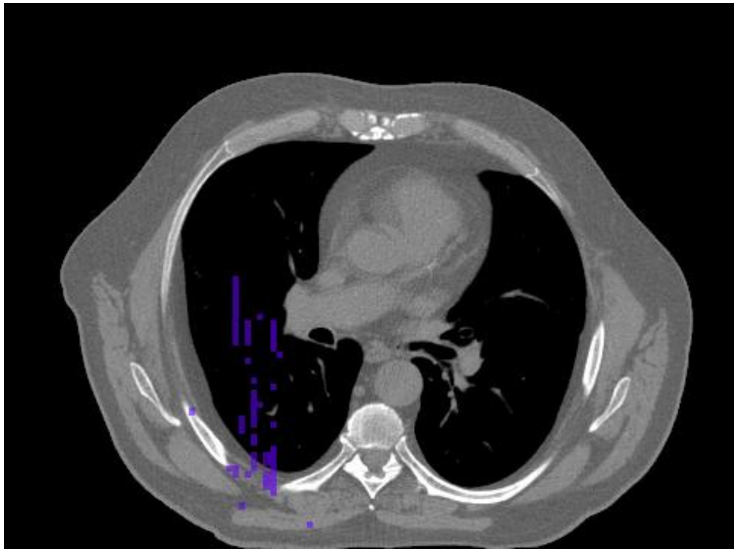
  GEANT4 base software to model physics of nuclear medicine.
  Use **Monte Carlo simulation** to improve accuracy of computations (as compared to the deterministic classical approach)







ThIS: Therapeutic Irradiation Simulator

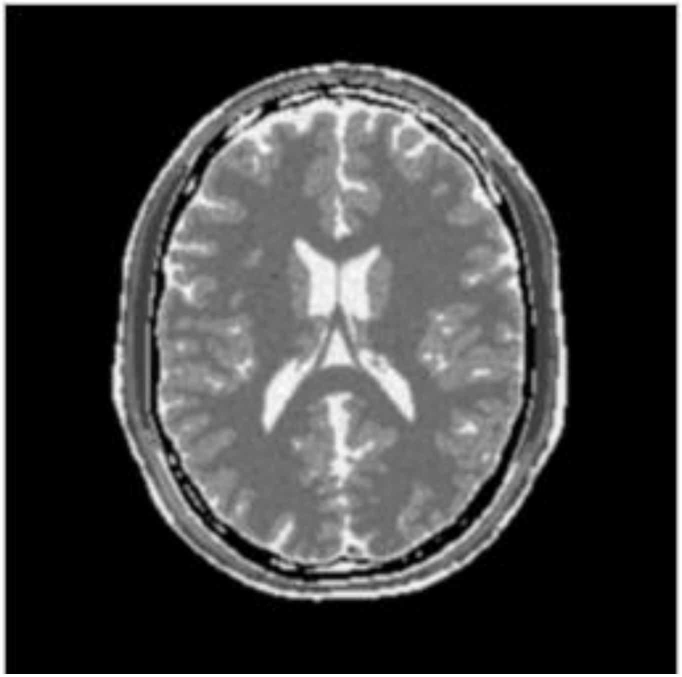


- Cancer treatment by irradiation of patient with beams of photons, protons or carbons
- CT image (482x360x141)
- 3D dose distribution, 700h CPU

- Offer an open platform to researchers for Monte Carlo simulations optimisation
- Offer a fast and reliable simulation tool for researchers in medical physics and medical imaging for treatment control
- Produce a reference dataset for non-conventional therapies (hadrontherapy).

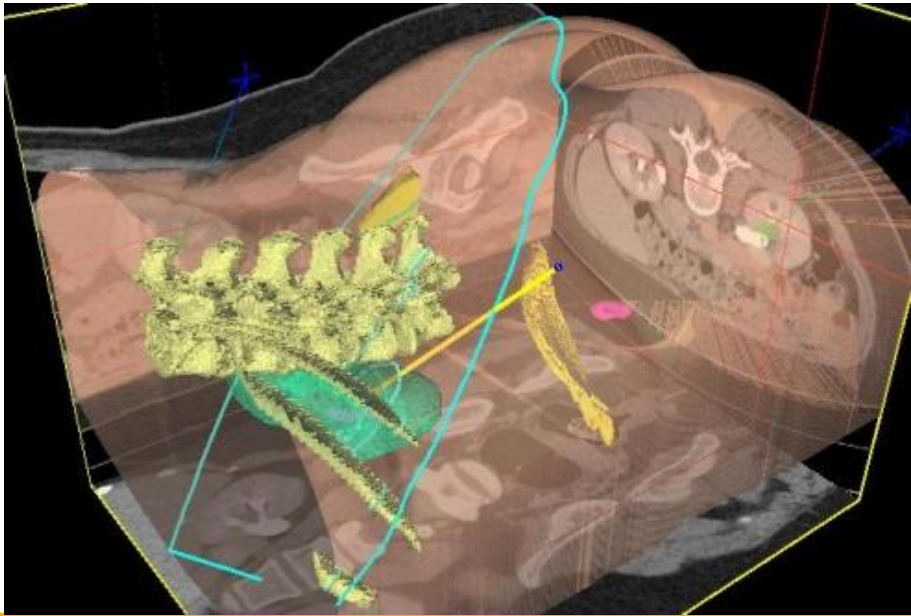
SiMRI3D: MRI simulator

- **Scientific objectives**
  - Better understand MR physics.
  - Study MR sequences in-silico.
  - Study MR artefacts.
  - Validate MR Image processing algorithms on synthetic yet realistic images.
- **Method**
  - Simulate Bloch's electromagnetism equations.
  - Parallel (MPI) implementation to speed-up computations.
- **Computational requirements**
  - 1000's of CPU hours per simulated image



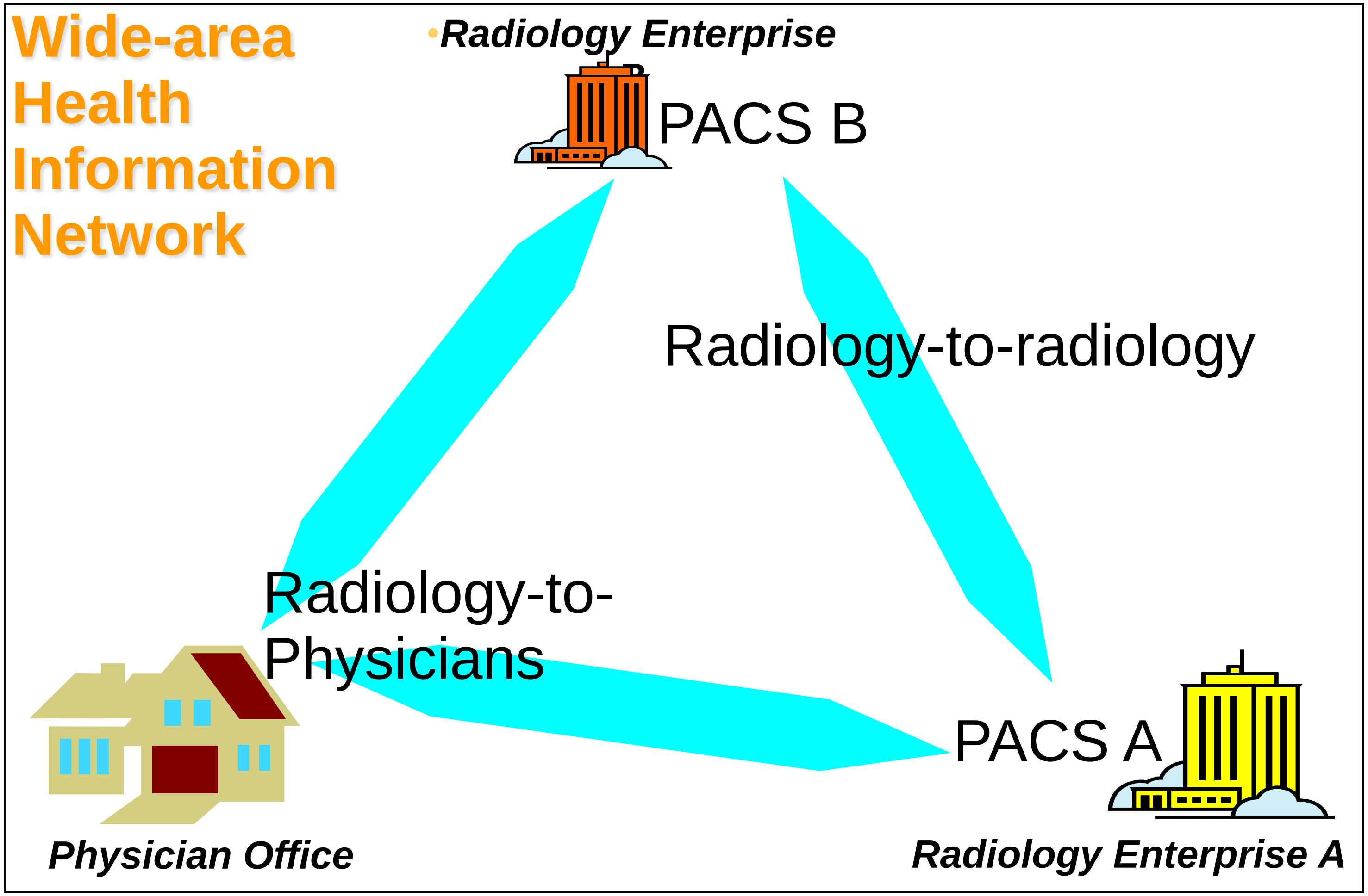
gPTM3D: radiology analysis

- **Scientific objectives**
  Interactive volume reconstruction on large radiological data.
  PTM3D is an interactive tool for performing computer-assisted 3D segmentation and volume reconstruction and measurement (RSNA 2004)
  Reconstruction of complex organs (e.g. lung) or entire body from modern CT-scans is involved in augmented reality use case e.g. therapy planning.
- **Method**
  Starting from an hand-made rough Initialization, a snake-based algorithm segments each slice of a medical volume. 3D reconstruction is achieved in parallel by triangulating contours from consecutive slices.

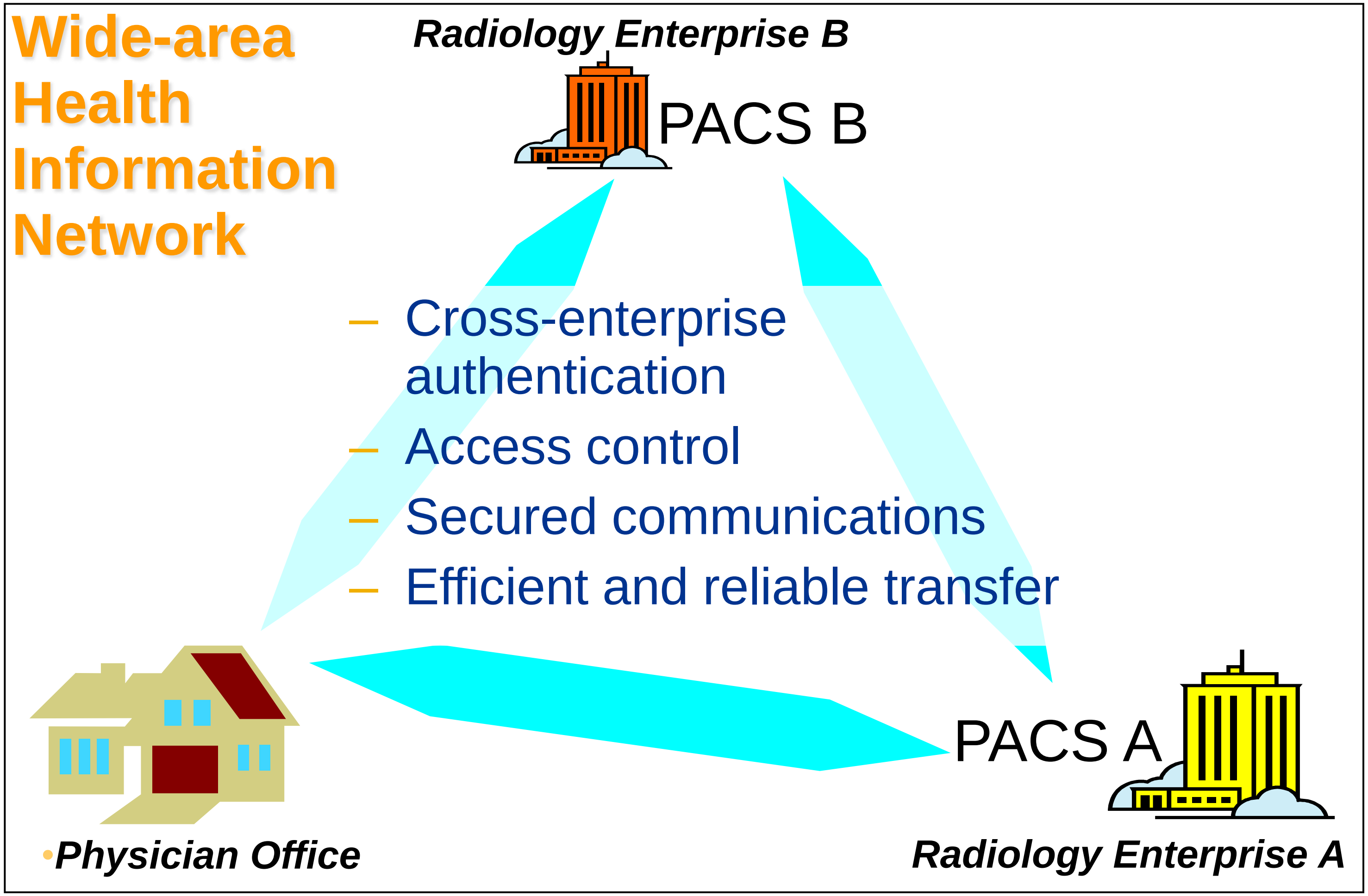


WAN medical image exchange

- *Cross-enterprise exchange of radiology reports and images*



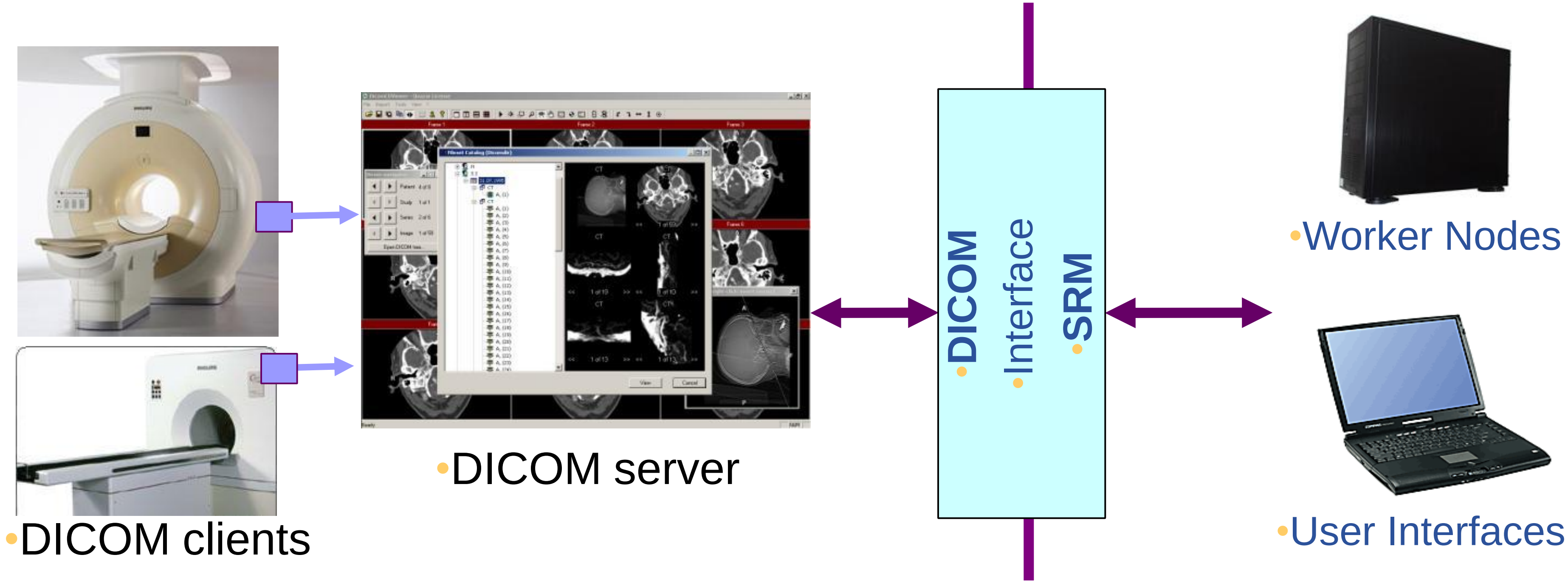
- ***Grid technologies***



– Cross-enterprise authentication
– Access control
– Secured communications
– Efficient and reliable transfer

EGEE Medical Data Manager

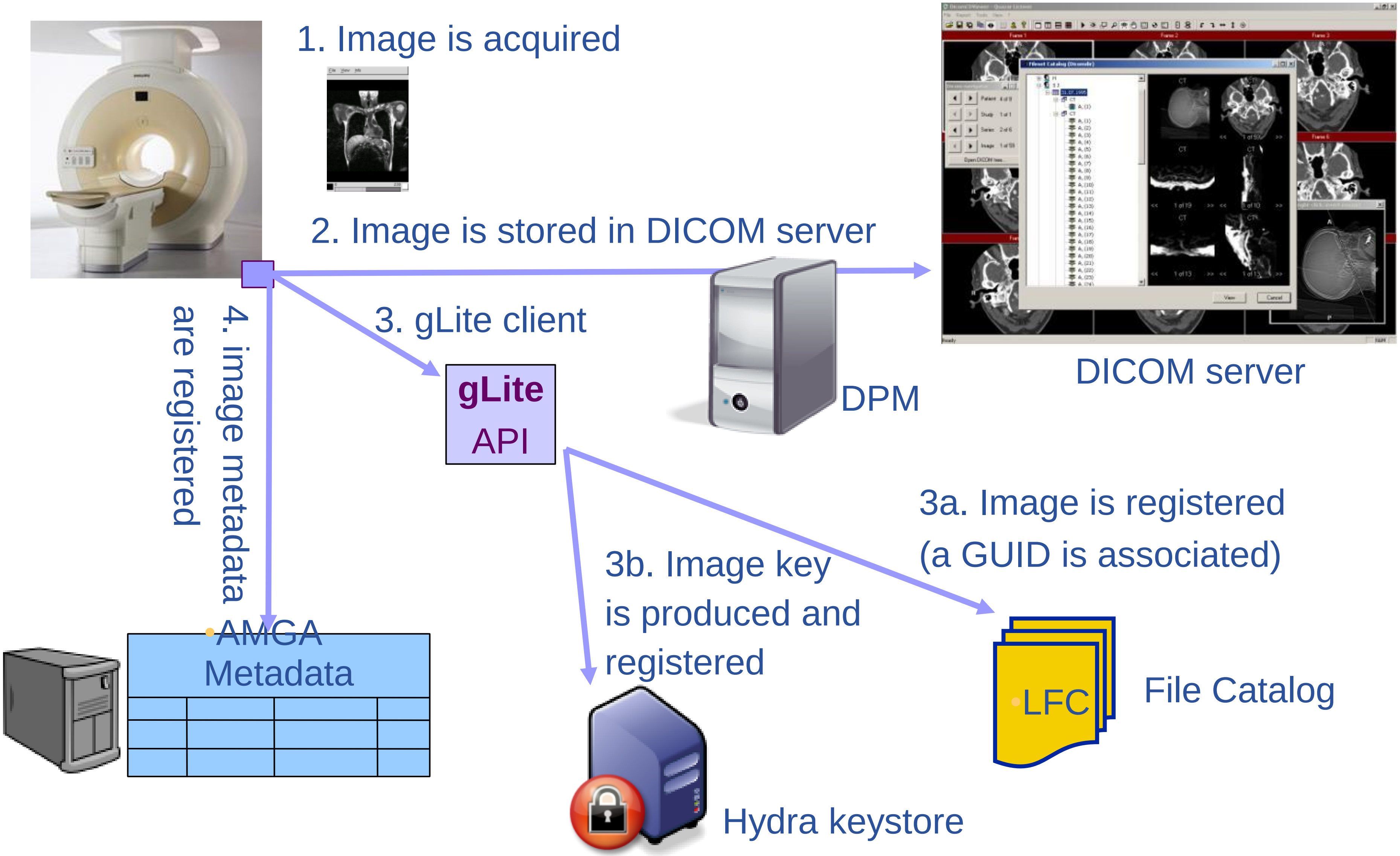
- **Objectives**
  - Expose a **standard grid interface** (SRM) for **medical image servers** (DICOM)
  - Use native DICOM storage format
  - Fulfill medical applications security requirements
  - Do not interfere with clinical practice



Medical data protection

- **Content**
  - Medical images (data, confidential)
  - Patient folder (attached metadata, very sensitive)
- **Requirements**
  - Patient privacy
    - Needs fine access control (ACLs on all data and metadata)
    - Needs metadata contention (metadata databases administrated by accredited staff)
  - Data protection
    - Needs data encryption (even grid sites administrators are not accredited to access the data)
- **How important it is?**
  - The medical community will just not use a system in which they are not trustful (both a technical and a human problem)

Medical Data Registration



Health-e-Child

Information Society Technologies

Health-e-Child

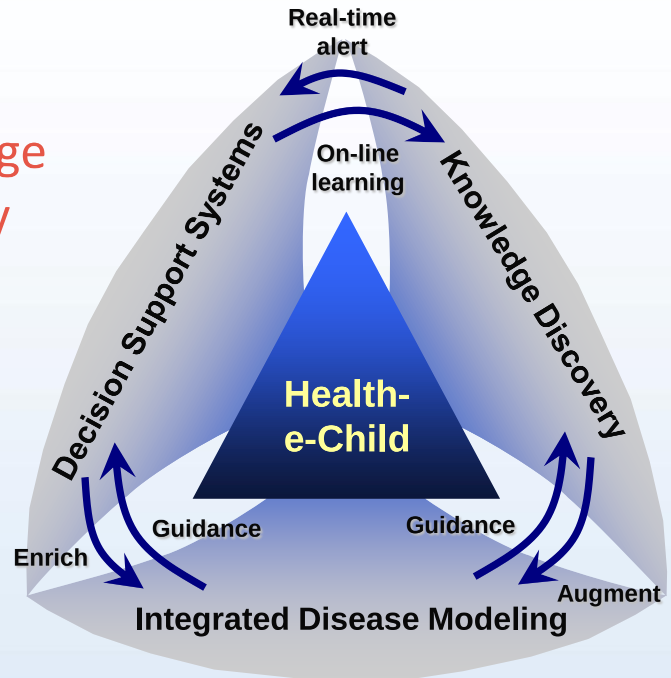
European e-Health Platform for Pediatrics

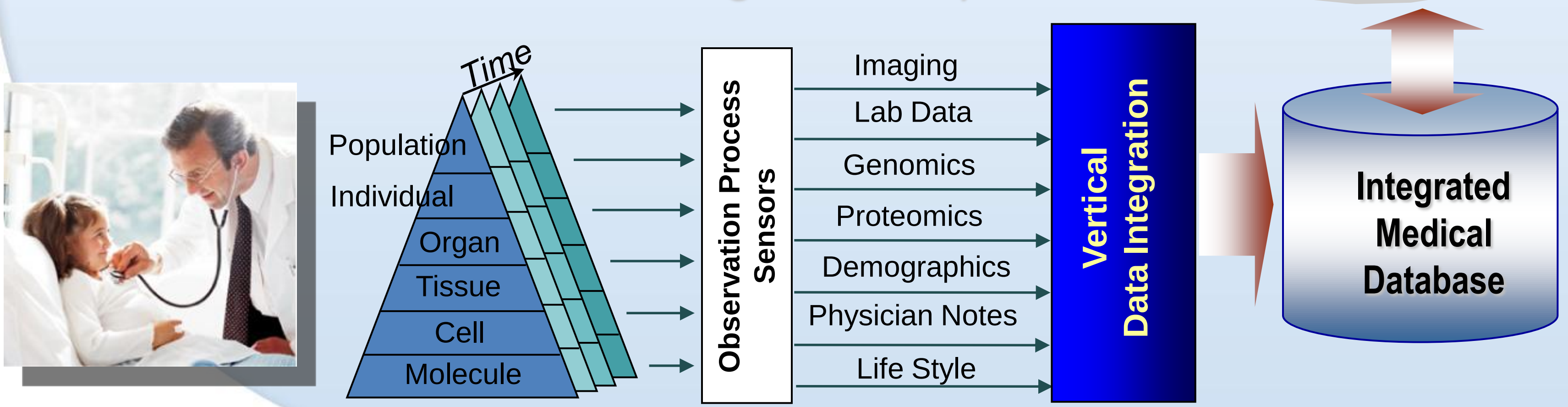
David MANSET,
maatG

On behalf of the Health-e-Child Consortium

Health-e-Child at a Glance

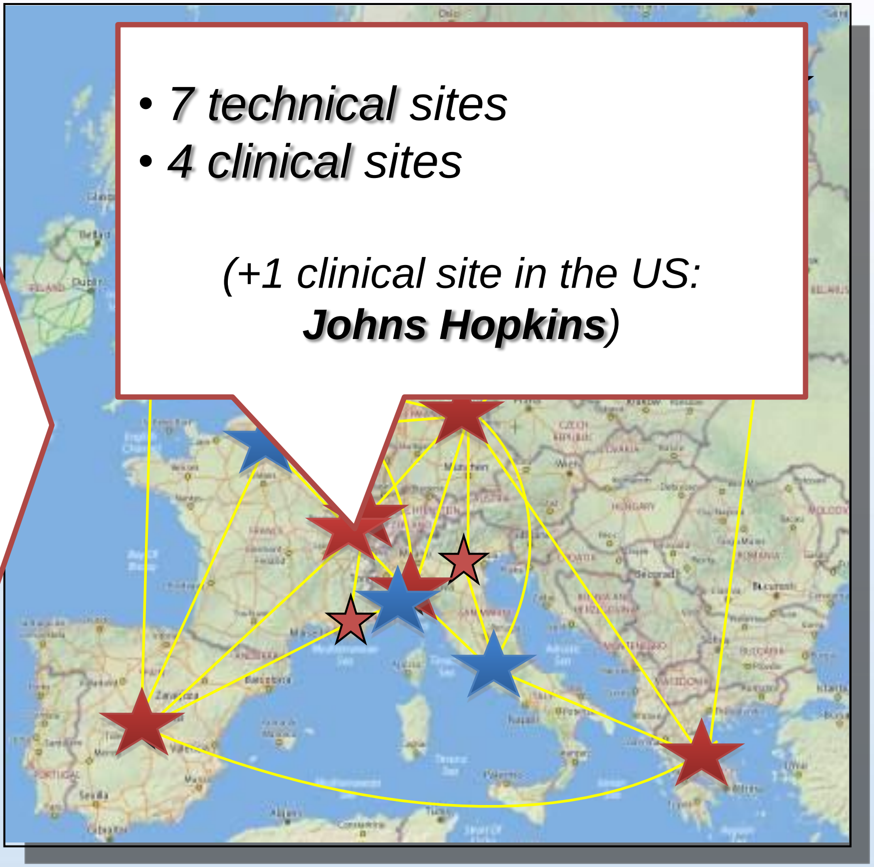
- Establish multi-site, vertical, and longitudinal integration of data, information and knowledge
- Develop a GRID based platform, supported by robust search, optimisation and matching
- Build enabling tools and services that improve patient care
- Two main use case scenarios leveraging disease models:
  - “Aiding the Clinician in Decision Making”
  - “Clinical Studies, Knowledge Discovery”





Health-e-Child Network

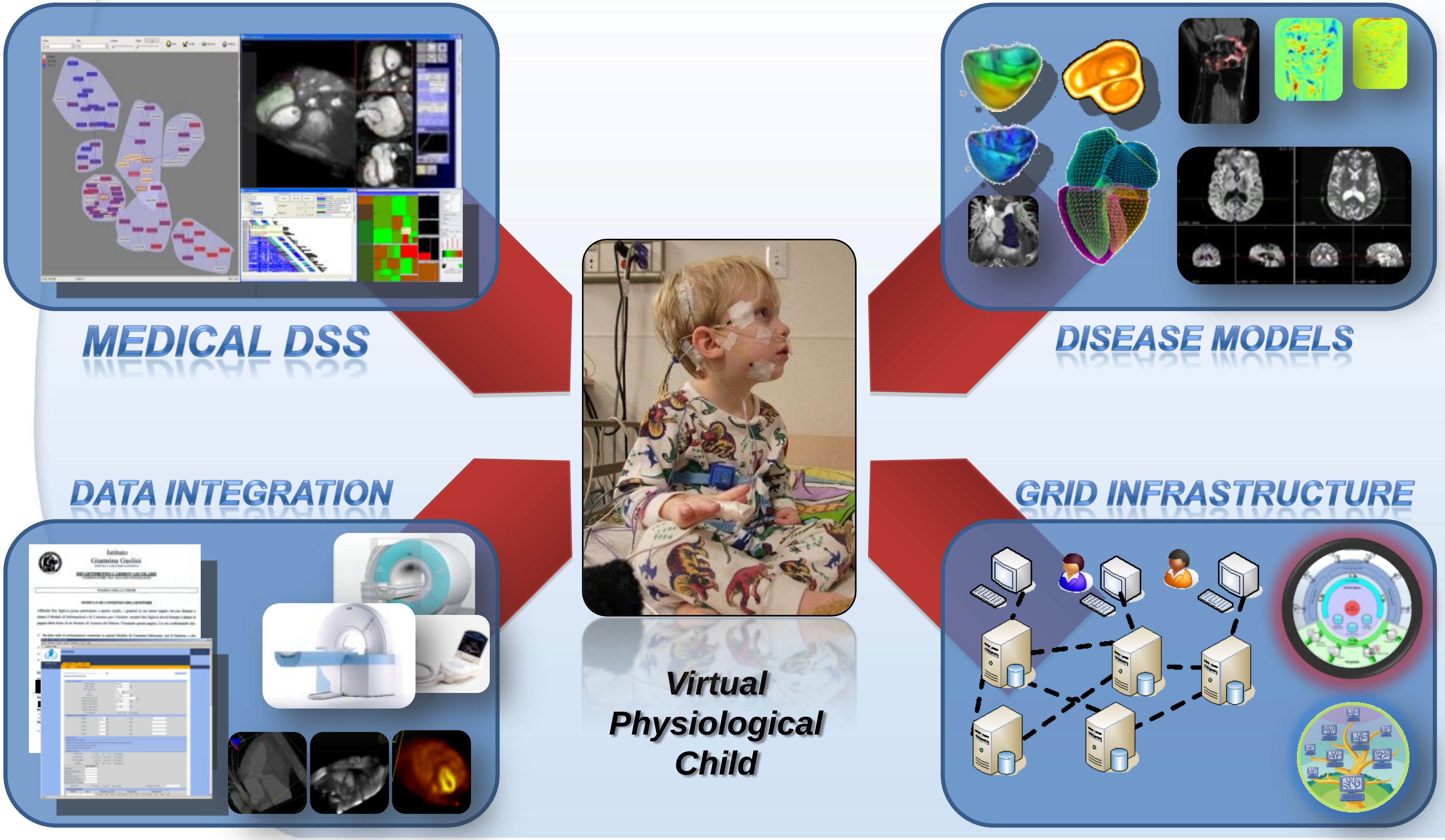
- *4 paediatric hospitals*
  - *IGG - Gaslini, Genoa, Italy*
  - *GOSH, London, UK*
  - *NECKER, Paris, France*
  - *OPBG, Rome, Italy*
- *Strong interdisciplinary team across*
  - *Countries and languages*
  - *Technical and clinical fields*
- *Research on three paediatric areas*
  - *Arthritis*
  - *Cardiac Disorders*
  - *Brain Tumours*



- *7 technical sites*
- *4 clinical sites*

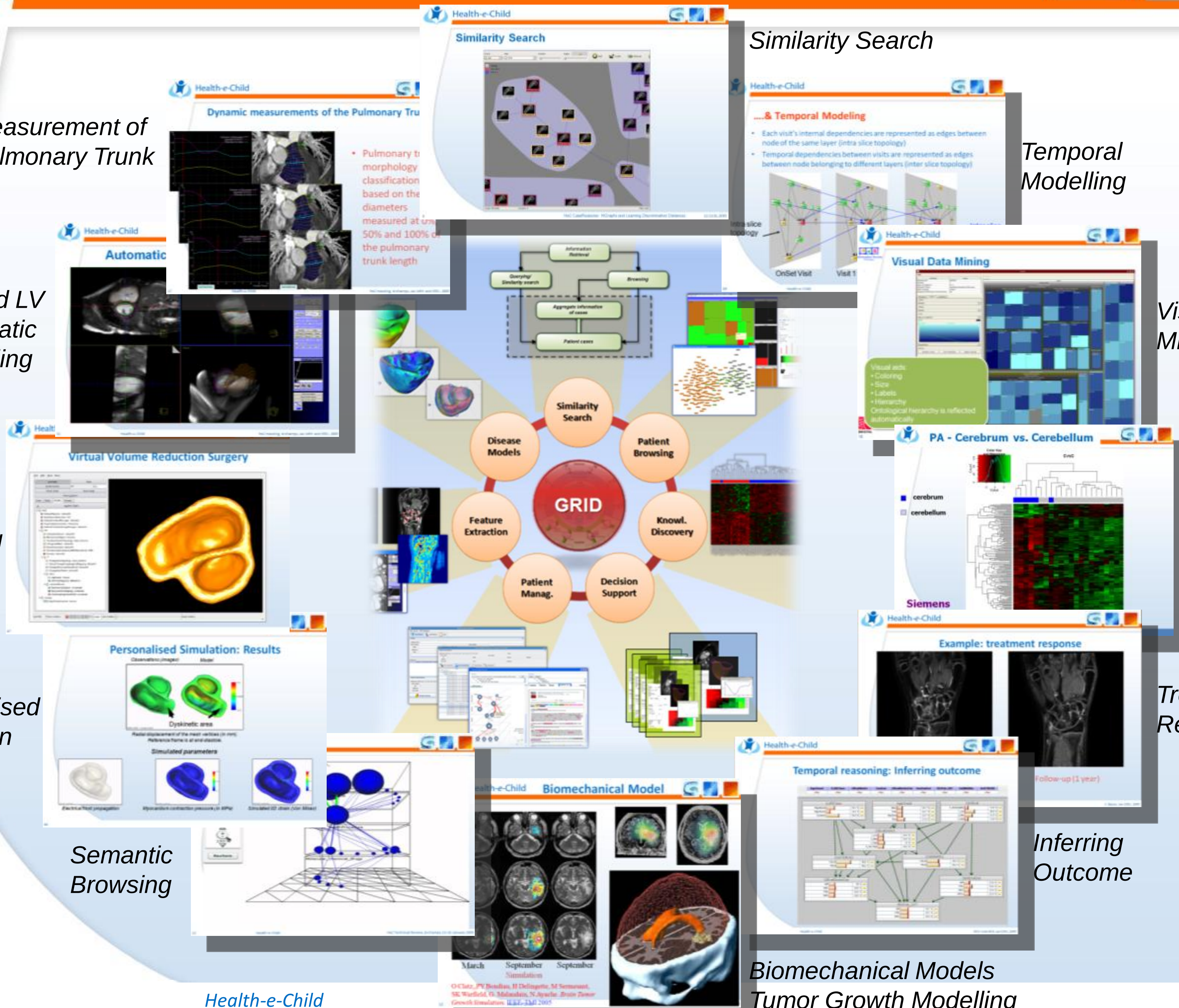
(+1 clinical site in the US: ***Johns Hopkins****)*

Decision Support



Health-e-Child

Information Society Technologies



Similarity Search

Measurement of Pulmonary Trunk

Temporal Modelling

RV and LV Automatic Modelling

Visual Data Mining

Surgery Planning

Genetics Profiling

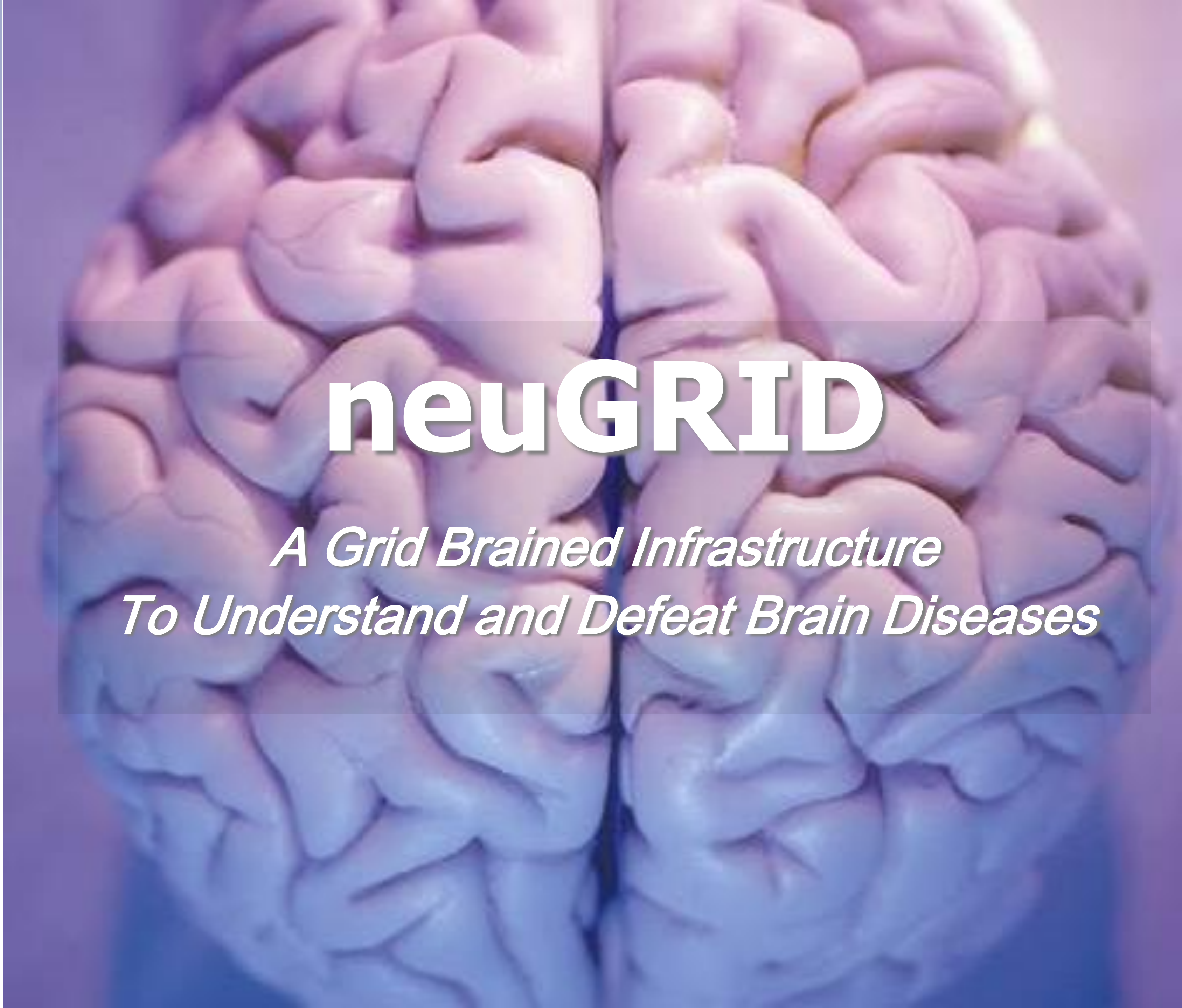
Treatment Response

Personalised Simulation

Semantic Browsing

Inferring Outcome

Biomechanical Models Tumor Growth Modelling



neuGRID

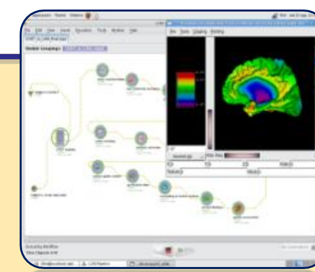
A Grid Brained Infrastructure
To Understand and Defeat Brain Diseases

Imaging Markers & Pipelines

Toolkits

What are markers used for?

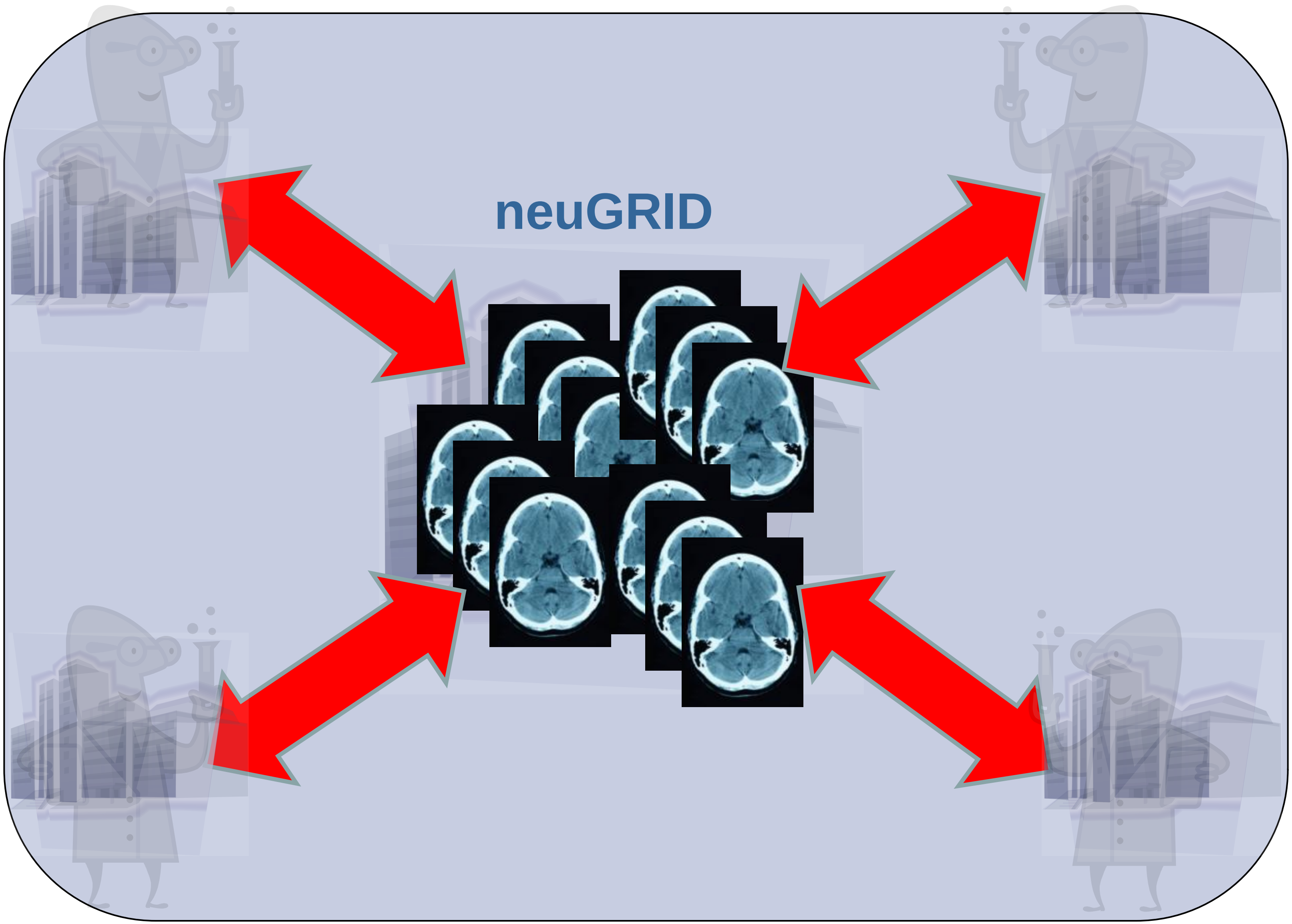
- To support physicians in diagnosing diseases,
    - Prognosing may become a reality!
- To measure disease evolution,
- To assess treatment(s)/drug(s) efficacy,
    - Thus supporting pharma industries in drug developments,
- To further understand diseases and brain anatomy and functions



How do such markers materialize?

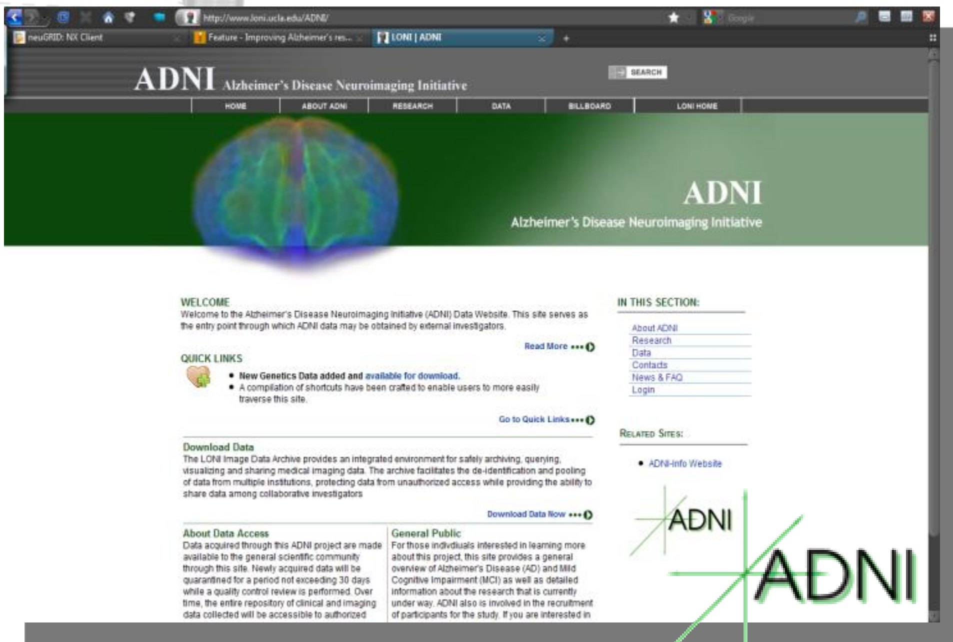
- Data mining Algorithms and Pipelines of Algorithms
- Heterogeneous Algorithms and Pipelines toolkits
    - I.e. FSL, MRIcron, FreeSurfer, MNI/BIC, LONI, SPM etc
- Computing and data intensive mining operations

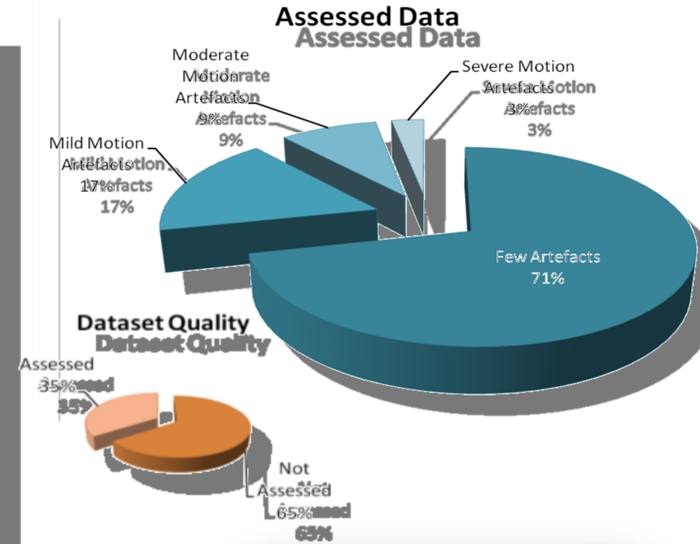
TOMORROW



Data Challenge (1/4)

Analyzing the US-ADNI Database





Alzheimer's Disease Neuroimaging Initiative

- To help researchers and clinicians in developing new treatments and testing their efficacy,
- The ADNI is a multisite, multiyear program which began in October 2004,
- More than 700 subjects recruited, 200 elderly controls, 400 with mild cognitive impairment (MCI) and 200 with Alzheimer's disease (AD)
    - Subjects have been followed for 2-3 years and have been seen approximately every 6 months

Data Challenge (3/4)
Facts & Figures

Expected Results

Experiment duration on the Grid		**< 2 Weeks**
Experiment duration on single computer		**> 5 Years**
Analyzed data	Patients MR Scans Images Voxels	715 6’235 ~1’300’000 ~9’352’500’000
Total mining operations		286’810
Max # of processing cores in parallel		184
Number of countries involved		4
Volume of output data produced		1 TB

neuGRID e-infrastructure

Another example:
eLearning easing healthcare HR crisis in Kenya

In Kenya, chronic shortage of highly skilled nurses

Enrolled Nurses (ENs) comprise 70% of nursing and 45% of the health workforce in Kenya

- First point of contact for communities, but are inadequately skilled to manage new and re-emerging diseases like HIV/AIDS

PPP led by the Nursing Council of Kenya (NCK), the African Medical and Research Foundation (AMREF) and Accenture to upgrade 22,000 ENs from 'enrolled' to 'registered' level within 5 years via eLearning (distance education through ICT) methods

Promising progress since start of program in Sep. 2005

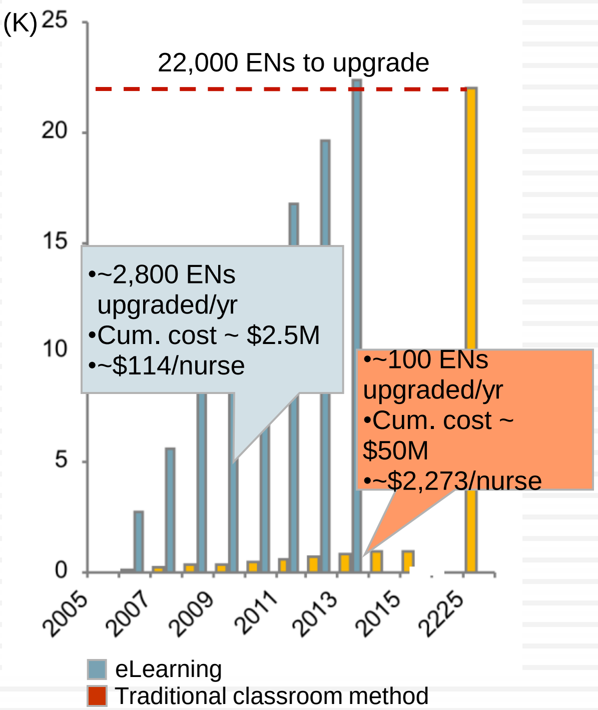
As of Nov. 2006, 3,265 nurses upgraded

27 colleges and schools participating including AMREF's Virtual Nursing School

Over 100 computer-equipped training centers set up in 8 provinces, including remote and marginalized districts

eLearning can reach goal w/in next decade versus >200 years w/ traditional classroom methods

eLearning vs. traditional methods for upgrading ENs



Source: Source: WHO, AMREF website

Results do not just represent dramatic cost and time improvements over status quo, they are nearly impossible without use of ICT

In summary

- e-Health is out of its infancy….
- ….but formidable challenges are to be overcome before it becomes an healthy adult!
- The challenge can be successfully met ONLY through synergies with a wide variety of actors
- Science communication in this field plays a key role


Thank You!