The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

1967-26

Advanced School in High Performance and GRID Computing

3 - 14 November 2008

Modeling and Evaluation of Performance of Scalable Architectures (Grid/Cluster Monitoring tools and procedures)

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Experimental Computer Science

« Performance Evaluation on Scalable Architectures »

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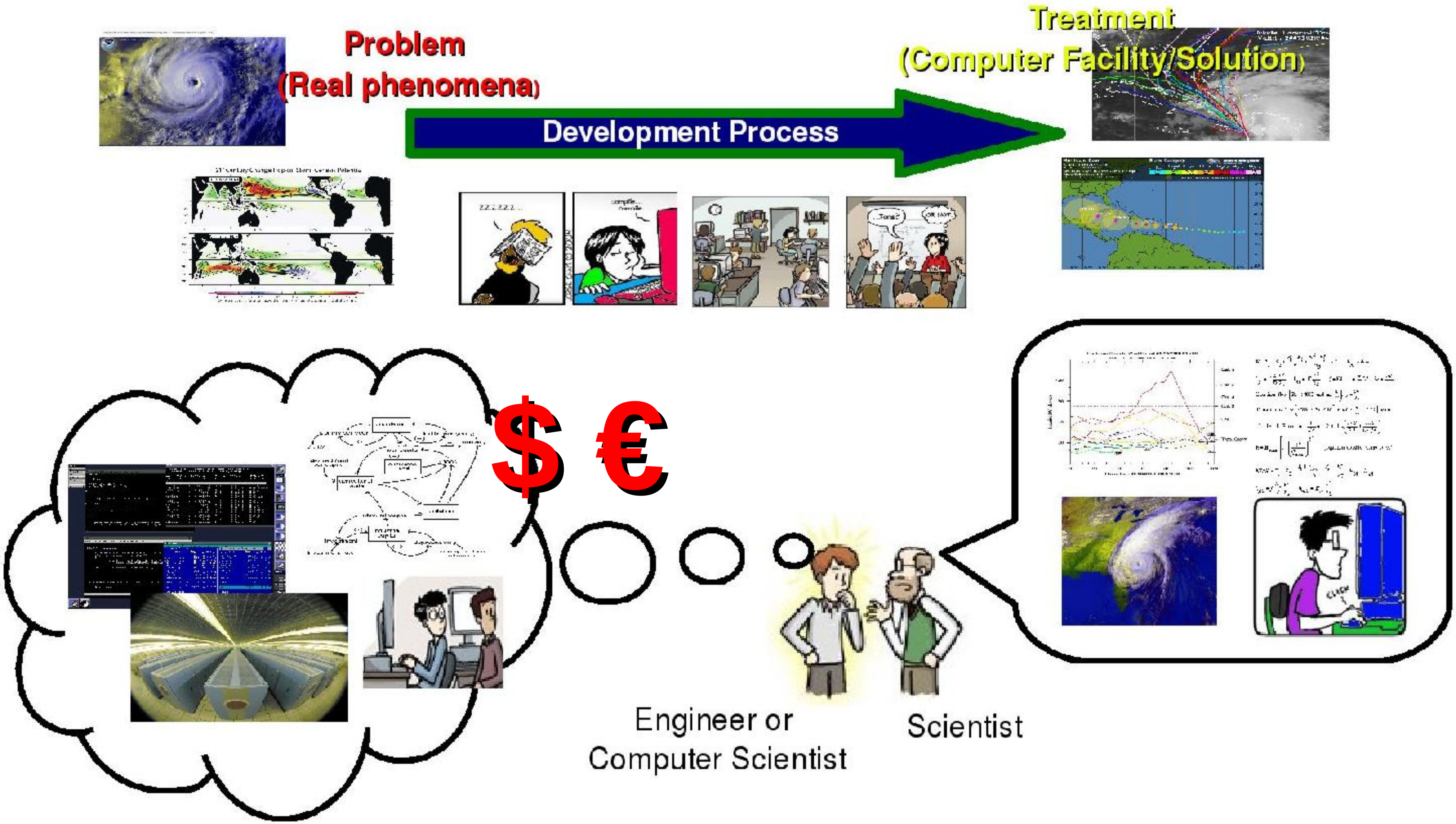
Advanced School in High Performance and GRID Computing
ICTP -Trieste, Italy, November 2008

Conception, Development and use of Computer Solutions



Problem
(Real phenomena)

Development Process

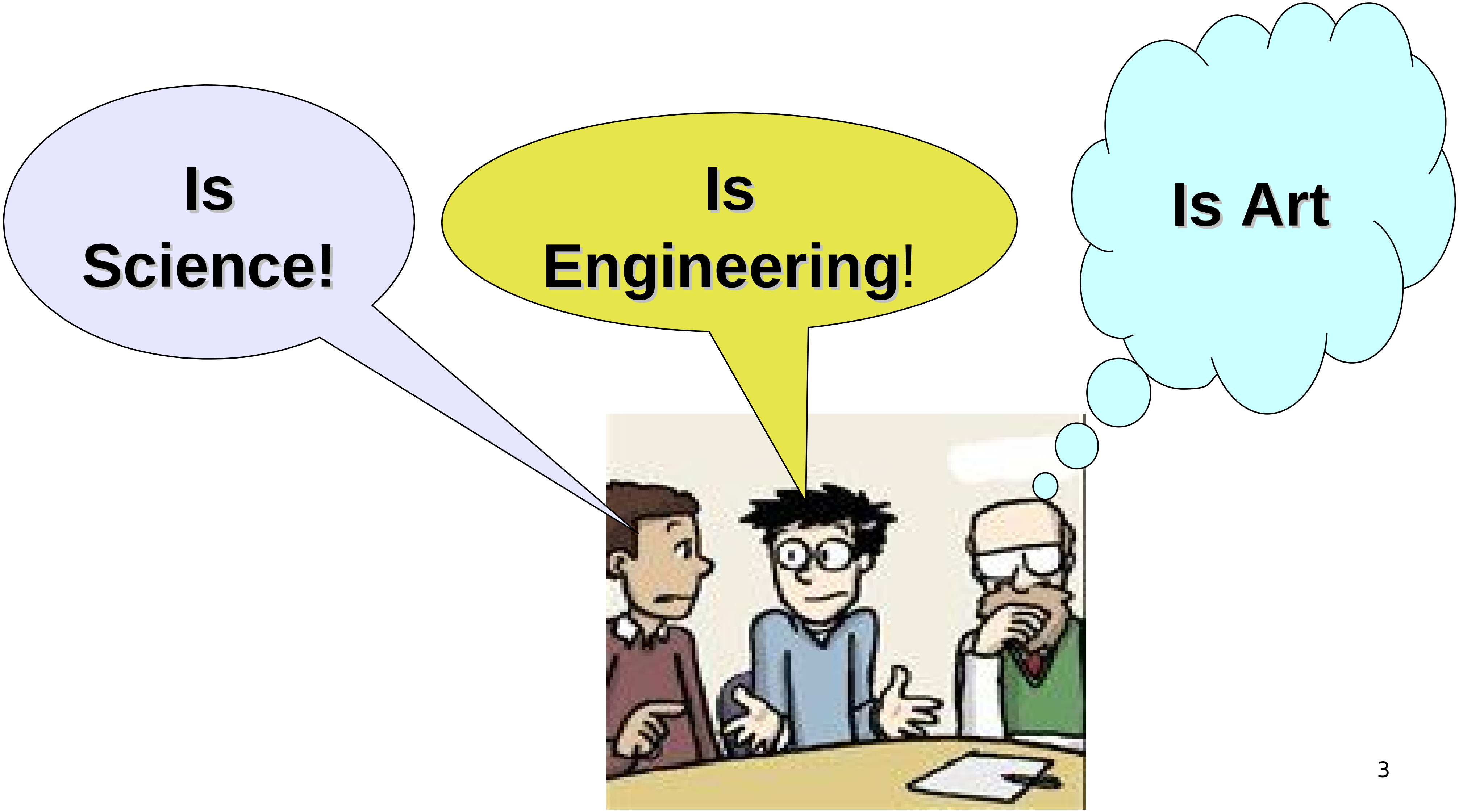
Treatment
(Computer Facility/Solution)

$ €

Engineer or
Computer Scientist

Scientist

The Computer Science Problem

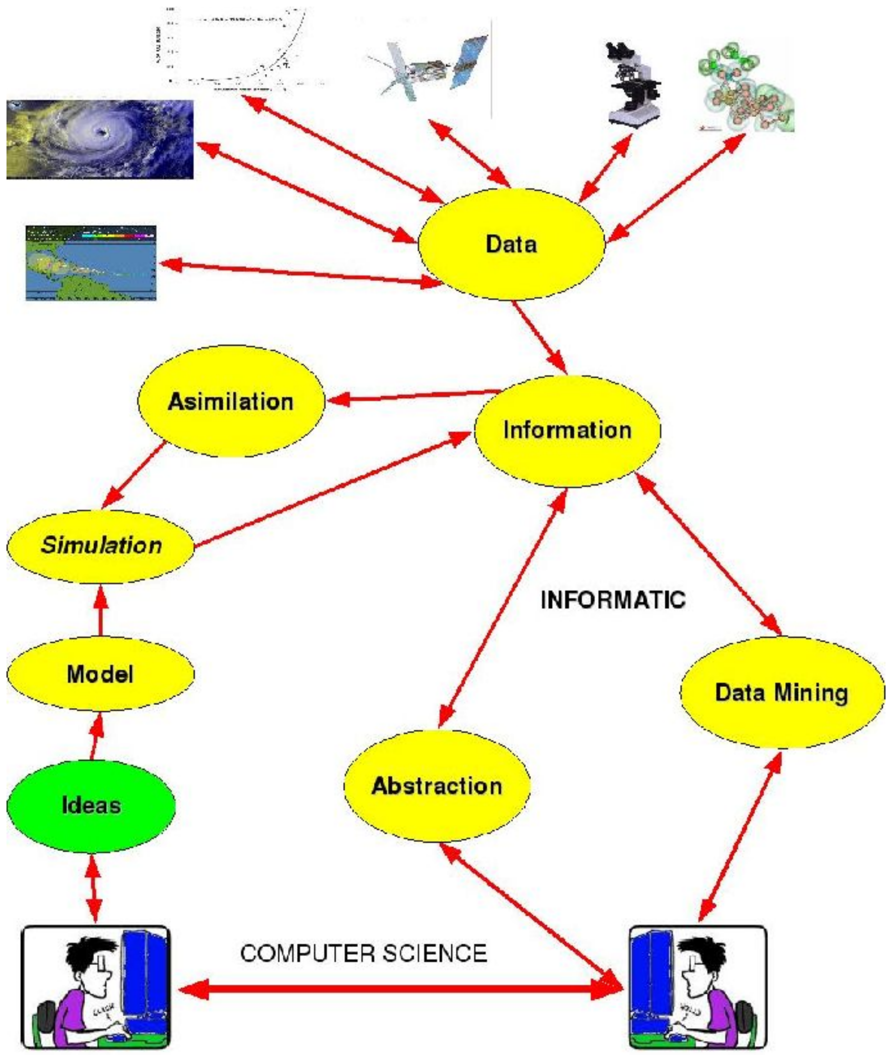


Is Science!

Is Engineering!

Is Art

The paradigm…



- What process are part of a scientific approach?
- What process are a technological or engineering approach?
- What process are made with intuition, experience or inspiration?

The Focus Problem

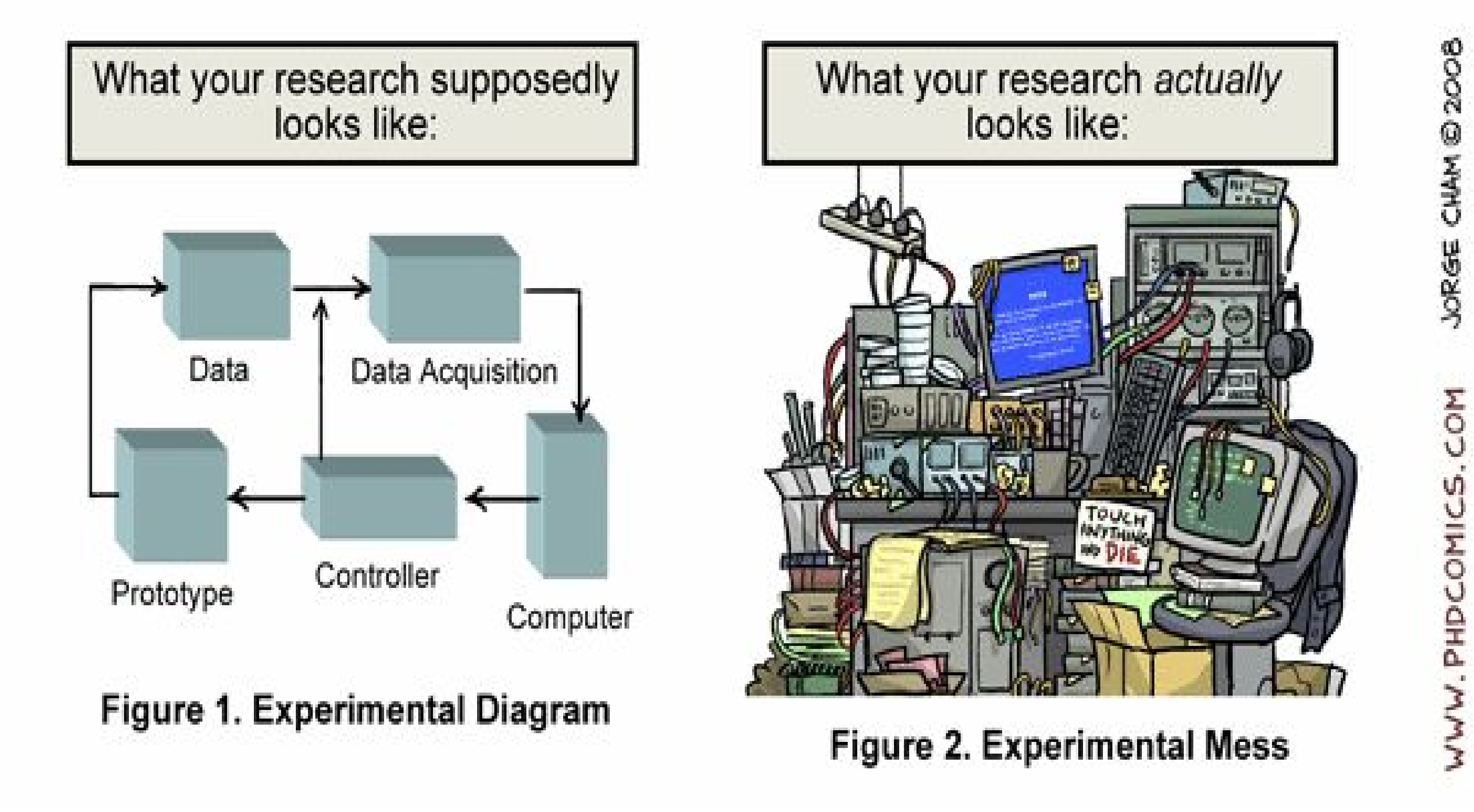
- Theoretical:
  - I know everything... but nothing works.
- Practical:
  - Everything works... but I don't know why.
- Theoretical-Practical (Hybrid):
  - Nothing works... and nobody knows why.

In any case, we need predict the behavior of our system

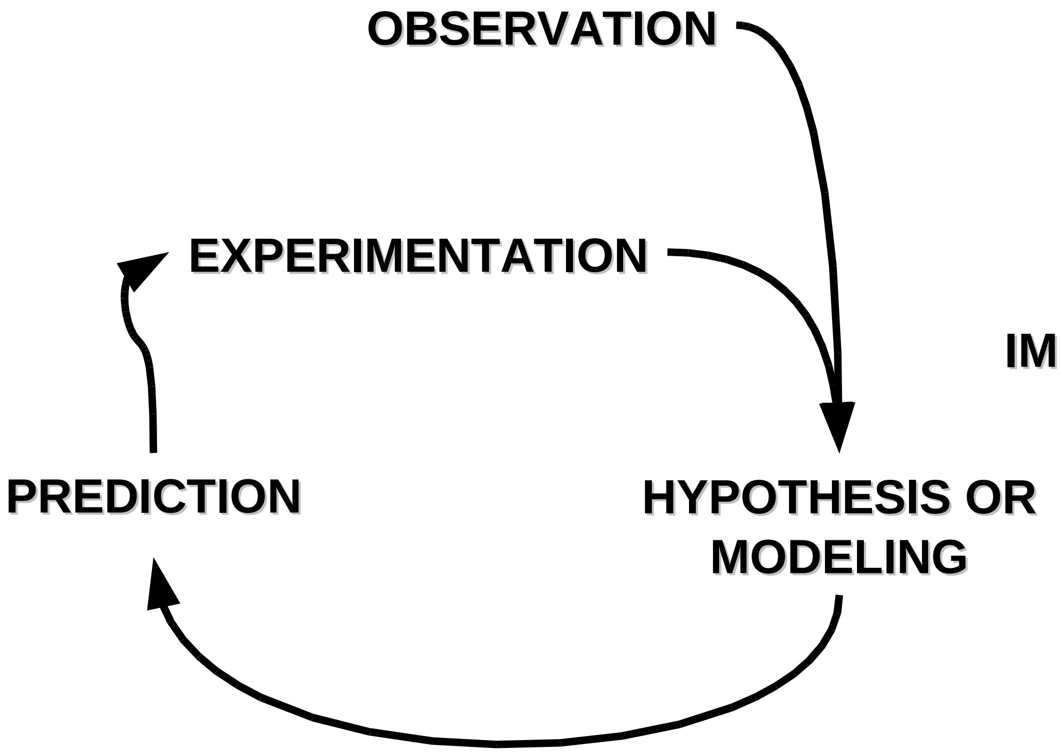
Outline

- Introduction
  - Experimentation in Computer Science
- Performance Evaluation
  - Techniques
  - Metrics
- The Grid Computing Case (and Scalable Architectures)
  - Grid'5000 Case
- Open Questions

Experimentation Mess


What your research supposedly looks like:
Data
Data Acquisition
Prototype
Controller
Computer
Figure 1. Experimental Diagram
What your research *actually* looks like:
TOUCH ANYTHING AND DIE
Figure 2. Experimental Mess
JORGE CHAM © 2008
WWW.PHDCOMICS.COM

Conception of Systems



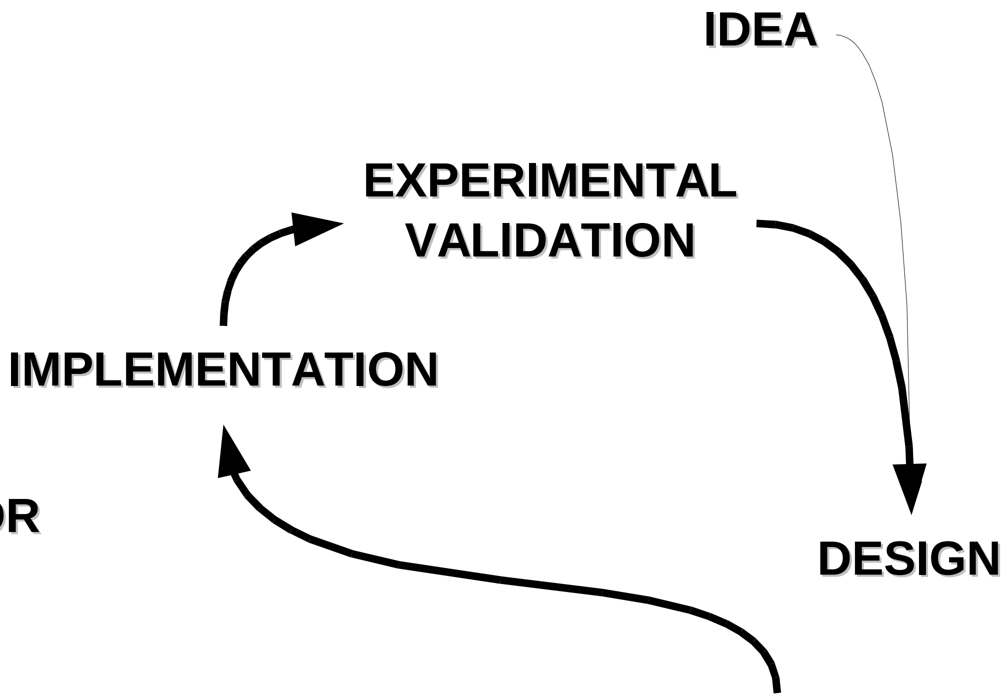
OBSERVATION

EXPERIMENTATION

PREDICTION

HYPOTHESIS OR MODELING

Scientific Method



IDEA

EXPERIMENTAL VALIDATION

IMPLEMENTATION

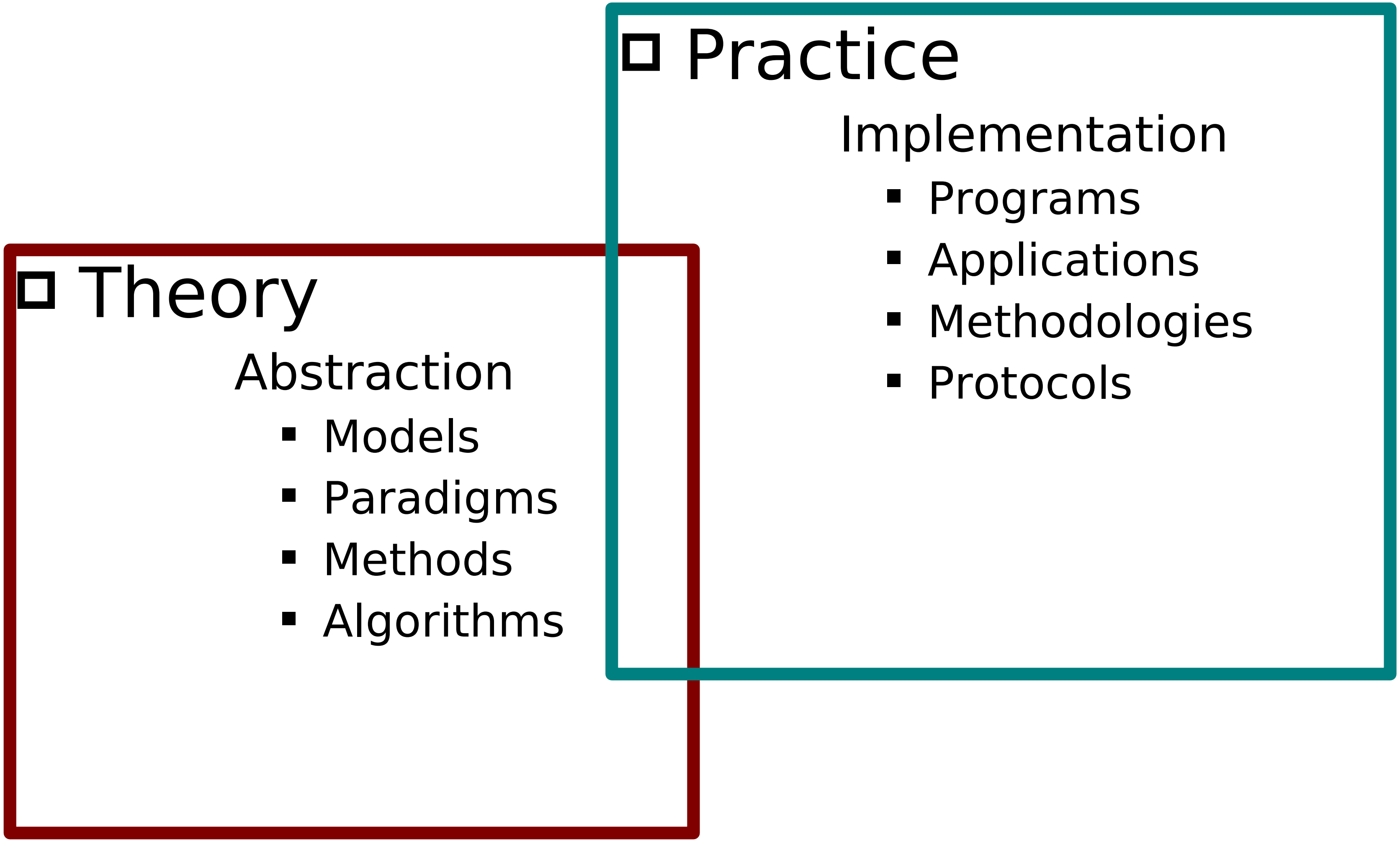
DESIGN

Conception and Design of Systems

- From Special section in Communications of the ACM 50(11), Nov 2007

Theory and Practice

(Point of view of Systems Conception)



- Practice

  Implementation
  - Programs
  - Applications
  - Methodologies
  - Protocols

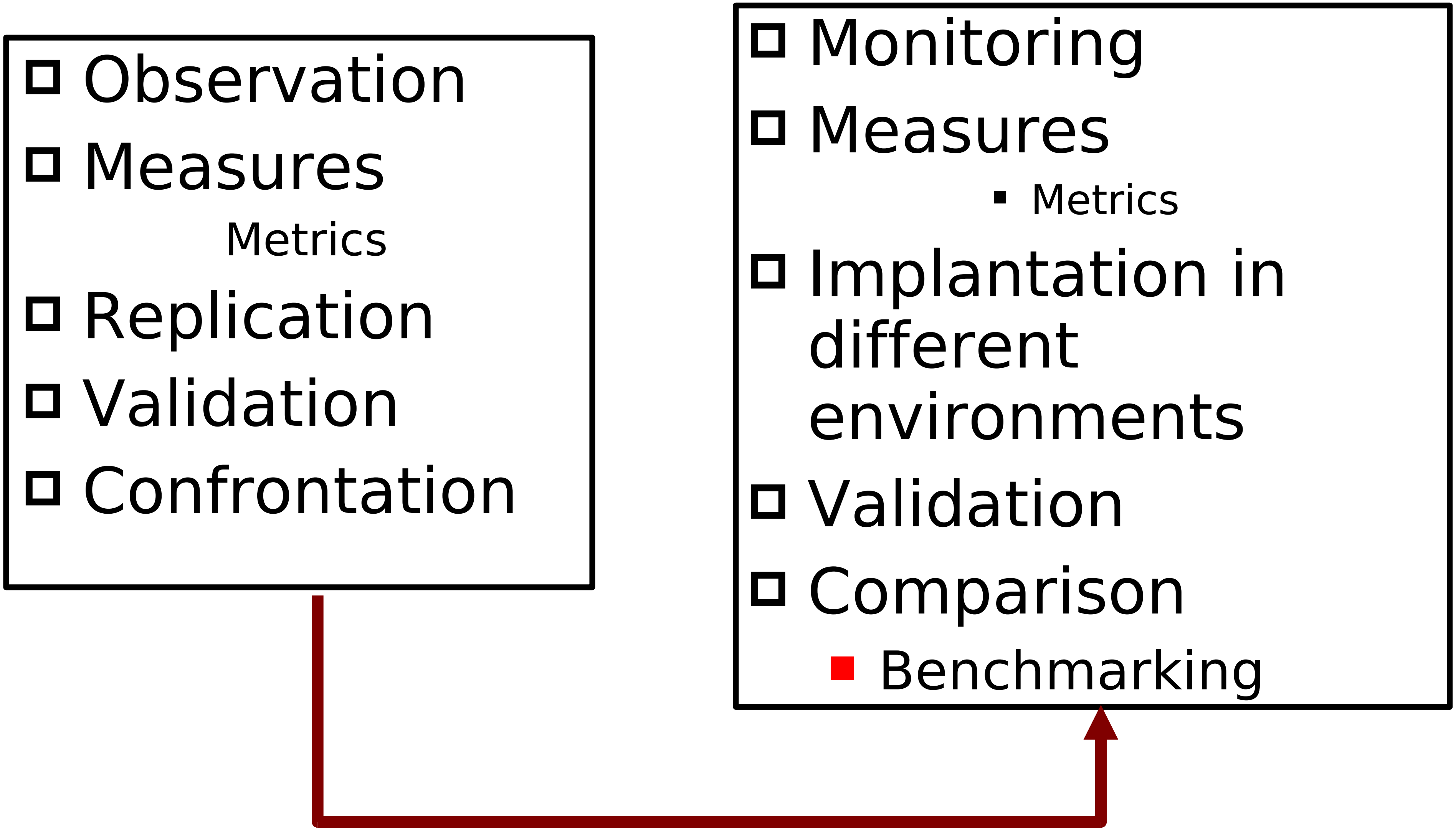
- Theory

  Abstraction
  - Models
  - Paradigms
  - Methods
  - Algorithms

Science of the Computer Science

- Experimentation (tests) could be confirm or refute the accuracy (efficiency) of a software (system) design.
- Questions and theoric motivations with experiences (tests) produce « good » algorithms and programs.
- Development Cycle of software (systems) include: modeling (design), experimentation (tests – performance evaluation), build (programming)... (It's not a linear cycle).

Observing the Behavior of a System



- Observation
- Measures
  - Metrics
- Replication
- Validation
- Confrontation

- Monitoring
- Measures
  - Metrics
- Implantation in different environments
- Validation
- Comparison
  - Benchmarking

Experimental Computer Science

- Experimental Computer Science includes:
  - Observation
  - Confrontation of hypothesis
  - Reproduction of tests

Performance Evaluation

Performance Evaluation

- Application goal is to run with the maximum performance at least cost.
  - Thus, It's necessary Performance Evaluation
- Performance Evaluation is constant in all life cycle of the Application (or system)
  - Design
  - Building
  - Implementation
  - Implantation
  - Use
  - Actualization

Performance Evaluation

(From the Computer Science Problem Heritage)

- Performance Evaluation is a technique:
  - Processes
  - Methodology
  - Tools
- Performance Evaluation is a science:
  - Theoric Basis
  - Experimentation
  - Replication and Validation
- Performance Evaluation is Art:
  - Intuition (Deep Knowledge)
  - Abstraction Capacity
  - Creativity
  - Activity non repetitive
  - Tools

Performance Evaluation allows to know the capacities and limitations of a system.

Modeling, Measuring and Simulating

- Modeling: It allows to build formal abstractions
  - Mathematical Models
  - Analytical Models
  - Causal Models
- Measurement: It allows to characterize
  - Tests, Experiences in environments controlled known.
- Simulating: It allows to observe defined scenarios
  - In according with the modeling.

Techniques

- MODELING (Analytical Model)
- SIMULATION
- EXPERIMENTATION (TESTS – MEASUREMENT)
  - Tests in controlled systems
  - Tests « On Live » (also controlled)

Benchmarking

Tracing and Profiling

ANYONE COULD BE VALIDATE FOR ALMOST ANOTHER ONE!!!

Solution Techniques

	Technique		
Characteristic	**Analytical**	**Simulation**	**Measurement**
Flexibility	High	High	Low
Cost	Low	Medium	High
Believability	Low	Medium	High
Accuracy	Low	Medium	High

From Measuring Computer Performance: A Practitioner’s Guide, David J. Lilja 2004

Performance Evaluation Steps

1. Stablish the goals of the study and define the system boundaries.
2. List system services and possible outcomes
3. Select performance metrics
4. List system and workload parameters.
5. Select factors and their values.
6. Select evaluation techniques.
7. Select the workload.
8. Design the experiments.
9. Analyze and interpret the data.
10. Present the results. Start over, if necessary.

- **From The Art of Computer Systems Performance Analysis Techniques For Experimental Design Measurements Simulation And Modeling de Raj Jain .Wiley Computer Publishing, John Wiley & Sons, Inc.**

About the Metrics

- Performance metrics are
  - Count
    - Of how many times an event occurs
  - Duration
    - Of a time interval
  - Size
    - Of some parameter
  - Derivated values from these measurements

Time-normalized metrics

- « Rate » metrics
  - Normalize metric to common time basis
    - Transactions per second
    - Bytes per second
  - (Number of events) ÷ (time interval over which events occurred)
- « Throughput »
  - Average rate of successful message delivery over a communication channel
- Useful for comparing measurements over different time intervals

Good Metrics Characteristics

- Allows accurate and detailed comparisons
- Leads to correct conclusions
- Is well understood by everyone
- Has a quantitative basis
- A good metric helps avoid erroneous conclusions

- Good metrics is
  - **Linear**

    If metric increases 2x, performance should increase 2x
  - **Reliable**

    If metric A > metric B

    Then, Perf. A > Perf.B
- **Repeatable**
- **Easy to use**
- **Consistent**
  - Units and definition are constant across systems
- **Independent**
  - Indepentent to pressure on manufacturers to *optimize* for a particular metric

Performance Metrics Summary

	Clock	MIPS	MFLOPS	SPEC	QUIPS	TIME
Linear					≈ ☺	☺
Reliable						≈ ☺
Repeatable	☺	☺	☺	☺	☺	☺
Easy to measure	☺	☺	☺	½ ☺	☺	☺
Consistent	☺			☺	☺	☺
Independent	☺	☺			☺	☺

From Measuring Computer Performance: A Practitioner's Guide, David J. Lilja 2004

Other metrics

- Response time
  - Elapsed time from request to response
- Throughput
  - Jobs, operations completed per unit time
    - E.g. video frames per second
- Bandwidth
  - Bits per second
- *Ad hoc* metrics
  - Defined for a specific need
    - Requests per transaction

About the means…

- Performance in systems is multidimensional
  - CPU time
  - I/O time
  - Network time
  - Read/Write speedup
  - Disk Access
  - Storage Capacity
  - Interactions of various components
  - …

About measurement tools and methodologies…

- Actually, measurement tools are based in ***events***:
  - Some predefined change to system state
- Event definition depends on metric being measured
  - Memory reference
  - Disk access
  - Change in a register’s state
  - Network message
  - Processor interrupt

Some measurement techniques comparaison

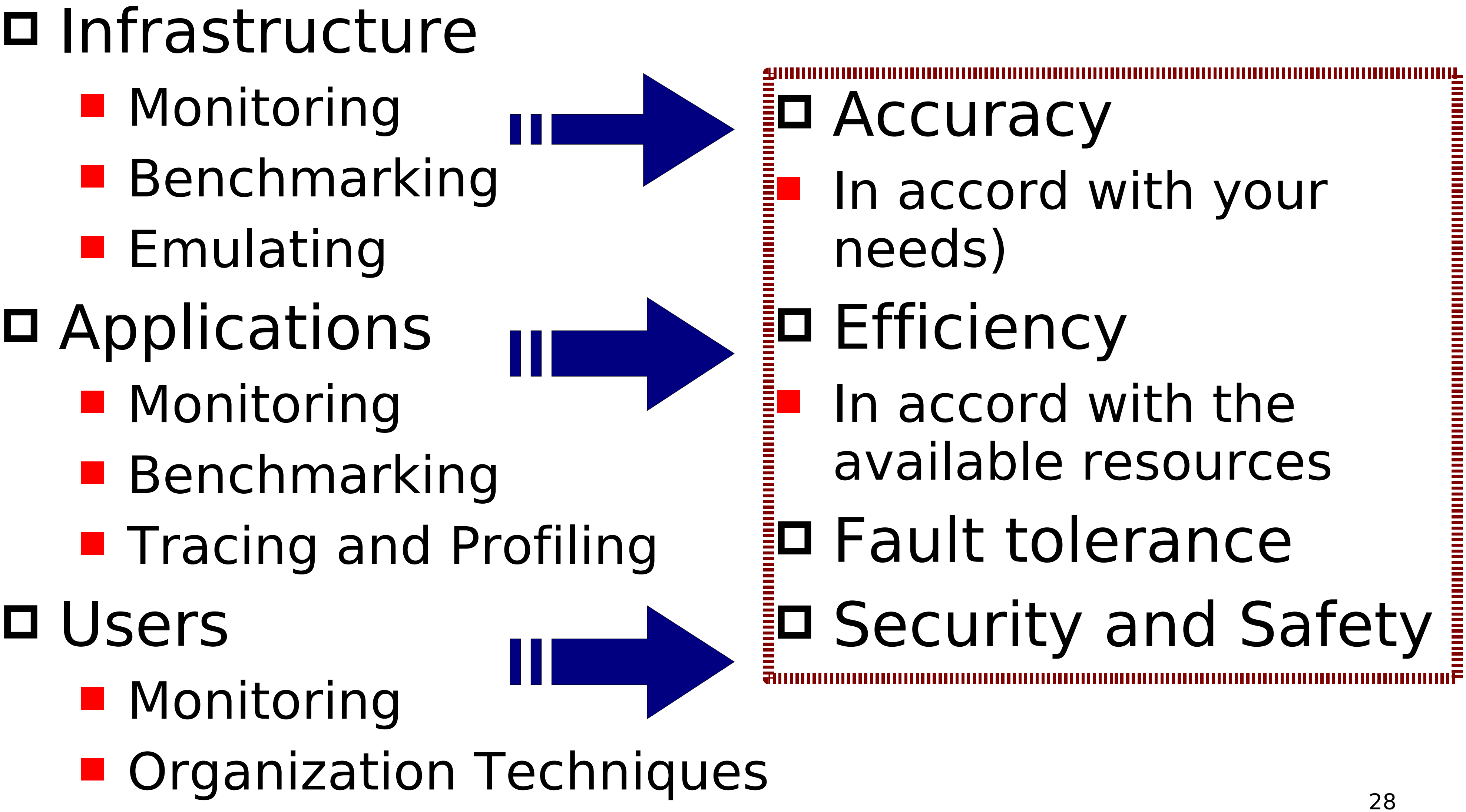
	Event count	Tracing	Sampling
Resolution	Exact count	Detailed info	Statistical summary
Overhead	Low	High	Constant
Perturbation	~ #events	High	Fixed

From Measuring Computer Performance: A Practitioner's Guide, David J. Lilja 2004

Grid Computing Case

- Distributed environments are too complex to model.
  - Grid Computing is a distributed system
- Grid Computing is heterogeneous, dynamic, pervasive...
  - HPC Utilization (sometimes HTC use too)
  - Infrastructure Services
  - Virtual Communities
    - Different users
    - Different goals
  - Different architectures and dynamic behaviors

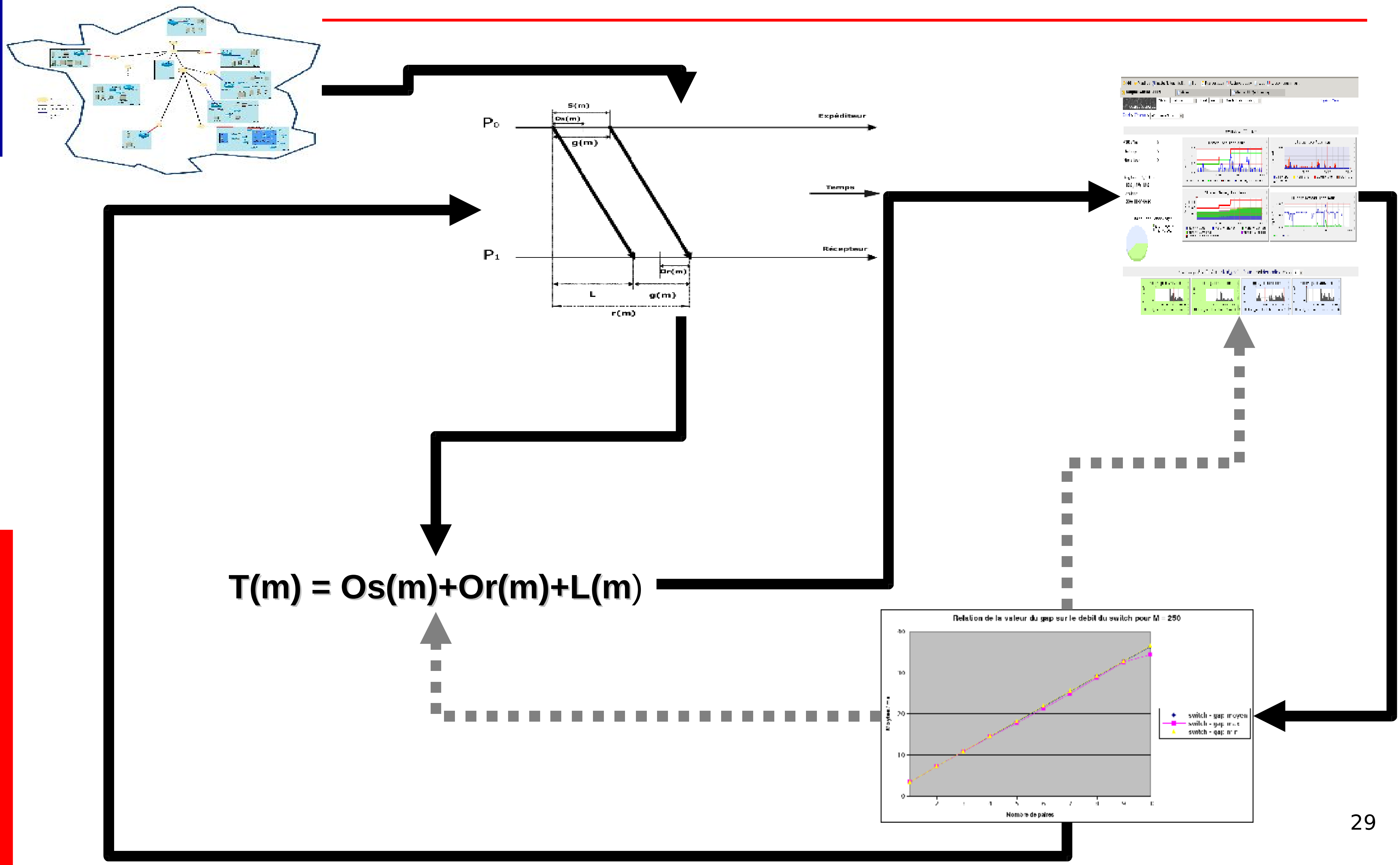
What Evaluate?



- Infrastructure
  - Monitoring
  - Benchmarking
  - Emulating
- Applications
  - Monitoring
  - Benchmarking
  - Tracing and Profiling
- Users
  - Monitoring
  - Organization Techniques

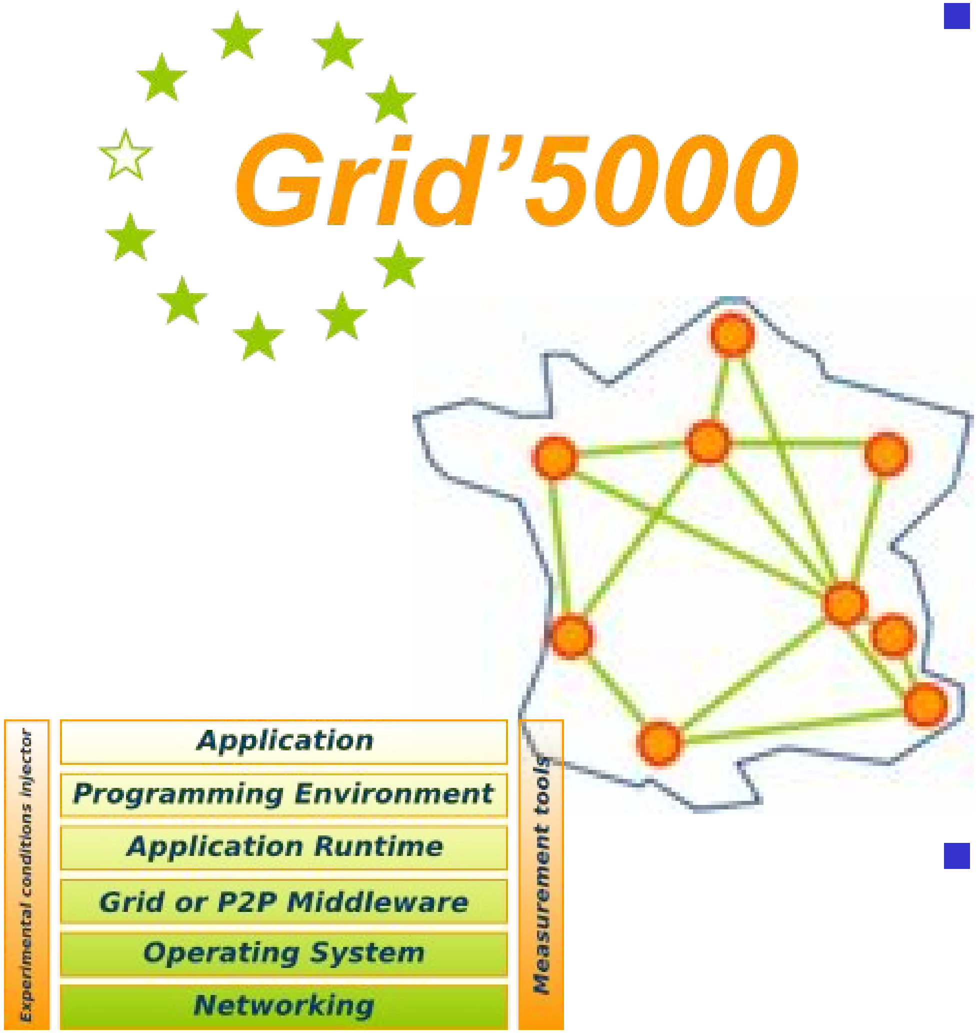
- Accuracy
  - In accord with your needs)
- Efficiency
  - In accord with the available resources
- Fault tolerance
- Security and Safety

A Case: A Grid'5000 Example



$$T(m) = Os(m)+Or(m)+L(m)$$

Grid'5000 (Today Aladdin-Grid'5000)



Experimental conditions injector

Application

Programming Environment

Application Runtime

Grid or P2P Middleware

Operating System

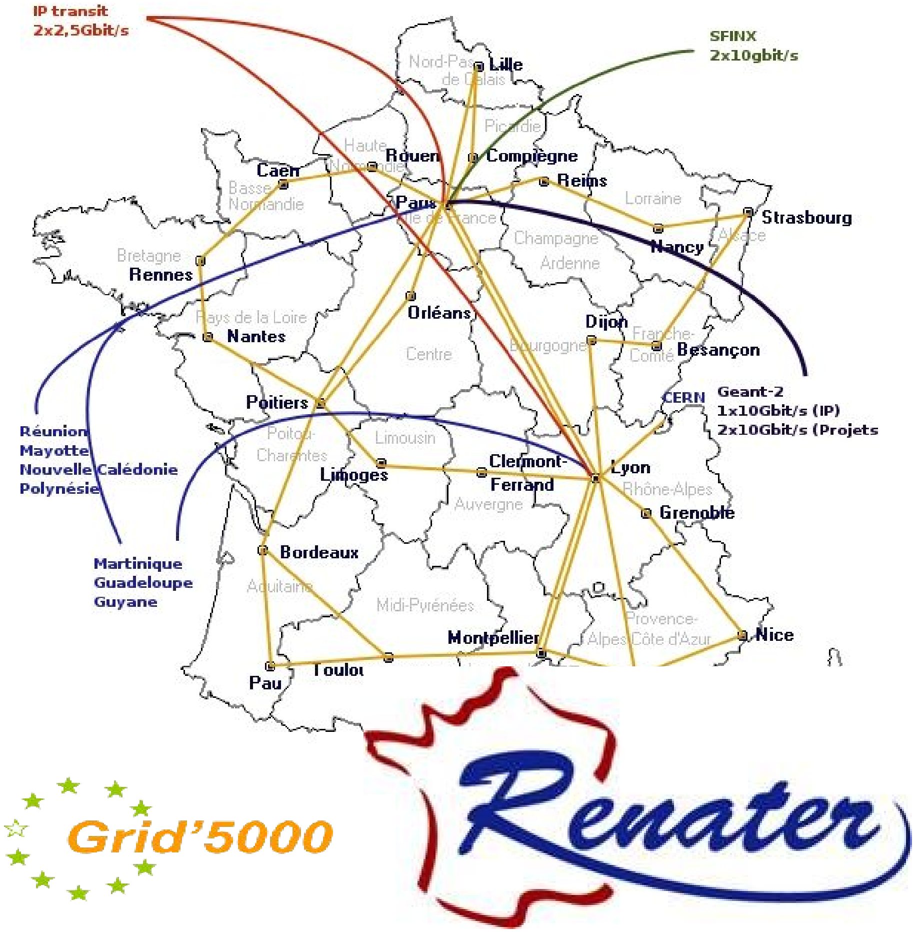
Networking

Measurement tools

- Grid'5000 is a research effort developping a large scale nation wide infrastructure for Grid research in France.

  Grid'5000 is highly reconfigurable, controlable and monitorable experimental Grid platform gathering 9 sites geographically distributed in France.
- Grid'5000 interactuate with external sites: Netherlands (DAS-3), Japan (Naregi) and Brazil (UFRGS)

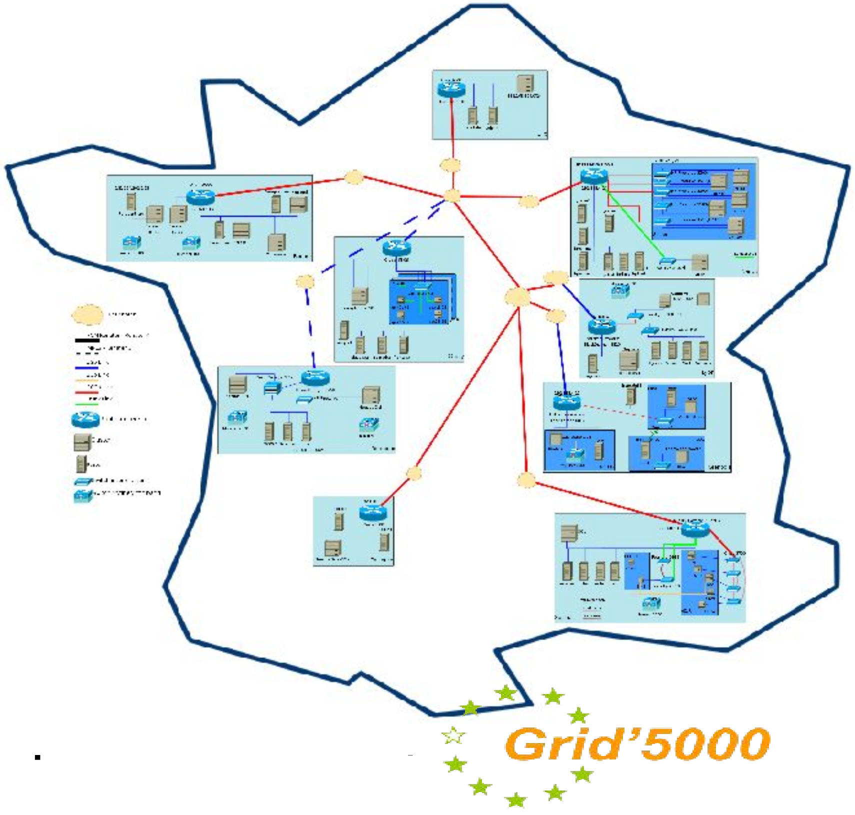
Grid'5000 Interconnexion



- 3 Levels:
  - IntraCluster
    - Myrinet
    - GigaEthernet / Infiniband
  - Grid
    - Giga Ethernet (Best Case 10GB/s, Worst Case: 1GB/s)
  - ExtraGrid
    - External links (~1GB/s)

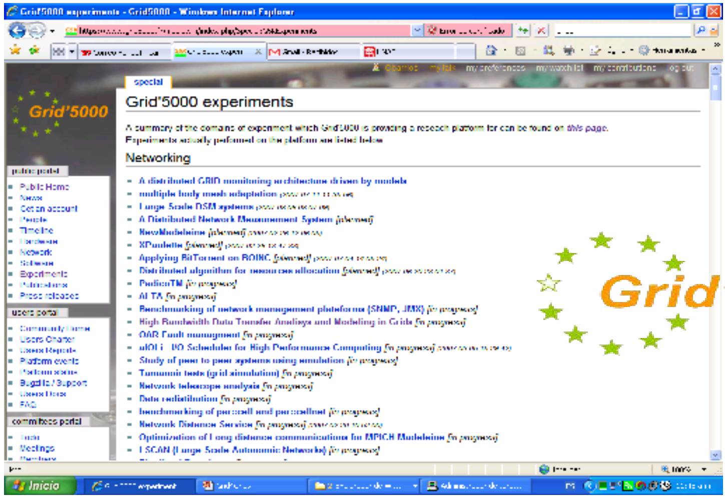
Heterogenity

- 9 National Sites:
  - Bordeaux, Grenoble, Lille, Lyon, Nancy, Orsay, Rennes, Sophia-Anipolis, Toulouse
  - 18 clusters
  - Processor Families (4792 Cores
    - AMD Opteron (78%) (Now)
    - Intel Xeon EM64T (22%) (Now)
    - Intel Xeon IA32 (Past)
    - Intel Itanium -2 (Past)
    - IBM Power PC (Past)
  - Software Resources:
    - A General Scheduler (OAR)
    - A General Deployer (Kadepl
    - Middlewares (Diet)
    - Monitoring tools (Nagios, Ka
    - Etc...



Users

- ~ 350 Experiments (Mainly in cyberstructures and e-Science)
- ~ 200 Users (Scientifics, enginners in different countries)
- Technical Committee (Engineers)
  - Developer/Support Team (Distributed in different sites ~30)
- Scientific Committee (~15)
  - Thierry Priol (INRIA – General Director)
  - Franck Cappello (INRIA – Scienfic Director)
  - David Margery (INRIA – Technical Director)



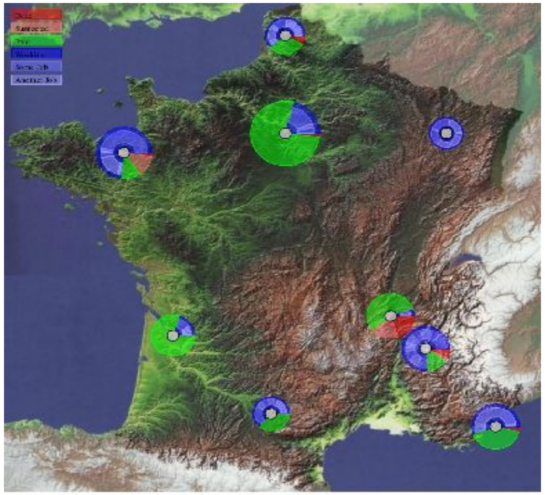
Grid'5000 experiments

A summary of the domains of experiment which Grid'5000 is providing a research platform for can be found on this page.
Experiments actually performed on the platform are listed below

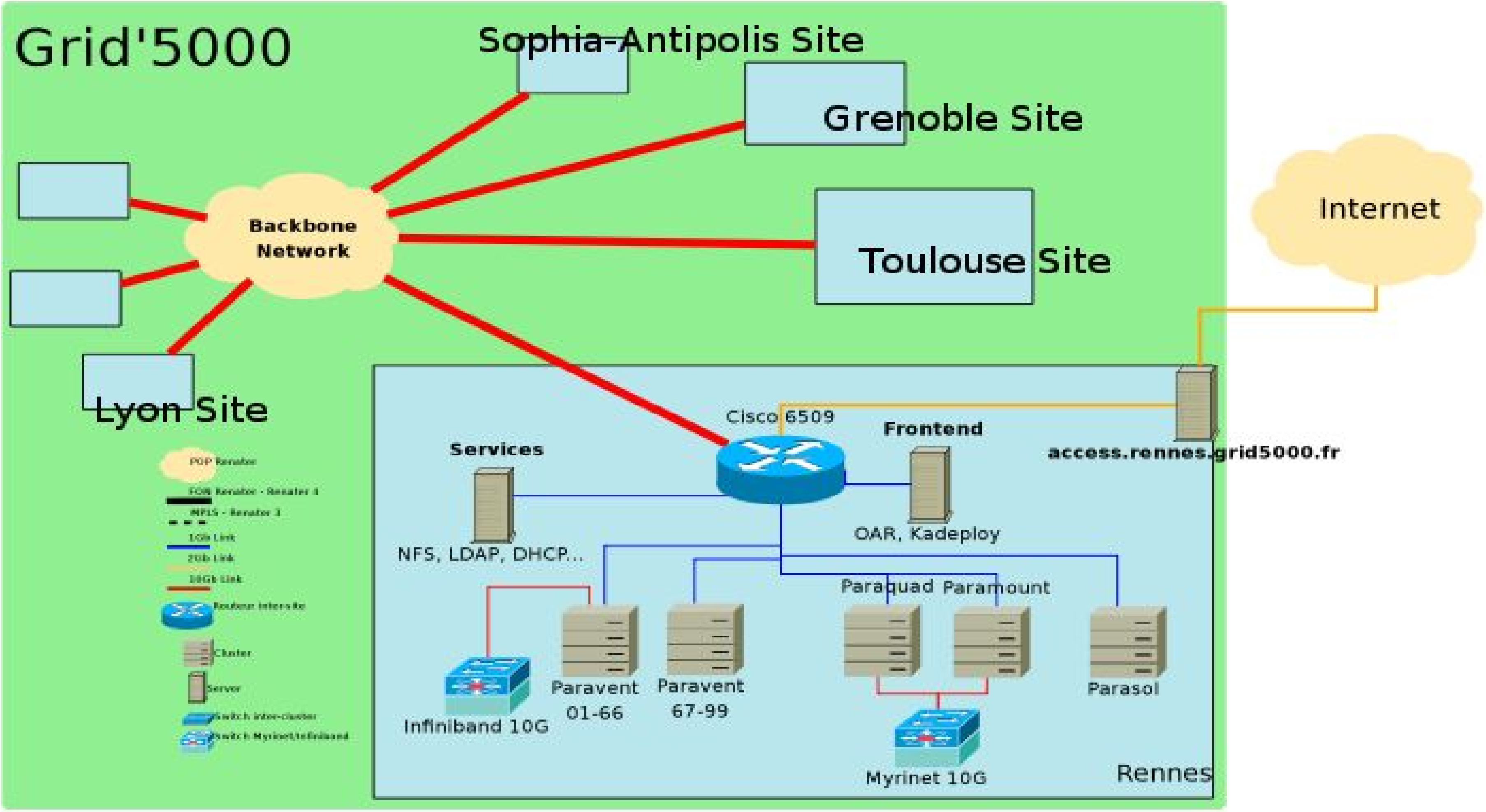
Networking

- A distributed GRID monitoring architecture driven by models
- multiple body mesh adaptation
- Large Scale DSM systems
- A Distributed Network Measurement System [planned]
- NewMadeleine [planned]
- XPaulette [planned]
- Applying BitTorrent on BOINC [planned]
- Distributed algorithm for resources allocation [planned]
- PadicoTM [in progress]
- ALTA [in progress]
- Benchmarking of network management plateforms (SNMP, JMX) [in progress]
- High Bandwidth Data Transfer Analisys and Modeling in Grids [in progress]
- OAR Fault management [in progress]
- aIOLi - I/O Scheduler for High Performance Computing [in progress]
- Study of peer to peer systems using emulation [in progress]
- Tomonori tests (grid simulation) [in progress]
- Network telescope analysis [in progress]
- Data redistribution [in progress]
- benchmarking of parcell and parcellnet [in progress]
- Network Distance Service [in progress]
- Optimization of Long distance communications for MPICH Madeleine [in progress]
- LSCAN (Large Scale Autonomic Networks) [in progress]

Grid’5000



Topology Site



Grid'5000

From Introduction to Grid'5000(c) 2008

Benchmark and Workload

- Benchmark:
  - Result of running a computer program, or a set of programs, in order to assess the relative performance of an object by running a number of standard tests and trials against it *(wikipedia)*
- Workload:
  - Quantified effort
    - Adition Instructions
    - Hybrid Instructions
    - Syntetics Programs
    - Kernels
    - Benchmark Applications

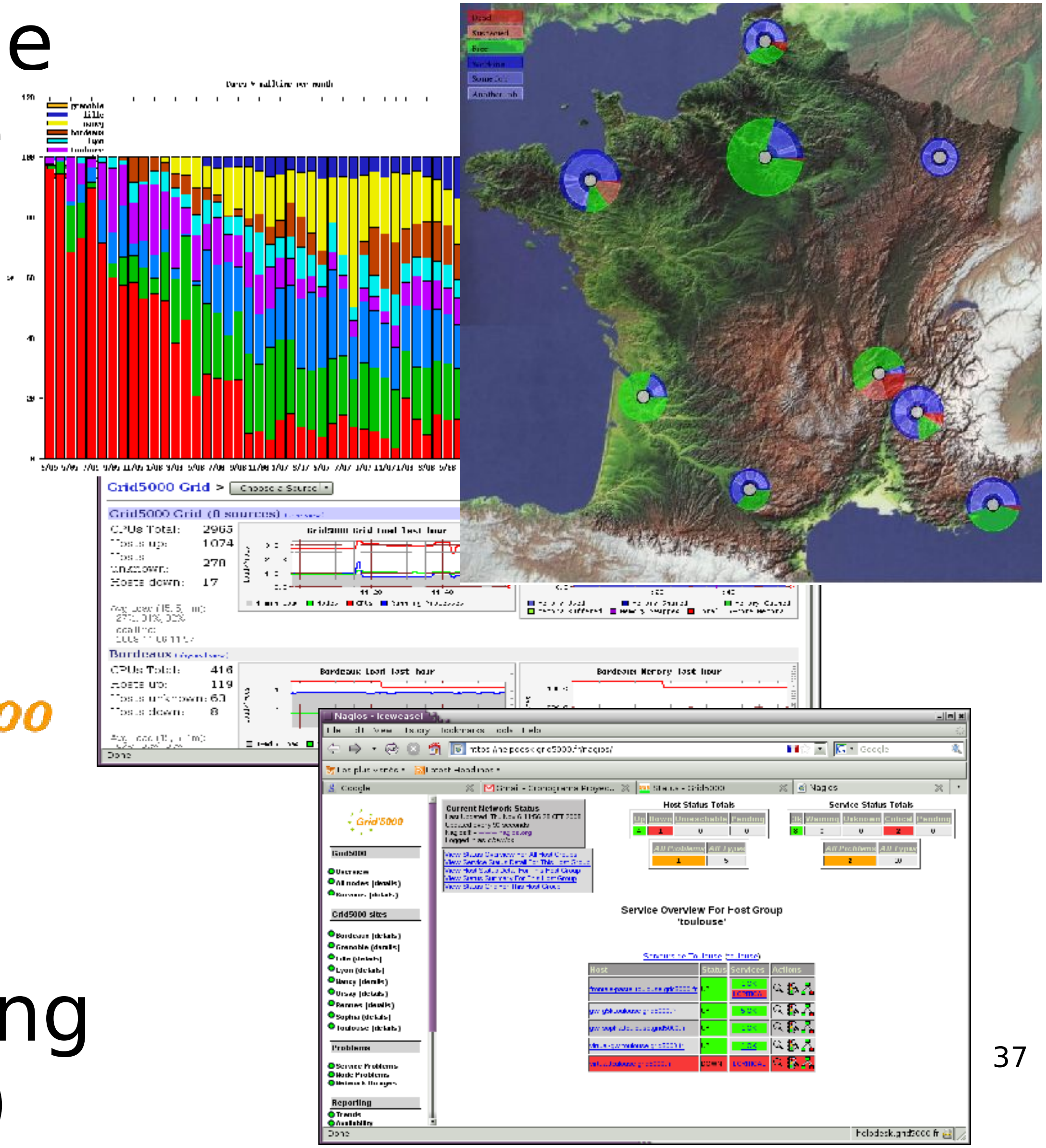
Examples of Benchmarks used in Grid'5000

- Sieve
  - First N- prime numbers
  - Multiprocessor comparaison
- Debit-Credit Benchmark
  - Representaiton fo a bank network
  - Comparaison Standar to transaction process
- SPEC Benchmark Suite
  - Systems Performance Evaluation Cooperative (SPEC): 10 Benchmark Tools to evaluate scientific and enginnering applications.
- MagPIE Benchmark Tools
- NWS Benchkmark Tools
  - Communication Performance in Network Infrastructures

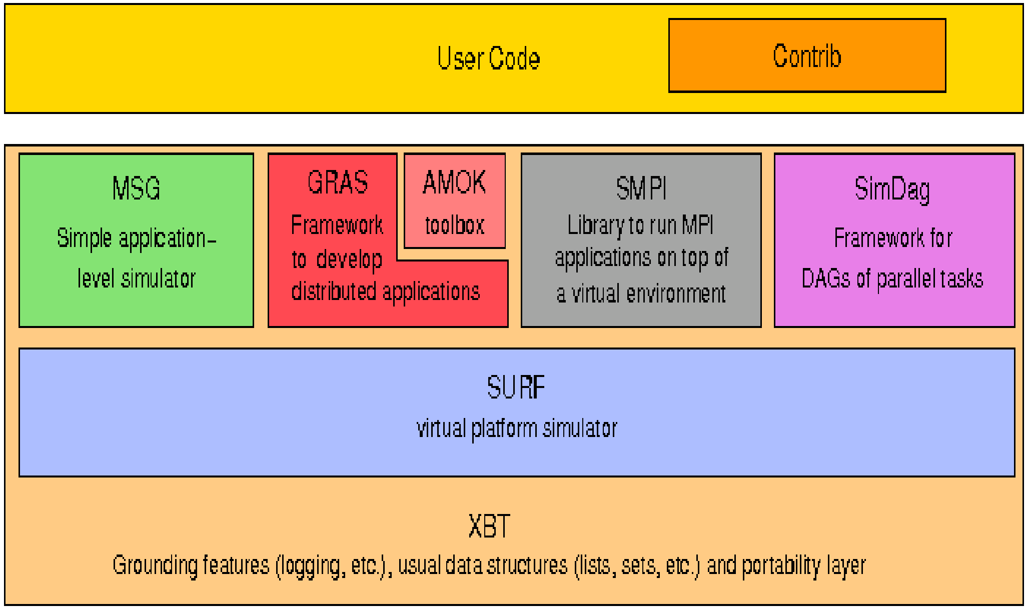
Monitors in Grid'5000

- Visualization of the State of the Syste
  - Invasives (Add workload to the system)
  - Non-Invasives
- Ganglia
- MoniKa
- Nagios
- Kaspied
- Pajé (Allows Tracing and Profiling also)

Grid'5000



Simulators: SIMGRID


User Code
Contrib
MSG
Simple application-level simulator
GRAS
Framework to develop distributed applications
AMOK
toolbox
SMPI
Library to run MPI applications on top of a virtual environment
SimDag
Framework for DAGs of parallel tasks
SURF
virtual platform simulator
XBT
Grounding features (logging, etc.), usual data structures (lists, sets, etc.) and portability layer

http://simgrid.gforge.inria.fr/

- SimGrid is a toolkit that provides core functionalities for the simulation of distributed applications in heterogeneous distributed environments.
  - Network of Workstations
  - Grid Computing Platforms

The Critical Behaviors to Evaluate

- Data Transfer
  - High Bandwidth Data Transfer implies heterogenity, dynamicity, concurrence and so on.
- File System Sensibility
  - I/O Sensibility
- Adaptation and Effectiveness
- Scalability
- Fault Tolerance
- Security
- Energy Consumption
- ... and the « Human invervention »
- Processing is critical but...

Open Questions

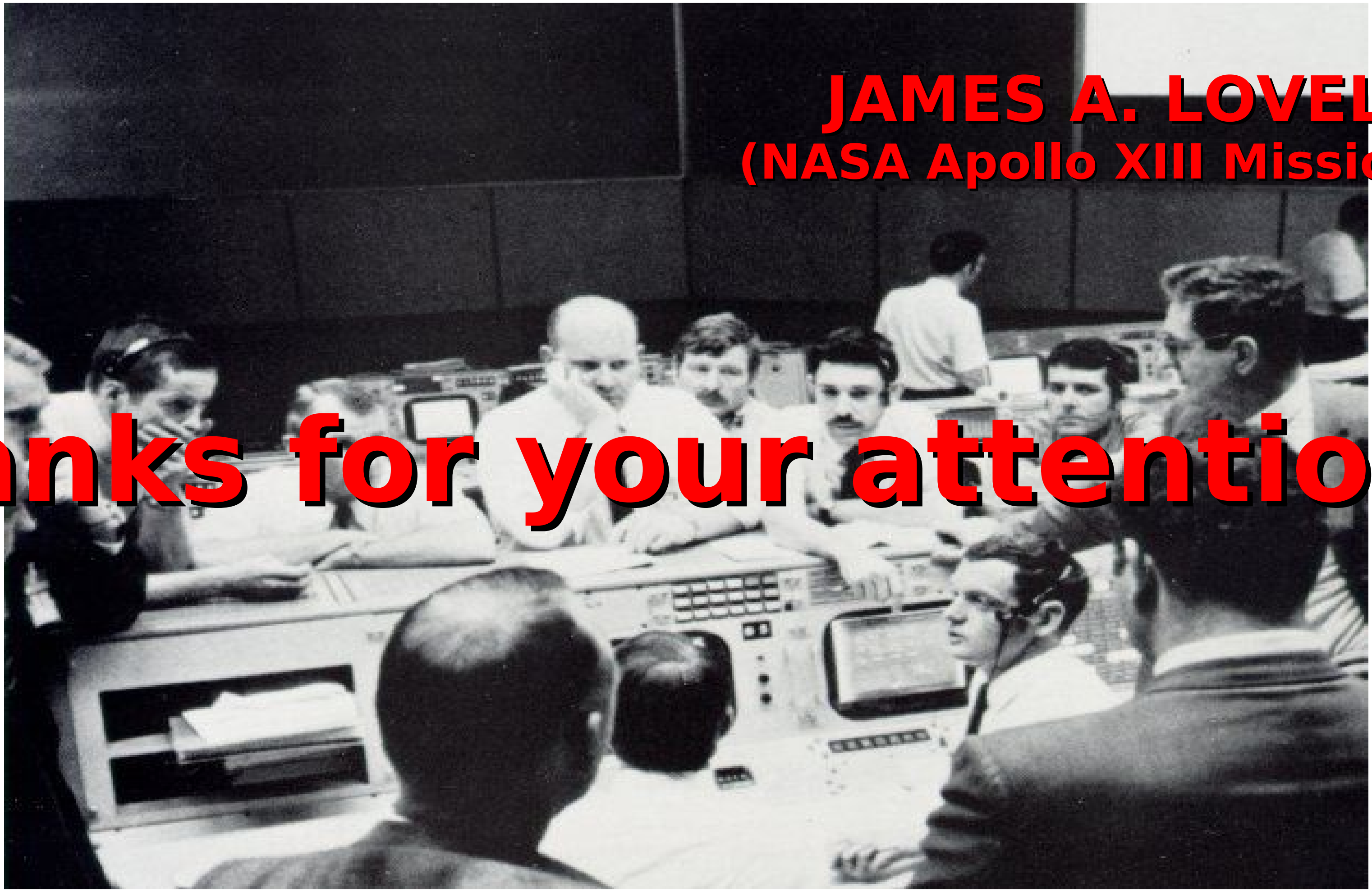
- Performance Evaluation of Systems is REALLY important… then,
  - How to increase the level of accuracy of performance models?

    Of course, it's necessary the definition of metrics and build tools.
  - How to implementate realistic models to performance evaluation?

    On live process (i.e. Production Grid Computing)
  - How to integrate the needs of scientifics and enginner/computer science scientist in performance evaluation?

    Typical example: Program adaptation from clusters to grids.

"Houston, We've Had a Problem"



JAMES A. LOVELL
(NASA Apollo XIII Mission)

Thanks for your attention!!

http://www-id.imag.fr/~barrios