# Grid Computing


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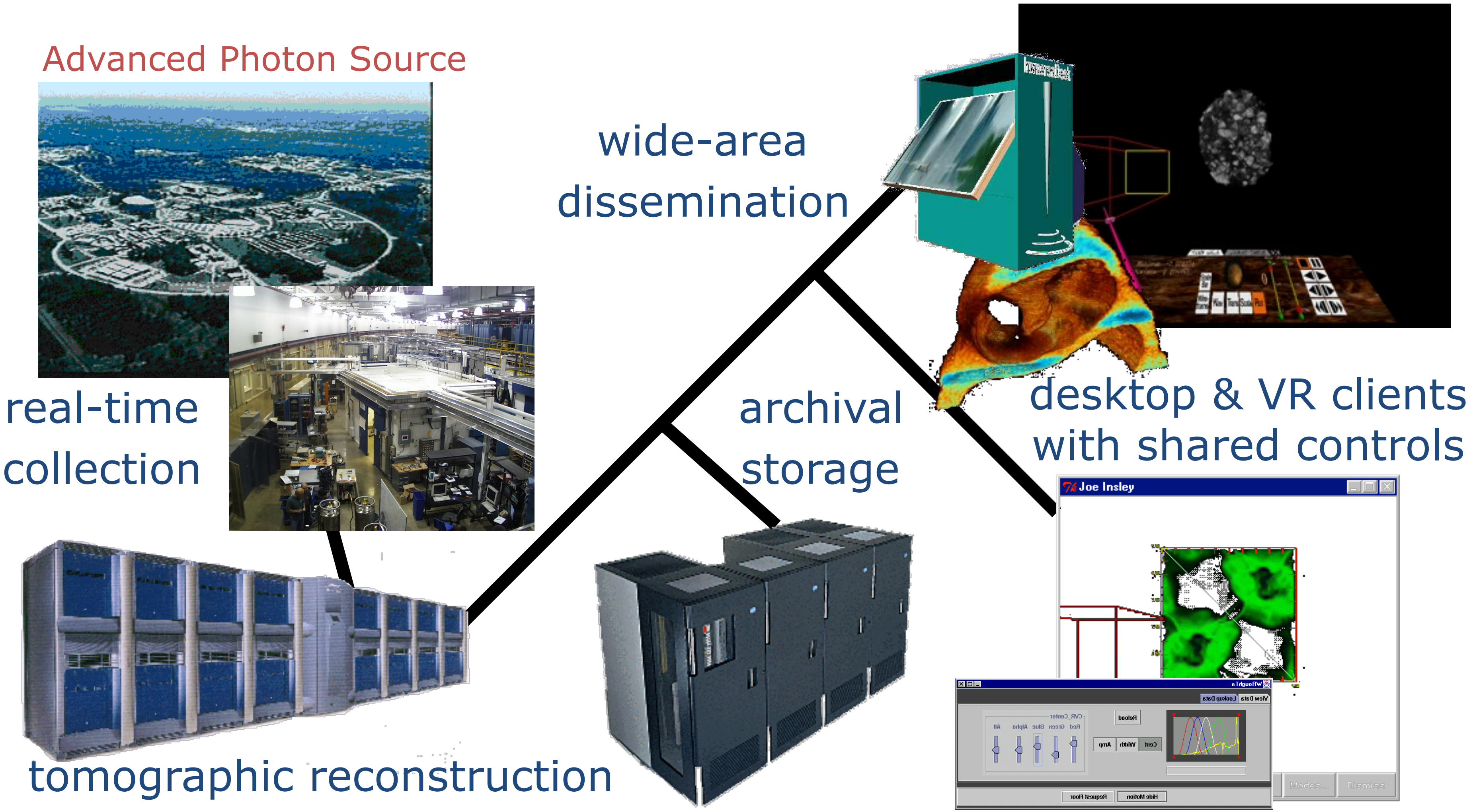
# outline

- e-Science
- Grid approach
- Grid computing
- Programming models for the Grid
- Grid-middleware
- Web Services
- Open Grid Service Architecture (OGSA)

# Doing Science in the 21th century

- Nowadays Scientific Applications are
  - CPU intensive
  - Produce/process Huge sets of Data
  - Requires access to *geographically distributed* and *expensive* instruments

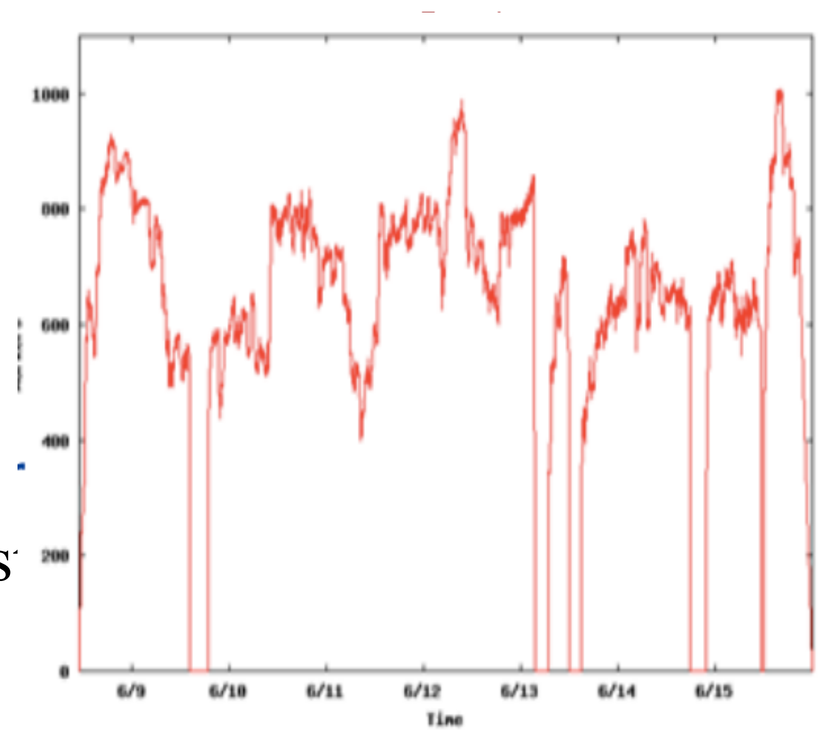
# Online Access to Scientific Instruments




DOE X-ray grand challenge: ANL, USC/ISI, NIST, U.Chicago

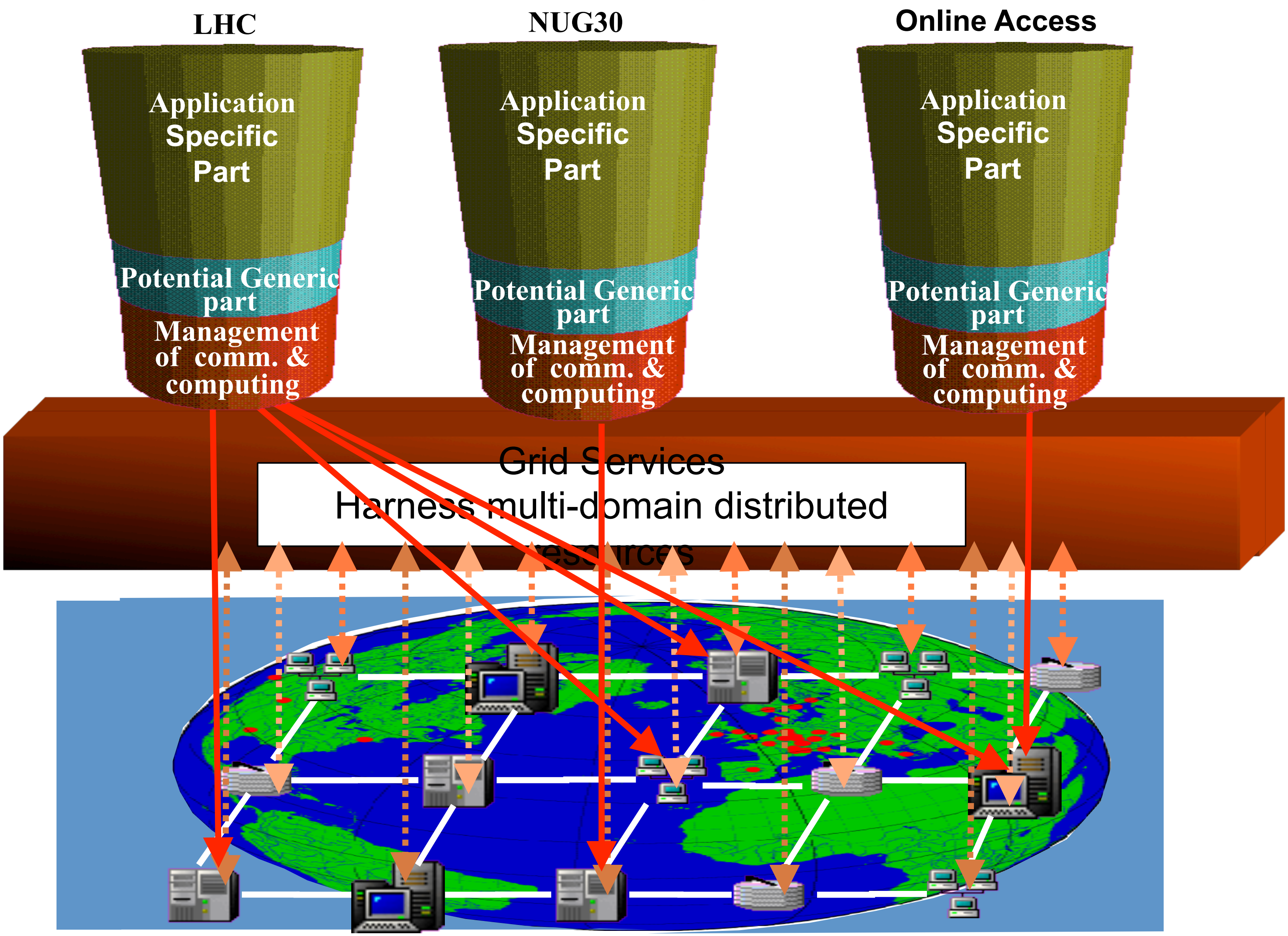
# CPU intensive Science: Optimization problem NUG30

- The problem, a quadratic assignment problem (QAP) known as NUG30
  - given a set of n locations and n facilities, the goal is to assign each facility to a location.
  - There are **n!** possible assignments
- NUG30 proposed in 1968 as a tes of computer capabilities, but remained unsolved because of its great complexity.

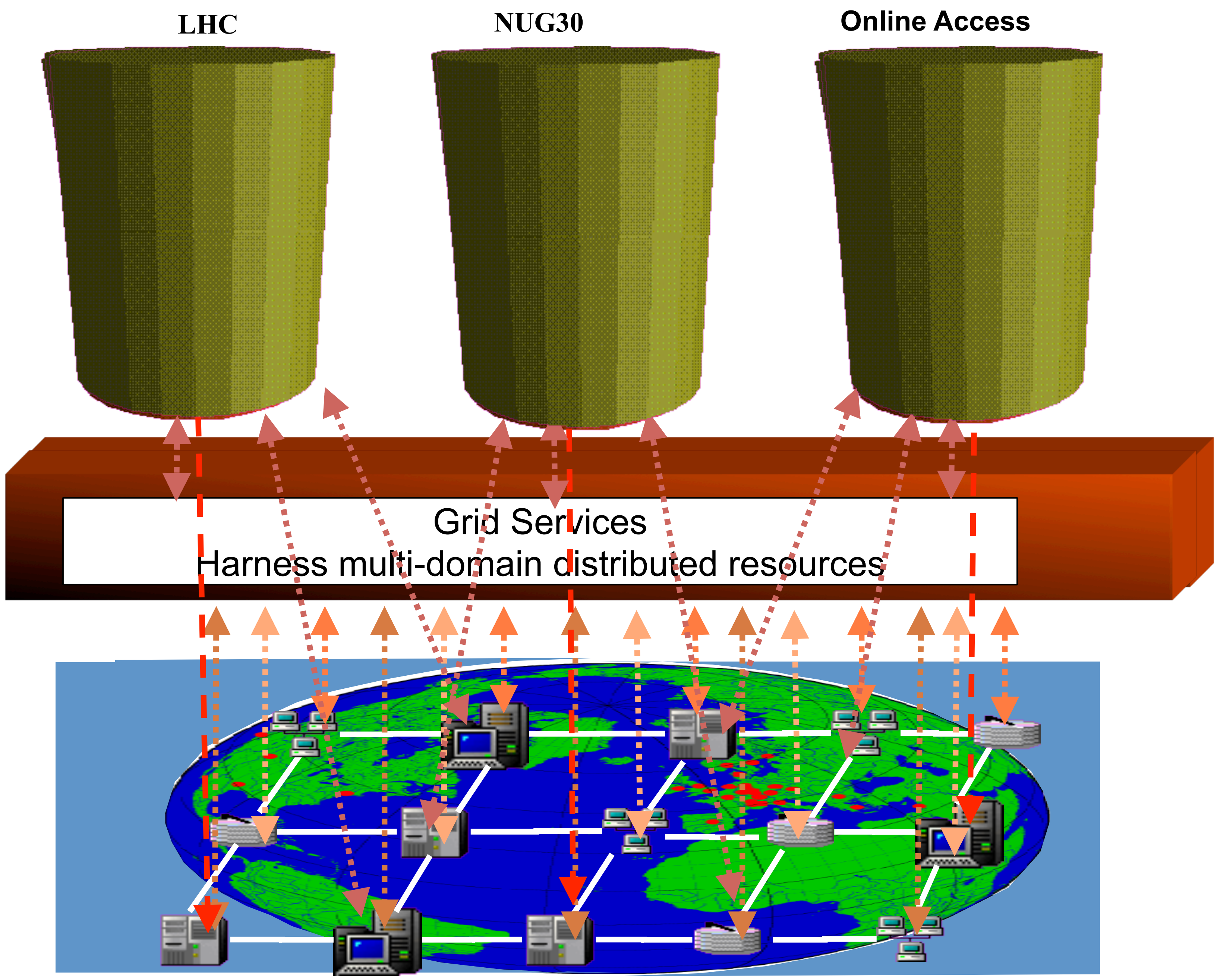



**Nug30 Quadratic Assignment Problem Solved by 1,000** https://scout.wisc.edu/archives/r7125

# To solve these problems?




"VL-e project" UvA


LHC
NUG30
Online Access
Grid Services
Harness multi-domain distributed resources

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# The Grid Problem

- Flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources

- Enable communities (“Virtual Organizations”) to share geographically distributed resources as they pursue common goals -- *assuming the absence* of : central location, central control, existing trust relationships.

From the Grid tutorials available at : http:.//www.globus.org

# Some Definitions of the Grid?

“A Computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities”. Karl Kesselman & Ian Foster.

“The overall motivation for Grids is to enable the routine interactions of resources geographically and organizationally dispersed to facilitate Large-scale Science and engineering” The Vision for a DOE Science Grid, William Johnston, Lawrence Berkeley Nat. Lab.

“Making possible a shared large wide-area Computational infrastructure a concept which has been named the Grid” Peter Dinda, Gorgia Tech, 2001.

# What people think of the Grid?

"The Grid is the next evolutionary step for supercomputing."
Jim Gray, Microsoft Research

"The Grid represents the first wave of Computing in the well-connected world into which we are heading"
David Culler, University of California, Berkeley

"It is clear that distributed information processing will lie at the heart of many of the technology of the 21st century"
William J. Feiereisen, Program Manager High Performance Computing and Communications, NASA

etc.

# Misuse of the term Grid?

"the term Grid has been conflated, at least in the popular perception, to embrace everything from advanced networking to artificial intelligence".

"One may wonder whether the term has any real substance and meaning"

From "The Anatomy of the Grid: Enabling Scalable Virtual Organizations" Foster et al

# A more realistic point of view

- “ The biggest hurdle for the Grid right now is that there is a lot of really hard work to do.

  There has been considerable underestimation of the level of difficulty of the problems that one must address in order to deploy the most sophisticated vision of the grid”

  Prof. Francine Berman, UCSD, Director NPACI and SDSC (July 2002)

The promise of the Grid has been not been oversold, but the difficulty of developing the requisite Grid infrastructure has been underestimated

“BAEgrid”, Alan Gould BAE System, Advanced Technology Center, London 2004

# The real Grid target

- A Grid is a system that is able to
  - Coordinate resources
    - not subject to centralized control
  - Use standard, open, general-purpose protocols and interfaces
  - Deliver nontrivial qualities of service.

"Ian Foster's 3 point checklist"

# Coordinated Sharing

- The sharing is controlled by the providers and consumers
  - what is shared?
  - who is allowed to share?
  - and the conditions under which sharing occurs?
- sharing relationships
  - client-server, peer-to-peer, and brokered
  - access control: fine AC, delegation, local/global policies

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# What is Grid Computing

- Grid computing is the use of hundreds, thousands, or millions of geographically and organizationally disperse and diverse resources to solve:

  ➔ problems that require more computing power than is available from a single machine or from a local area distributed system

# Potential Grid Application

- An application which requires the grid solution is likely distributed (Distributed Computing) and fit in one of the following paradigms:
  - High throughput Computing
  - High performance Computing

Grid computing will be mainly needed for large-scale, high-performance computing.

# Distributed Computing

- Distributed computing is a programming model in which processing occurs in many geographically distributed places.
  - Processing can occur wherever it makes the most sense, whether that is on a server, Web site, personal computer, etc.
- Distributed computing and grid computing either
  - overlap or distributed computing is a subset of grid computing

From "The Anatomy of the Grid: Enabling Scalable Virtual Organizations" Foster et al

# High Throughput Computing

- HTC employs large amounts of computing power for very lengthy periods
  - HTC is needed for doing sensitivity analyses, parametric studies or simulations to establish statistical confidence.
- The features of HTC are
  - Availability of computing power for a long period of time
  - Efficient fault tolerance mechanism
- The key to HTC in grids
  - Efficiently harness the use of all available resources across organizations.

# High Performance Computing

- HPC brings enormous amounts of computing power to bear over relatively short periods of time.
  - HPC is needed for decision-support or applications under sharp time-constraint, such as weather modeling
- HPC applications are:
  - Large in scale and complex in structure.
  - Real time requirements.
  - Ultimately must run on more than one type of HPC system.

# HPC/HTC requirements

- HPC/HTC requires a balance of computation and communication among all resources involved.
  - Managing computation,
  - communication,
  - data locality

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# Programming Model for the grid

- To achieve petaflop rates on tightly/loosely coupled grid clusters, applications will have to allow:
  - extremely large granularity or produce massive parallelism such that high latencies can be tolerated.
- This type of parallelism, and the performance delivered by it in a heterogeneous environment, is
  - currently manageable by hand-coded applications

# Programming Model for the grid

- A programming model can be presented in different forms: a language, a library API, or a tool with extensible functionality.

- The successful programming model will
  - enable both high-performance and the flexible composition and management of resources.
  - influence the entire software lifecycle: design, implementation, debugging, operation, maintenance, etc.
  - facilitate the effective use of all manner of development tools, e.g., compilers, debuggers, performance monitors, etc

# Grid Programming Issues

- Portability, Interoperability, and Adaptability
- Discovery
- Performance
- Fault Tolerance
- Security

# Programming models

- Shared-state models
- Message passing models
- RPC and RMI models
- Hybrid Models
- Peer to Peer Models
- Web Service Models
- ...

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# Grid Middleware Definition

- Architecture identifies the fundamental system components, specifies purpose and function of these components, and indicates how these components interact with each other.
- Grid architecture is a protocol architecture, with protocols defining the basic mechanisms by which VO users and resources negotiate, establish, manage and exploit sharing relationships.
- Grid architecture is also a service standard-based open architecture that facilitates extensibility, interoperability, portability and code sharing.

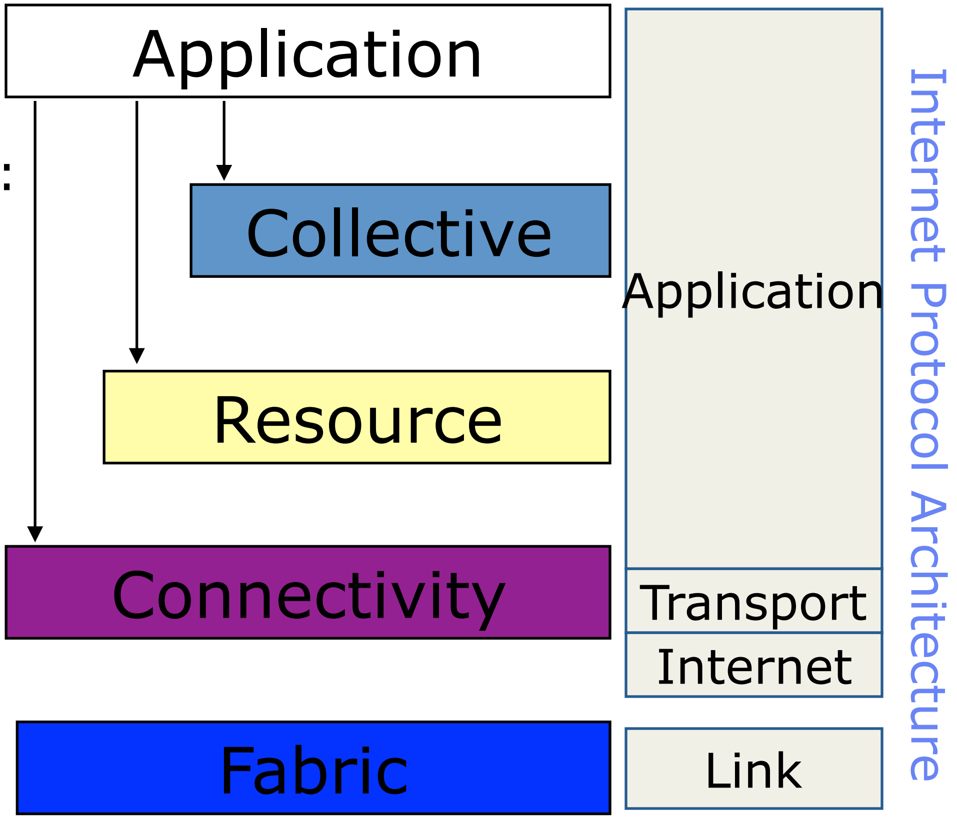
# Architecture

"Coordinating multiple resources": ubiquitous infrastructure services, app-specific distributed services

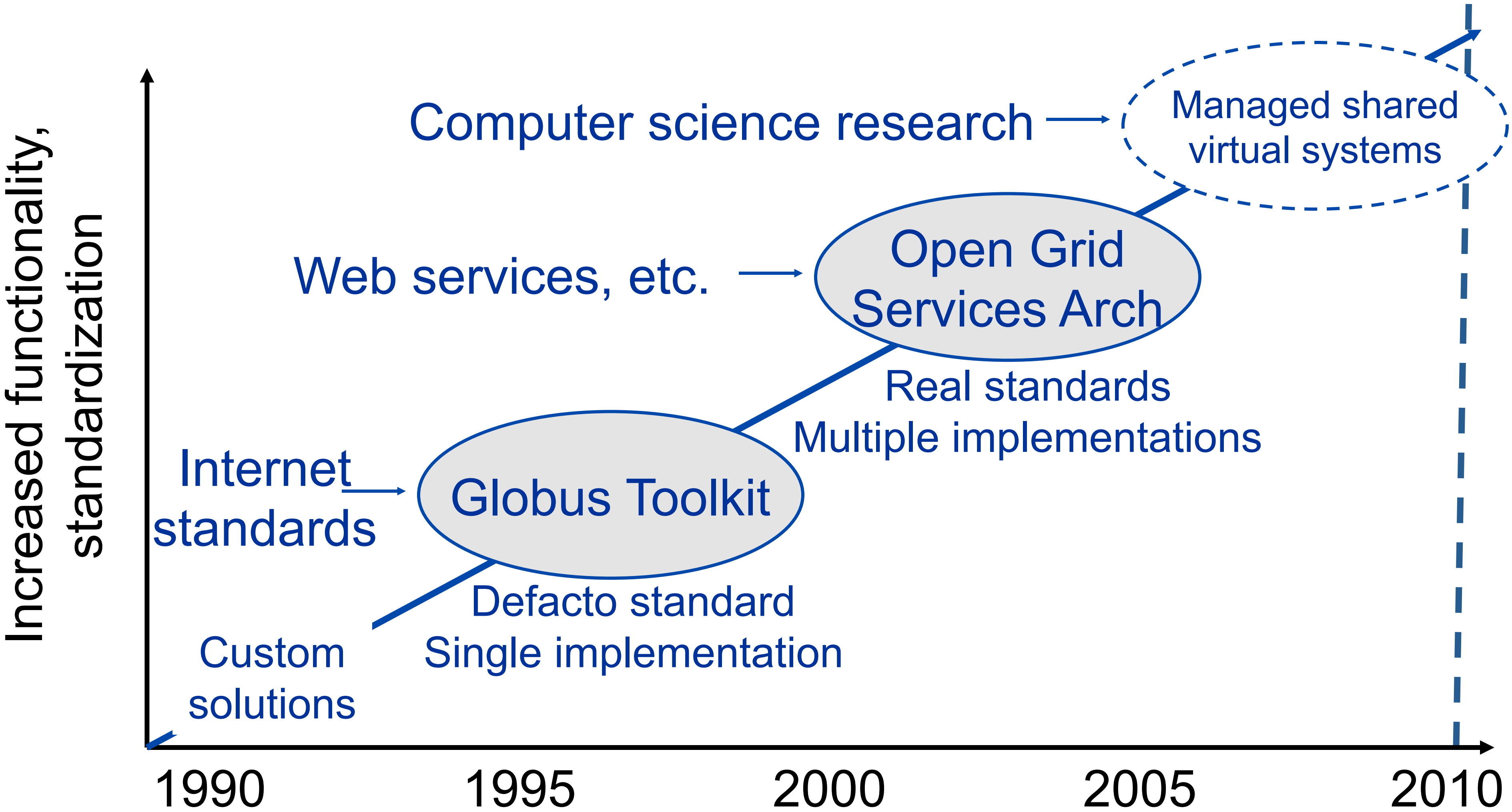
"Sharing single resources": negotiating access, controlling use

"Talking to things": communication (Internet protocols) & security

"Controlling things locally": Access to, & control of resources



# Emergence of Open Grid Standards




"Grid Computing and Scaling Up the Internet" I. Foster, IPv6 Forum, an

# Examples of Grid Middleware

- Globus Toolkit (GT4.X) now (GT5.X)
  - www.globus.org
- Legion/Avaki
  - http://www.avaki.com/
  - http://legion.virginia.edu/
- Grid Sun engine
  - http://www.sun.com/service/sungrid/overview.jsp
- Unicore
  - http://www.unicore.org

# The Grid Middleware

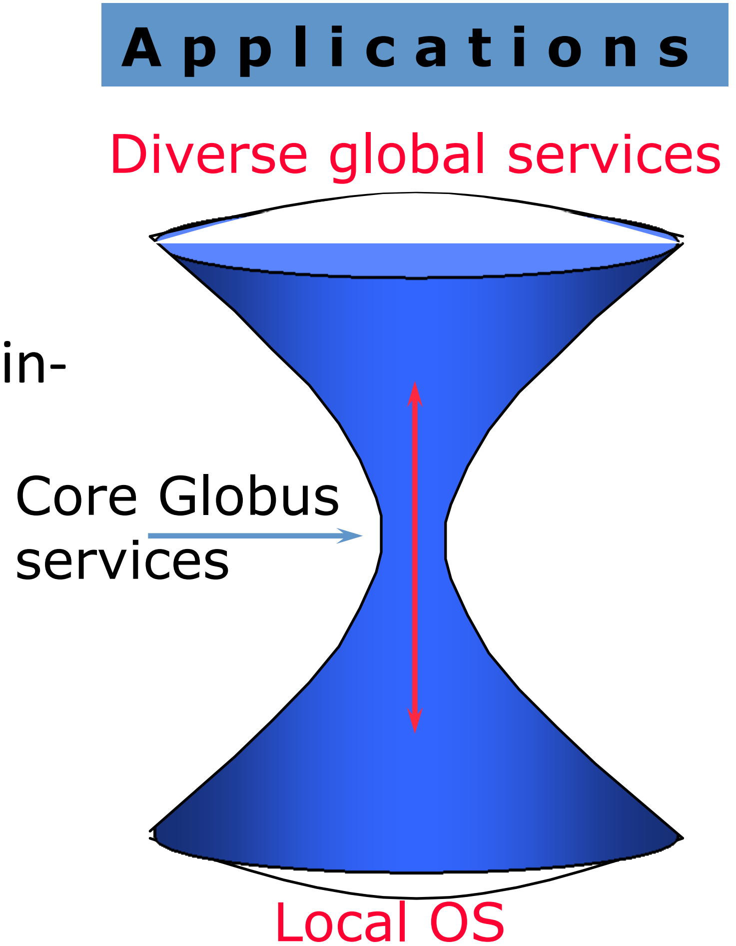
- Software toolkit addressing key technical areas
  - Offer a modular "bag of technologies"
  - Enable incremental development of grid-enabled tools and applications
  - Define and standardize grid protocols and APIs

- Focus is on inter-domain issues, not clustering
  - Collaborative resource use spanning multiple organizations
  - Integrates cleanly with intra-domain services
  - Creates a "collective" service layer

"Basics Globus Toolkit™ Developer Tutorial" Globus Team, 2003

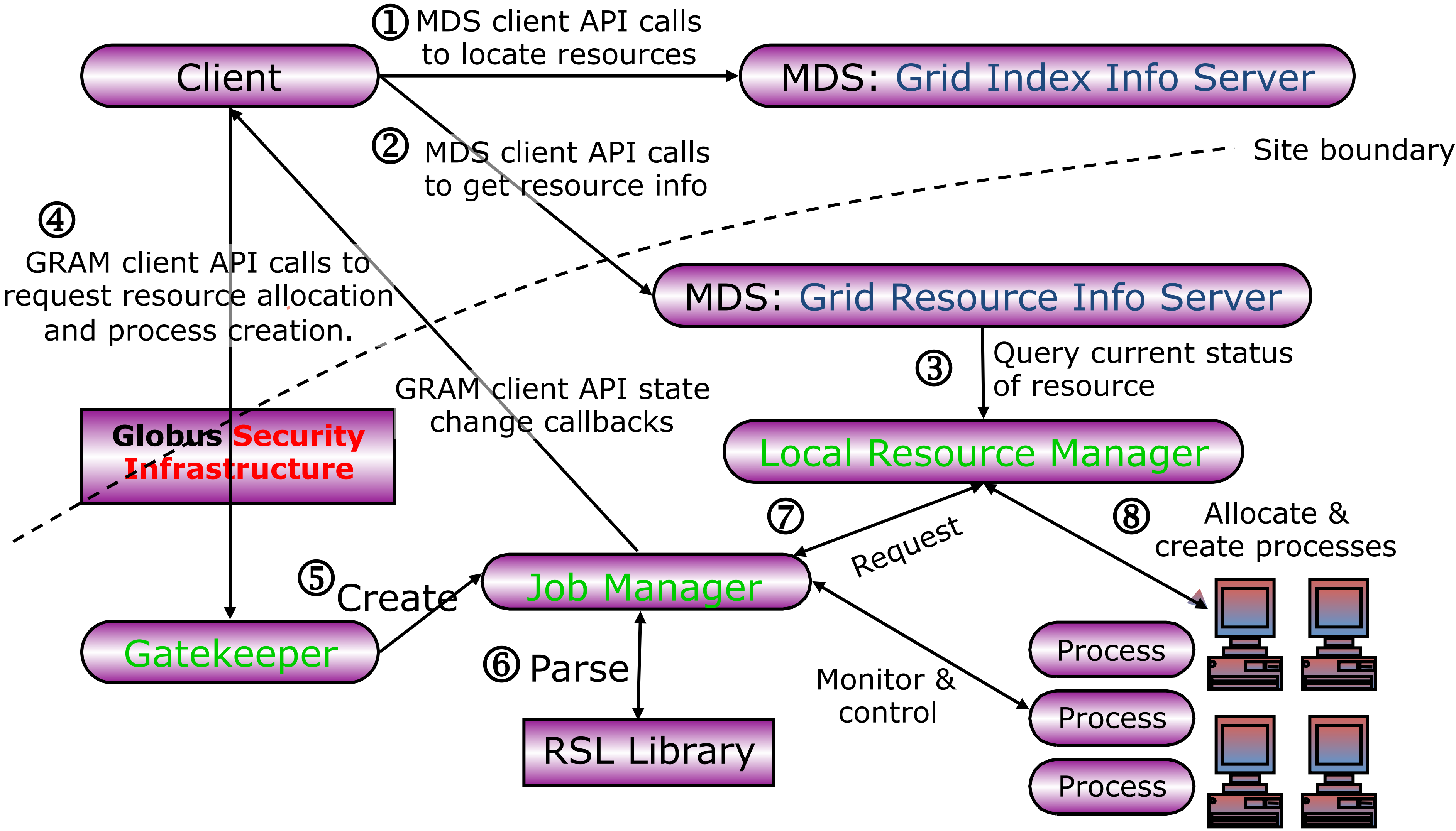
# Globus Approach

- Focus on architecture issues
  - Provide implementations of grid protocols and APIs as basic infrastructure
  - Use to construct high-level, domain-specific solutions
- Design principles
  - Keep participation cost low
  - Enable local control
  - Support for adaptation




"Basics Globus Toolkit™ Developer Tutorial" Globus Team, 2003

# Globus Toolkit 2.0 Components



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# Web Services

- Increasingly popular standards-based framework for accessing network applications
  - W3C standardization; Microsoft, IBM, Sun, others
- WSDL: Web Services Description Language
  - Interface Definition Language for Web services
- SOAP: Simple Object Access Protocol
  - XML-based RPC protocol; common WSDL target
- WS-Inspection
  - Conventions for locating service descriptions
- UDDI: Universal Desc., Discovery, & Integration
  - Directory for Web services

# The Need to Support Transient Service Instances

- "Web services" address discovery & invocation of persistent services
  - Interface to persistent state of entire enterprise
- In Grids, must also support transient service instances, created/destroyed dynamically
  - Interfaces to the states of distributed activities
  - E.g. workflow, video conf., dist. data analysis
- Significant implications for how services are managed, named, discovered, and used
  - In fact, much of the work is concerned with the management of service instances

"Globus Toolkit Futures: An Open Grid Services Architecture" Ian Foster et al.
Globus Tutorial, Argonne National Laboratory, January 29, 2002

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# Open Grid Services Architecture

- Service orientation to virtualize resources
- From Web services:
  - Standard interface definition mechanisms: multiple protocol bindings, multiple implementations, local/remote transparency
- Building on Globus Toolkit:
  - Grid service: semantics for service interactions
  - Management of transient instances (& state)
  - Factory, Registry, Discovery, other services
  - Reliable and secure transport
- Multiple hosting targets: J2EE, .NET, …

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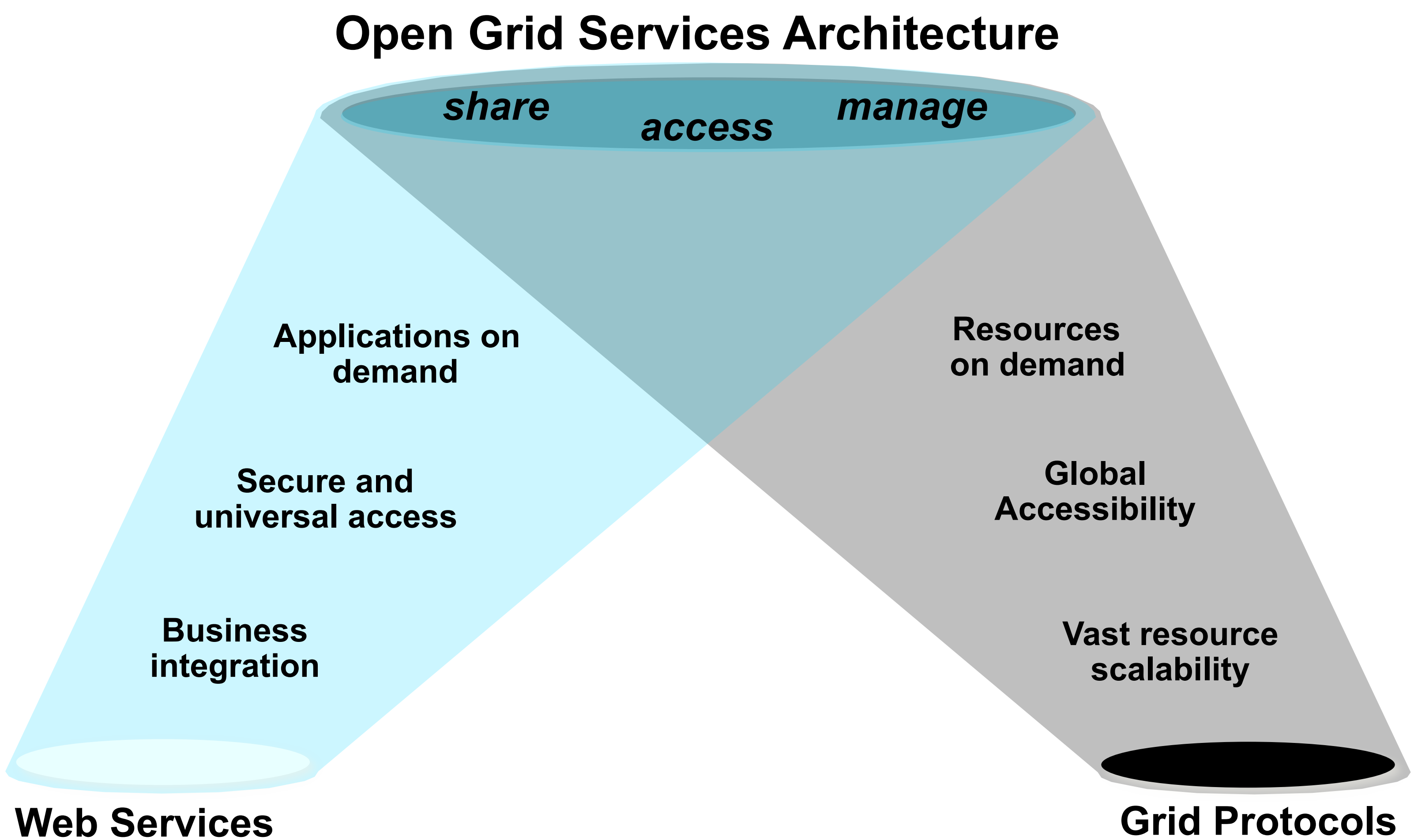
# Open Grid Services Architecture Objectives

- Manage resources across distributed heterogeneous platforms
- Deliver seamless QoS
- Provide a common base for autonomic management solutions
- Define open, published interfaces
- Exploit industry-standard integration technologies
  - Web Services, SOAP, XML,...
- Integrate with existing IT resources

'Open Grid Services Architecture Evolution, J.P. Prost, IBM Montpellier, France, Ecole Bruide 2004

# Best of Two Worlds

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