# The Grid: Reality, Technology, and Applications


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## Abstract


The Grid seems to be everywhere, with announcements of sales from major computer vendors, deployment in a wide range of application spaces, and many national and international scale infrastructure deployment. However, in spite of the popularity of the term, there is often confusion as to what the Grid is and what problems it solves. Is there any "there there" or is it all just marketing hype?

In this talk, I will address these questions, describing what the Grid is, what problems it solves, and what technology has been developed to build Grid infrastructure and create Grid applications. I will review the current status of Grid infrastructure and deployment and give examples of where Grid technology is being used not only to perform current tasks better, but to provide fundamentally new types of capabilities that are not possible otherwise.




## Overview

- Grid motivation and definition
- The need for standards
- The power of open source
- Grid in practice
- Summary



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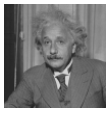
## The Grid


*Enable "coordinated resource sharing & problem solving in dynamic, multi-institutional virtual organizations."*
(Source: **"The Anatomy of the Grid"**)

- Access to shared resources
  - Virtualization, allocation, management
- With predicable behaviors
  - Provisioning, quality of service
- In dynamic, heterogeneous environments
  - Standards-based interfaces and protocols



## Why the Grid? Origins: Revolution in Science



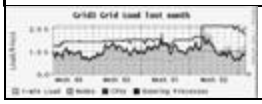
- Pre-Internet
  - Theorize &/or experiment, alone or in small teams; publish paper
- Post-Internet
  - Construct and mine large databases of observational or simulation data
  - Develop simulations & analyses
  - Access specialized devices remotely
  - Exchange information within distributed multidisciplinary teams

## Origins in Science

Engage via telepresence in an experiment at a remote facility

Discover & access a genome analysis service (running on high-end computer)

Integrate data from multiple sources in support of global change research



Harness computers across sites to process data from a physics experiment

## Open Science Grid : Astronomy Mosaic Construction

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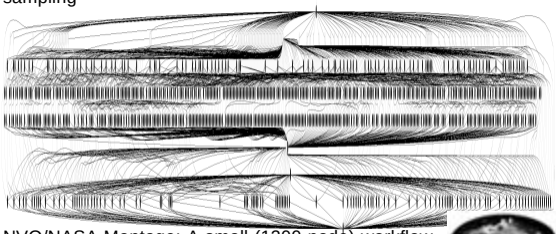
Construct custom mosaics on demand from multiple data sources

User specifies projection, coordinates, size, rotation, spatial sampling



NVO/NASA Montage: A small (1200 node) workflow

Work by Ewa Deelman et al., USC/ISI and Caltech

## Why the Grid? New Driver: Revolution in Business

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- Pre-Internet
  - Central data processing facility
- Post-Internet
  - Enterprise computing is highly distributed, heterogeneous, inter-enterprise (B2B)
  - Business processes increasingly computing- & data-rich
  - Outsourcing becomes feasible ✍ service providers of various sorts
  - Growing complexity & need for more efficient management

## eBusiness Use of Grid: SAP Demonstration @ TechEd

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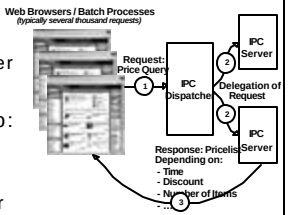
- 3 Globus-enabled applns:
  - CRM: Internet Pricing Configurator (IPC)
  - CRM: Workforce Management (WFM)
  - SCM: Advanced Planner & Optimizer (APO)
- Applications modified to:
  - Adjust to varying demand & resources
  - Use Globus to discover & provision resources




SAP AG R/3 Internet Pricing & Configurator (IPC)

## Cheaper or Faster ...

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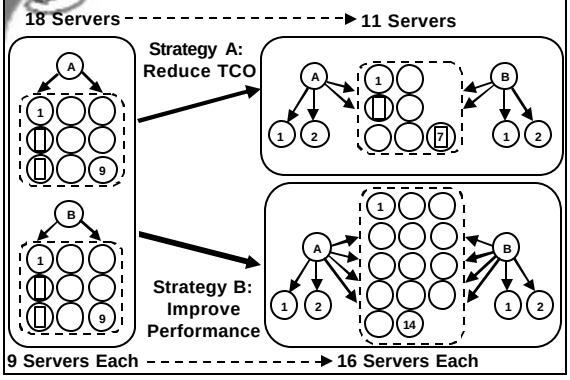


## Bridging the Gap Between Application & Infrastructure

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- Common virtualization/provisioning interfaces
  - Resource allocation & management
  - Application-driven provisioning
- Service-sharing federation and management
  - Access to programs, hardware, data, services across departmental boundaries
- Deliver: enhanced performance &/or lower total cost of ownership
  - E.g., large scale data management
  - On-demand resource allocation

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## Avoiding Silos & Vendor Lock-In: Open Standards & Software

- Standardized & interoperable mechanisms for secure & reliable:
  - Authentication, authorization, policy, …
  - Representation & management of state
  - Initiation & management of computation
  - Data access & movement
  - Communication & notification
- Good quality open source implementations to accelerate adoption & development
  - E.g., Globus Toolkit

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## Web Services as a Foundation

- Web services provide
  - Interface definition & service invocation
  - Nice semantics & extensibility
  - First steps towards security, workflow, etc.
  - Considerable commercial adoption
- But are not
  - A silver bullet
  - A complete solution
  - Fixed in stone

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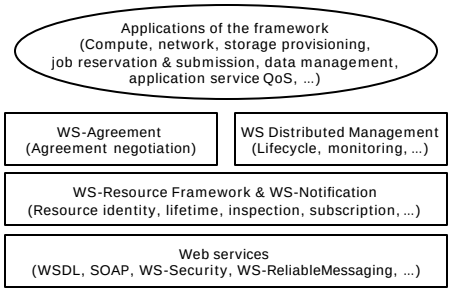
## Grid Requires that We Define WS-Based Frameworks

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## Web Services and Stateful Resources

- "State" appears in almost all applications
  - Data in a purchase order
  - Current usage agreement for resources
  - Metrics associated with work load on a server
- Web services can model, access and manage state in many different ways
  - Ad-hoc, per-application approaches
  - WSRF proposes a standard approach

Modeling Stateful Resources with Web Services,
Foster, Frey, Graham, et al. www.globus.org/wsrf, 2004.

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## WSRF & WS-Notification

- **Naming and bindings** (basis for virtualization)
  - Every resource can be uniquely referenced, and has one or more associated services for interacting with it
- **Lifecycle** (basis for fault resilient state mgmt)
  - Resources created by services following factory pattern
  - Resources destroyed immediately or scheduled
- **Information model** (basis for monitoring, discovery)
  - Resource properties associated with resources
  - Operations for querying and setting this info
  - Asynchronous notification of changes to properties
- Service groups (basis for registries, collective svcs)
  - Group membership rules & membership management
- Base Fault type

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## WS Distributed Management

- OASIS Web Services Distributed Management (WSDM) technical committee
  - Management using Web Services
  - HP submitted its Web Services Management Framework (WSMF) to WSDM in July 2003
- Framework that builds on WSRF to provide (among other things):
  - Service lifecycle (state) models
  - Service monitoring abstractions
  - Service relationships

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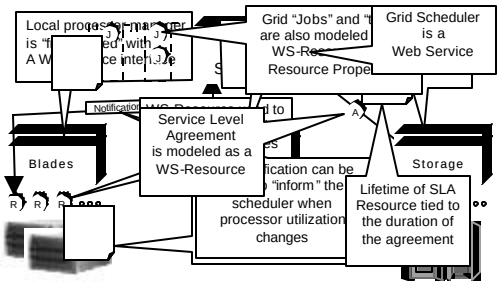
## Bringing it All Together

*Scenario: Resource management & scheduling*

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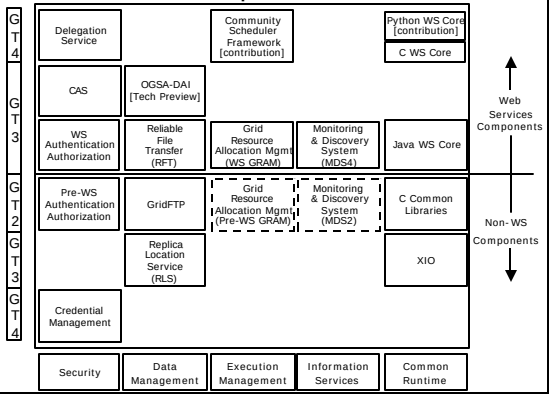
## Globus Toolkit Main Components

- Core Web services
  - Infrastructure for building new services
- Security
  - Apply uniform policy across distinct systems
- Execution management
  - Provision, deploy, & manage services
- Data management
  - Discover, transfer, & access large data
- Monitoring
  - Discover & monitor dynamic services

## Globus Toolkit: Open Source Grid S/W

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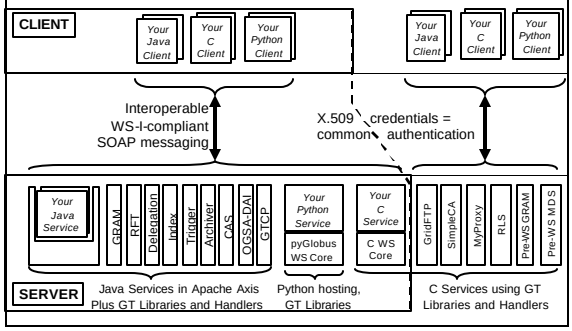
## GT4 Components



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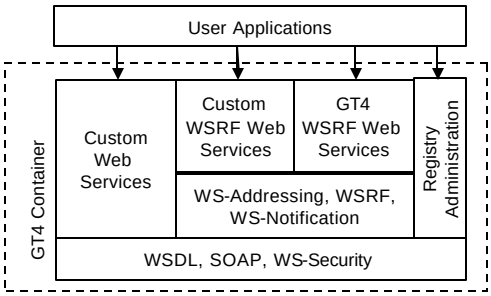
## Application Development with GT4

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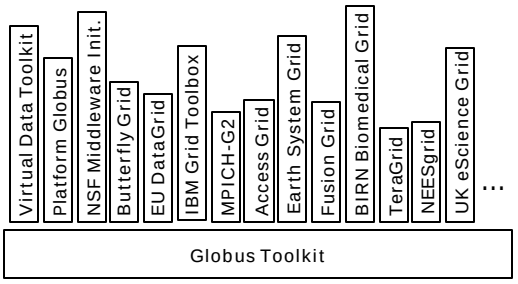
## GT-Based Grid Tools & Solutions

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## Grid Security

- Control access to shared services across administrative domains
  - Driven by autonomous management, e.g., different policy in different work-groups
- Multi-user collaborations
  - Federate through mutually trusted services
  - Local policy authorities rule
- Users able to set up dynamic trust domains
  - Personal collection of resources working together based on trust of user

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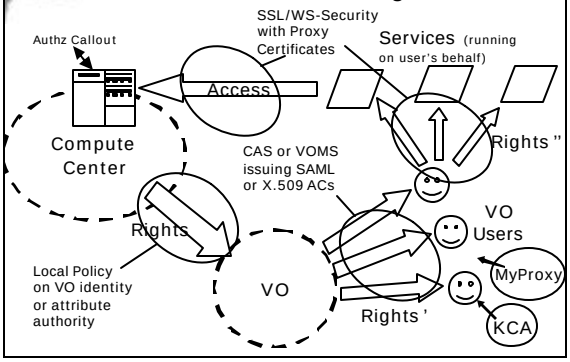
## GT4 Grid Security: Standards-Based Delegation

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## GT4's Use of Security Standards

| | Message-level Security w/X.509 Credentials | Message-level Security w/Usernames and Passwords | Transport-level Security w/X.509 Credentials |
|---|---|---|---|
| Authorization | SAML and grid-mapfile | grid-mapfile | SAML and grid-mapfile |
| Delegation | X.509 Proxy Certificates/ WS-Trust | | X.509 Proxy Certificates/ WS-Trust |
| Authentication | X.509 End Entity Certificates | Username/ Password | X.509 End Entity Certificates |
| Message Protection | WS-Security WS-SecureConversation | WS-Security | TLS |
| Message format | SOAP | SOAP | SOAP |

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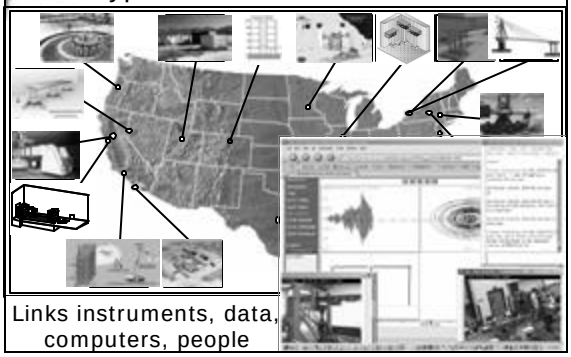
## A Typical eScience Use of Globus



Links instruments, data, computers, people

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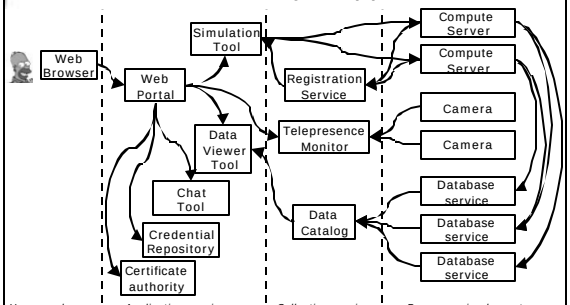
## How it Really Happens

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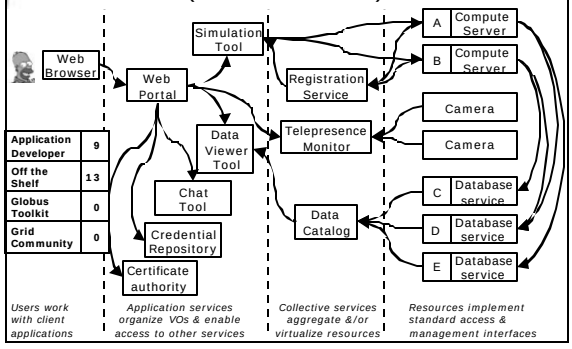
## How it Really Happens (without Globus)

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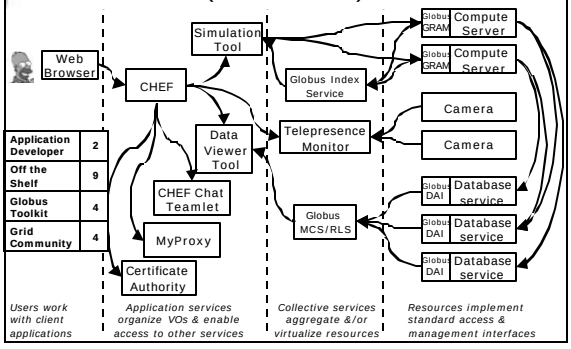
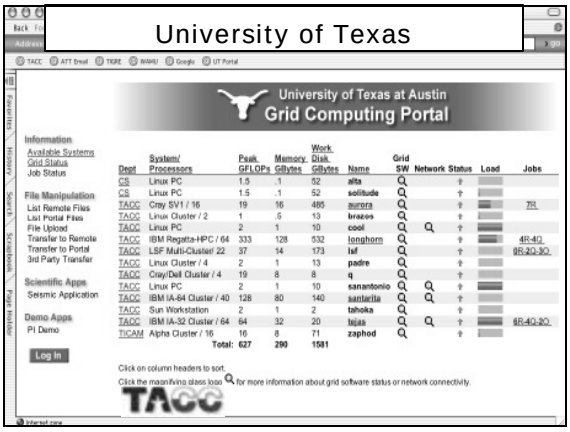
## How it Really Happens (with Globus)



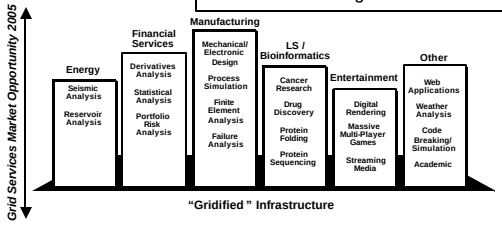

## University of Texas




## Global Community

## Early Commercial Applications

Leading adopters (Oct 2003) *
- Financial services: 31%
- Life sciences: 26%
- Manufacturing: 18%




Sources: IDC, 2000 and Bear Stearns- Internet 3.0 - 5/01 Analysis by SAI

*Grids 2004: From Rocket Science To Business Service*, The 451 Group



## Novartis

PC Grid links 3,700 desktop systems
- Research & development applications
- Potentially mainstream business computing
- > 5 teraflop/s computing power
- Estimate savings of $200M over 3 years

"We have projects we calculate would take 6 years on a single supercomputer. Today, the run time is 12 hours."

*Peter Sany, Novartis CIO*



## Globus Consortium (www.globusconsortium.com)

- "The Globus Consortium is comprised of global computing leaders who support the Globus Toolkit for use in enterprise data centers. Through the Globus Consortium, vendors of hardware, software and their customers can work together to accelerate use of the Globus Toolkit in the enterprise by hardening features and speaking with one voice on emerging Grid standards."
  - HP, IBM, Intel, Sun, Nortel, Univa are founding members

## Acknowledgments


- Carl Kesselman and Steve Tuecke, my long-time Globus co-conspirators
- Gregor von Laszewski, Kate Keahey, Jennifer Schopf, Mike Wilde, other Argonne colleagues
- Globus Alliance members at Argonne, U.Chicago, USC/ISI, Edinburgh, PDC
- Miron Livny, U.Wisconsin Condor project, Rick Stevens, Argonne & U.Chicago
- Other partners in Grid technology, application, & infrastructure projects
- DOE, NSF, NASA, IBM for generous support

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- A significant opportunity
  - Federate resources to increase capability &/or reduce cost
- Requires new technology
  - Bridge application-infrastructure gap
- Open standards & software are important
  - To address needs without vendor lock in
- We're perhaps at an inflection point
  - Major adoption for eScience
  - Growing adoption within industry

## For More Information

- Globus Alliance
  - www.globus.org
- Globus Consortium
  - www.globusconsortium.com
- Global Grid Forum
  - www.ggf.org
- Background information
  - www.mcs.anl.gov/~foster
- **GlobusWORLD 2005**
  - **Feb 7-11, Boston**