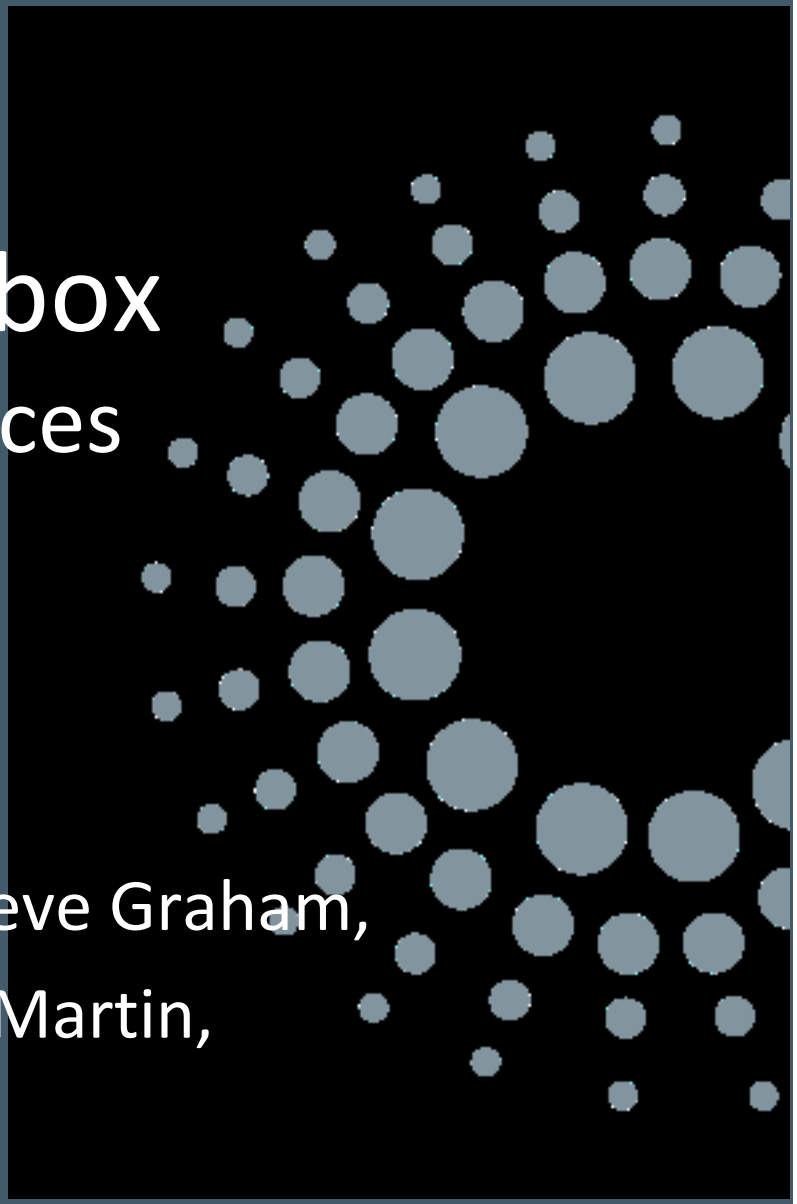
Computation Institute

Thinking outside the box

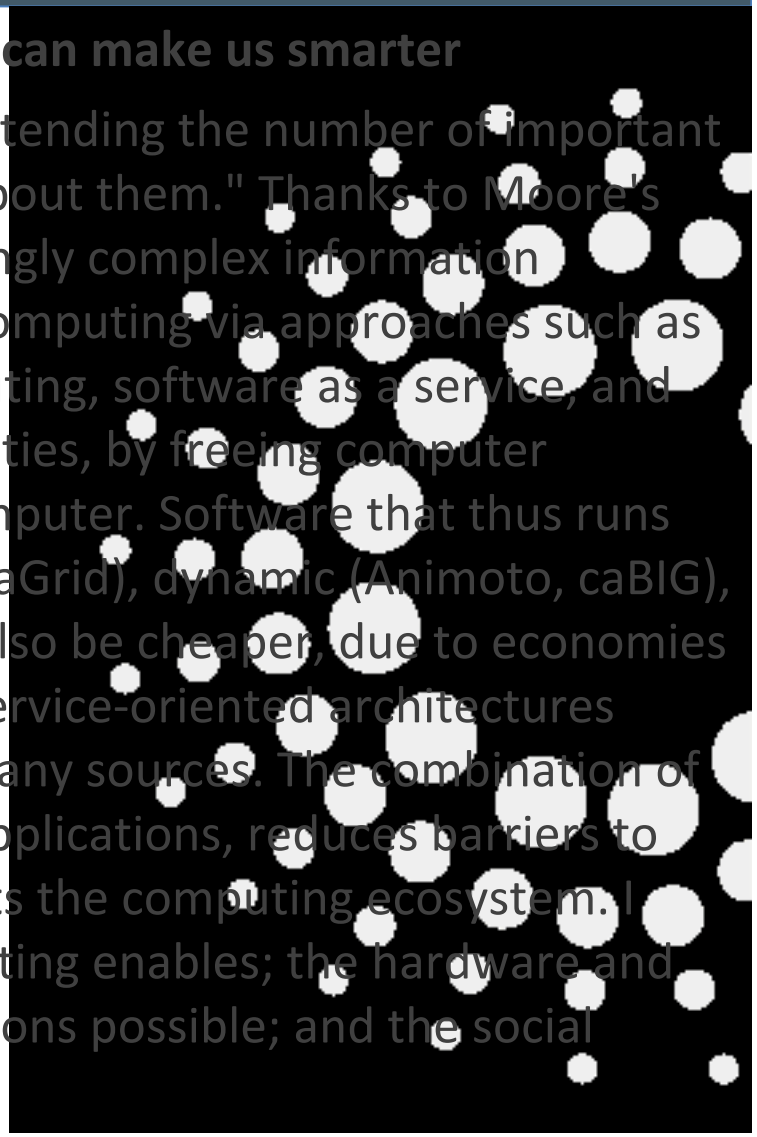
How cloud, grid, and services can make us smarter



Ian Foster

Joint work with: Steve Tuecke, Steve Graham, Lisa Childers, Dan Gunter, Stuart Martin, Vas Vasiliadis, and others

Abstract



inking outside the box: How cloud, grid, and services can make us smarter

Whitehead observed that "civilization advances by extending the number of important operations which we can perform without thinking about them." Thanks to Moore's Law, these operations can nowadays involve increasingly complex information manipulation and computation. The outsourcing of computing via approaches such as utility computing, on-demand computing, grid computing, software as a service, and cloud computing can further enhance human capabilities, by freeing computer applications from the limiting confines of a single computer. Software that thus runs "outside the box" can be more powerful (Google, TeraGrid), dynamic (Animoto, caBIG), and collaborative (FaceBook, myExperiment). It can also be cheaper, due to economies of scale in hardware and software. Simultaneously, service-oriented architectures make it easier to integrate data and software from many sources. The combination of new functionality and new economics inspires new applications, reduces barriers to entry for application providers, and in general disrupts the computing ecosystem. I discuss new applications that outside-the-box computing enables; the hardware and software architectures that make these new applications possible; and the social dimensions of outside-the-box computing.

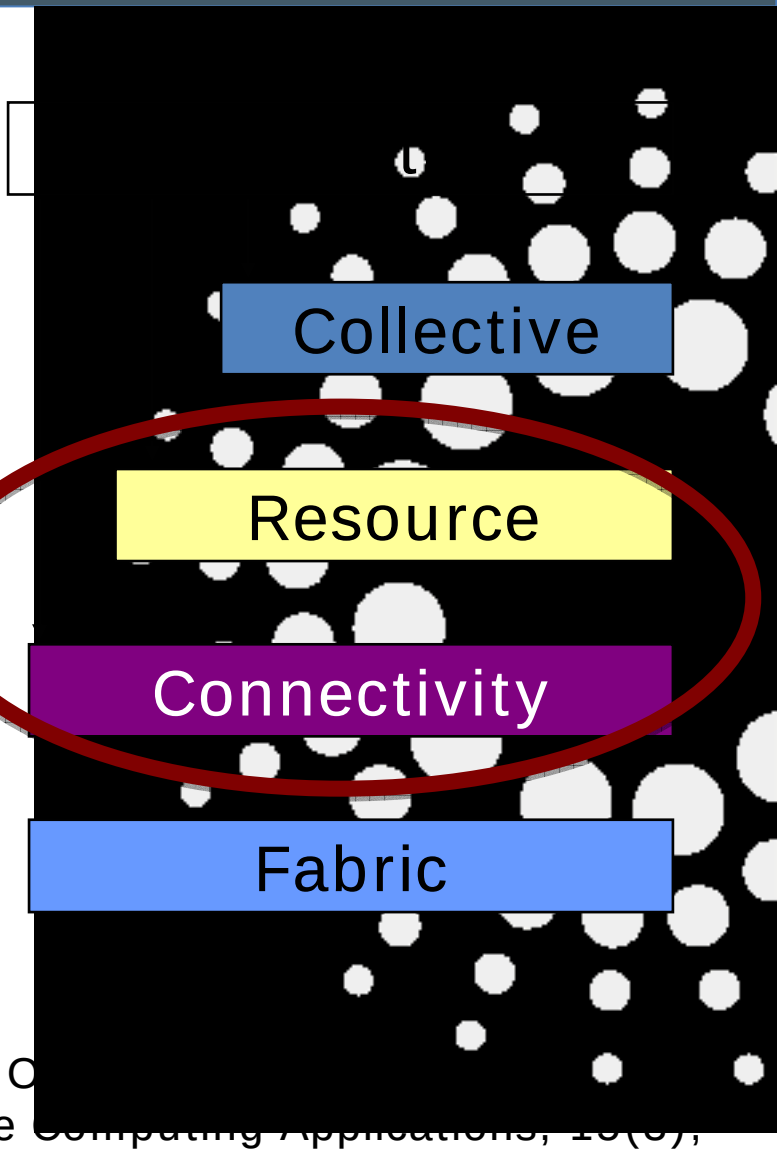
Alfred North Whitehead (1911)

Civilization advances
by extending
the number of
important operations
which we can perform
without thinking
about them

The changing nature of work

Collaborative and dynamic	Project focused, globally distributed teams, spanning organizations within and beyond enterprise boundaries
Distributed and heterogeneous	Each team member/group brings own data, compute, and other resources into the project
Data and computation intensive	Access to computing and data resources must be coordinated across the collaboration
Concurrent innovation cycles	Resources must be available to projects with strong QoS, and also reflect system-wide priorities

Integration v1: Standardize interfaces



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

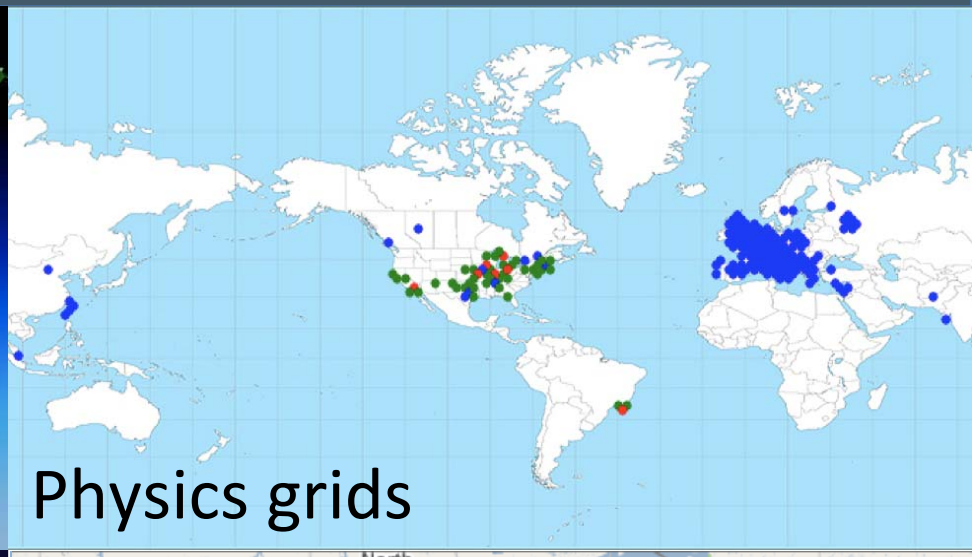
"Sharing single resources": negotiating access, controlling use

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

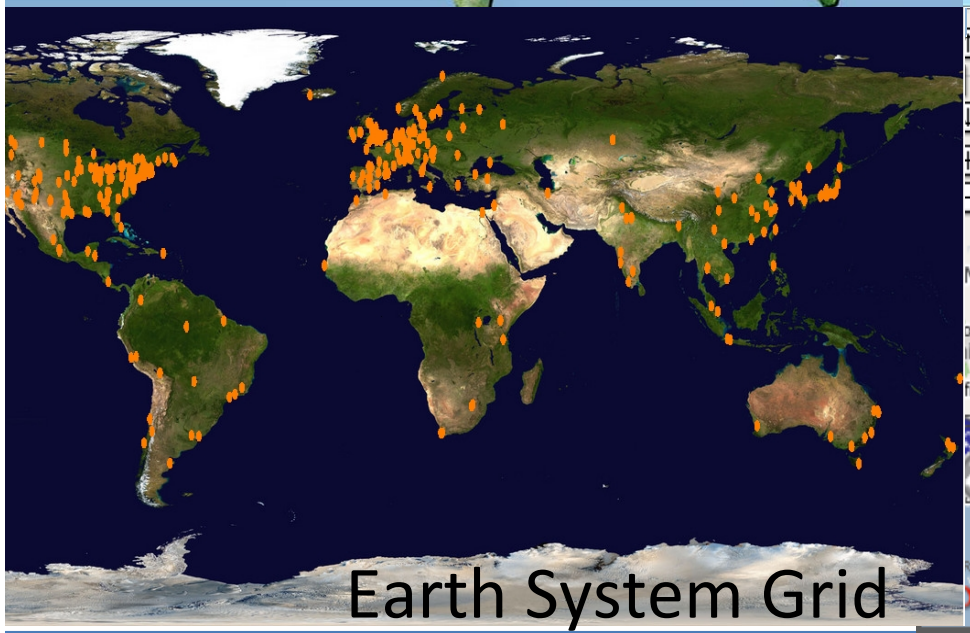
"Controlling things locally": Access to, and control of resources

"The Anatomy of the Grid: Enabling Scalable Virtual O
Kesselman, Tuecke, Intl Journal of High Performance Computing Applications, 15(3), 2001.

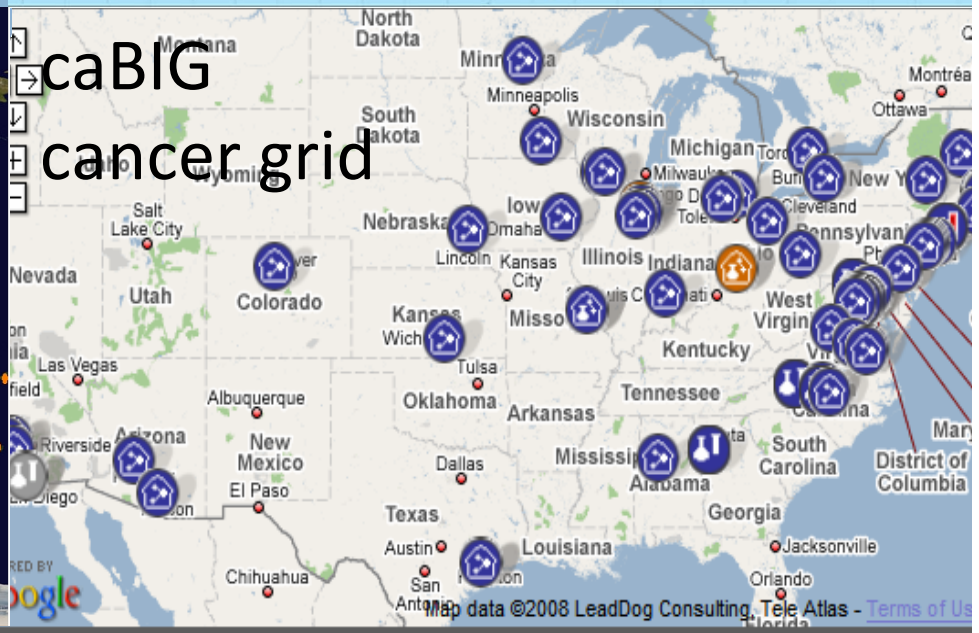
Integration v1: Standardize interfaces



Physics grids



Earth System Grid

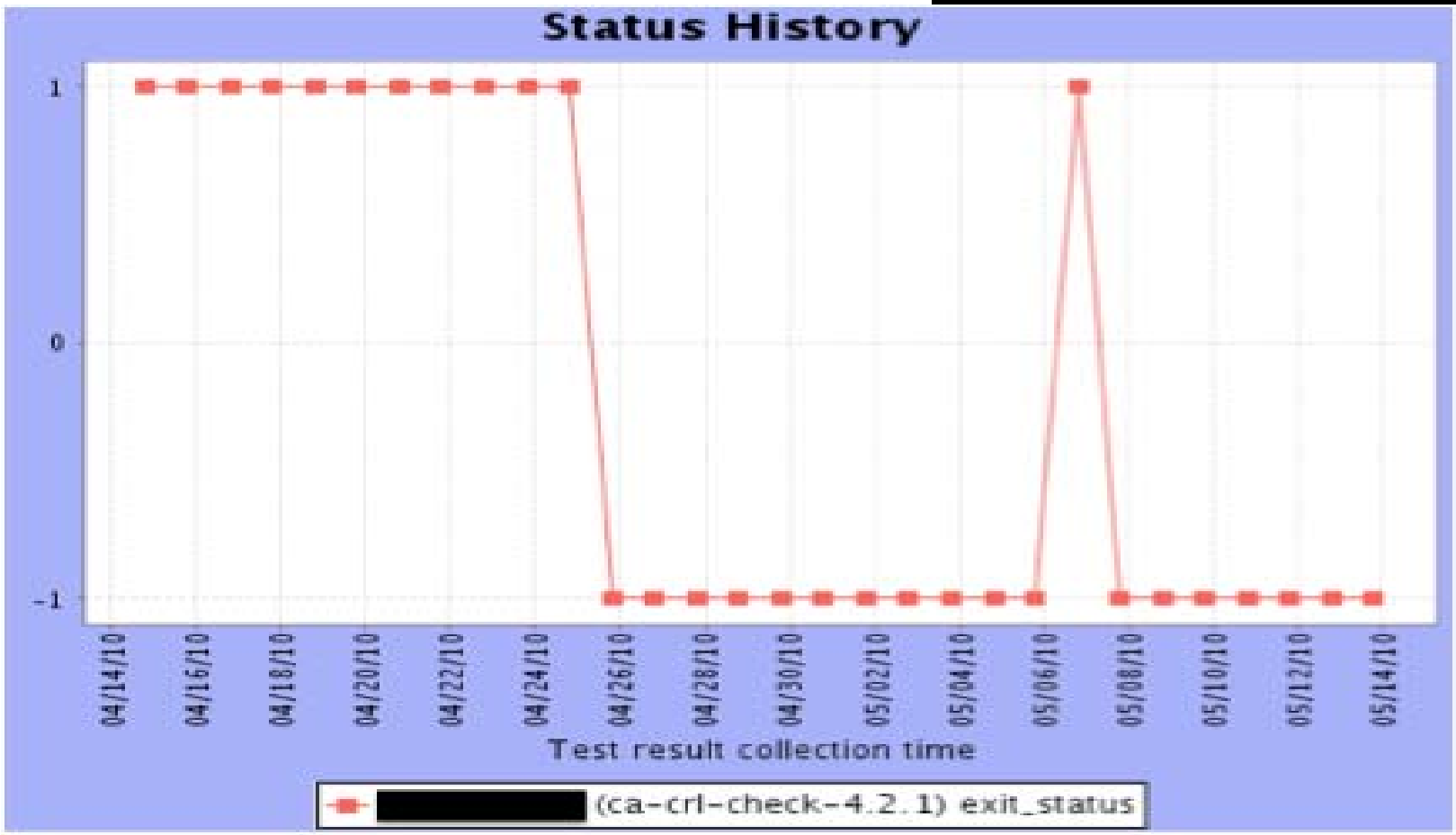


caBIG cancer grid

Resource providers not always reliable

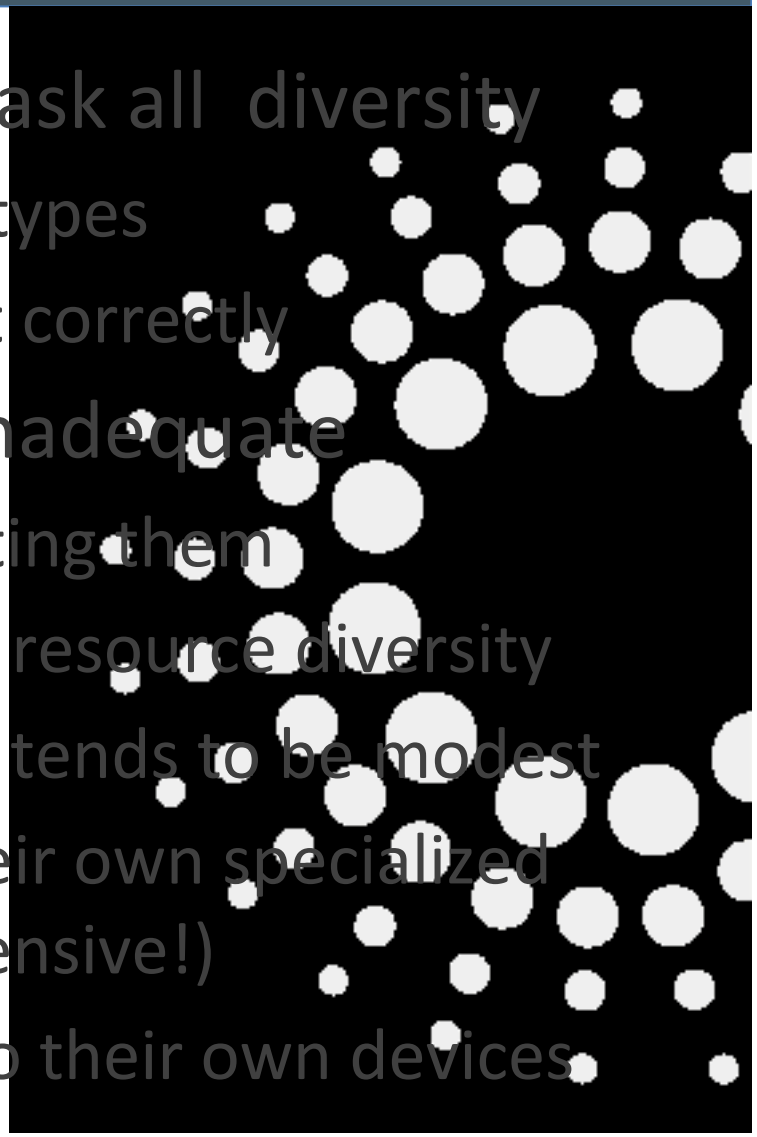
Subject: GridFTP AGAIN!
I am not able to send a file from XXX to YYY:
+ globus-url-copy -vb -stripe -p 12 -tcp-bs 11MXurlYurl
error: globus_ftp_control: gss_init_sec_context failed
globus_gsi_callback_module: Could not verify credential
globus_gsi_callback_module: Could not verify credential
globus_gsi_callback_module: Invalid CRL: The available CRL has expired
PLEASE PLEASE PLEASE _DO_ something about Globus!
(such as eliminate it from file transfers)

Collective services are too specialized?



Test name, resource	# Total Known Reports	# Passed Reports	# Failed Reports	# Total Unknown Reports	% Passed Reports
[redacted] (ca-crl-check-4.2.1) exit_status	30	12	18	0	40%

Where we are



- **Resource** interfaces do not mask all diversity
  - Diverse and dynamic resource types
  - Varied incentives to implement correctly
- **Collective** layer services are inadequate
  - Inadequate investment in creating them
  - Much effort spent dealing with resource diversity
  - Result: Implementation quality tends to be modest
  - Result: Big projects develop their own specialized versions of these services (expensive!)
  - Result: Small projects are left to their own devices

CMS collaboration

(144 Institutions with about 1700 scientists)

ARMENIA
- Yerevan Physics Inst., Yerevan

AUSTRIA
- HEPHY, Wien

BELARUS
- Institute of Nuclear Problems, Minsk
- National Centre of Part. and HEP, Minsk
- Res. Inst. of Applied Physical Probl., Minsk
- Byelorussian State Univ., Minsk

BELGIUM
- Univ. Instelling Antwerpen, Wilrijk
- Univ. Libre de Bruxelles, Brussels
- Vrije Universiteit Brussel, Brussels
- Univ. Catholique de Louvain, Louvain-la-Neuve
- Univ. de Mons-Hainaut, Mons

BULGARIA
- Inst. for Nucl. Res. and Nucl. Energy, Sofia
- Univ. of Sofia, Sofia

CHINA, PR
- Inst. of High Energy Physics, Beijing
- Peking Univ., Beijing
- Univ. for Science & Tech. of China, Hefei, Anhui

CROATIA
- Tech. Univ.of Split, Split
- Univ. of Split, Split

CYPRUS
- Univ. of Cyprus, Nicosia

ESTONIA
- Inst. of Chemical Phys. and Biophys., Tallinn

FINLAND
- Helsinki Institute of Physics, Helsinki
- Dpt.of Phys., Univ.of Helsinki, Helsinki
- Univ. of Jyvaskyla, Jyvaskyla
- Helsinki University of Technology, Helsinki
- Univ. of Oulu, Oulu
- Tampere Univ. of Tech., Tampere

FRANCE
- LAPP, IN2P3-CNRS, Annecy-le-Vieux
- IPN, IN2P3-CNRS, Univ. Lyon I, Villeurbanne
- LPNHE, Ecole Polytech., IN2P3-CNRS, Palaiseau
- DSM/DAPNIA, CEA/Saclay, Gif-sur-Yvette
- IRES, IN2P3-CNRS - ULP, UHA, LEPSI, Strasbourg

GEORGIA
- High Energy Phys. Inst., Tbilisi State Univ., Tbilisi
- Inst. of Physics Academy of Science, Tbilisi

GERMANY
- RWTH, I. Physik. Inst., Aachen
- RWTH, III. Physik. Inst. A, Aachen
- RWTH, III. Physik. Inst. B, Aachen
- Humboldt-Univ. zu Berlin, Berlin
- Inst. for Exp. Kernphysik, Karlsruhe

GREECE
- Univ. of Athens, Athens
- Inst. of Nucl. Phys. "Demokritos", Attiki
- Univ. of Ioánnina, Ioánnina

HUNGARY
- KFKI Res. Inst. for Part. & Nucl. Phys., Budapest
- Kossuth Lajos Univ., Debrecen
- Institute of Nuclear Research ATOMKI, Debrecen

INDIA
- Panjab Univ., Chandigarh
- Bhabha Atomic Res. Centre, Mumbai
- Univ. of Delhi South Campus, New Delhi
- TIFR - EHEP, Mumbai
- TIFR - HECR, Mumbai

ITALY
- Univ. di Bari e Sez. dell'INFN, Bari
- Univ. di Bologna e Sez. dell'INFN, Bologna
- Univ. di Catania e Sez. dell'INFN, Catania
- Univ. di Firenze e Sez. dell'INFN, Firenze
- Univ. di Genova e Sez. dell'INFN, Genova
- Univ. di Padova e Sez. dell'INFN, Padova
- Univ. di Pavia e Sez. dell'INFN, Pavia
- Univ. di Perugia e Sez. dell'INFN, Perugia
- Univ. di Pisa e Sez. dell'INFN, Pisa
- Univ. di Roma I e Sez. dell'INFN, Roma
- Univ. di Torino e Sez. dell'INFN, Torino

KOREA
- Chaju National University, Chaju
- Chonnam National University, Kwangju
- Choongbuk National University, Chongju
- Dongshin University, Naju
- Kangnung National University, Kangnung
- Kangwon National University, Chunchon
- Kon-Kuk University, Seoul
- Korea University, Seoul
- Kyungpook National University, Taegu
- Pohang University of Science and Technology, Pohang
- Gyeongsang National University, Jinju
- Seonam University, Namwon
- Seoul National Univ. of Education, Seoul
- Wonkwang University, Iri

PAKISTAN
- Quaid-I-Azam Univ., Islamabad
- Ghulam Ishaq Khan Institute, Swabi

POLAND
- Inst. of Exp. Phys., Warsaw
- Soltan Inst. for Nucl. Studies, Warsaw

PORTUGAL
- LIP, Lisboa

RUSSIA
- JINR, Dubna
- Inst. for Nucl. Res., Moscow
- Inst. for Theoretical and Exp. Phys., Moscow
- P.N. Lebedev Phys. Inst., Moscow
- Moscow State Univ., Moscow
- Budker Inst. for Nucl. Phys., Novosibirsk
- Inst. for High Energy Phys., Protvino
- Petersburg Nucl. Phys. Inst., Gatchina (St Petersburg)

SLOVAK REPUBLIC
- Slovak University of Technology, Bratislava

SPAIN
- CIEMAT, Madrid
- Univ. Autónoma de Madrid, Madrid
- Univ. de Oviedo, Oviedo
- IFCA, CSIC-Univ. de Cantabria, Santander

SWITZERLAND
- Univ. Basel, Basel
- CERN, Geneva
- Paul Scherrer Inst., Villigen
- Inst. for Teilchenphysik, ETH, Zurich
- Univ. Zürich, Zurich

TURKEY
- Cukurova Univ., Adana
- Middle East Technical Univ., Ankara

UKRAINE
- Inst. of Single Crystals of Nat. Acad. of Science, Kharkov
- Kharkov Inst. of Phys. and Tech., Kharkov
- Kharkov State Univ., Kharkov

UNITED KINGDOM
- Univ. of Bristol, Bristol
- Brunel Univ., Uxbridge
- Imperial College, Univ. of London, London
- RAL, Didcot

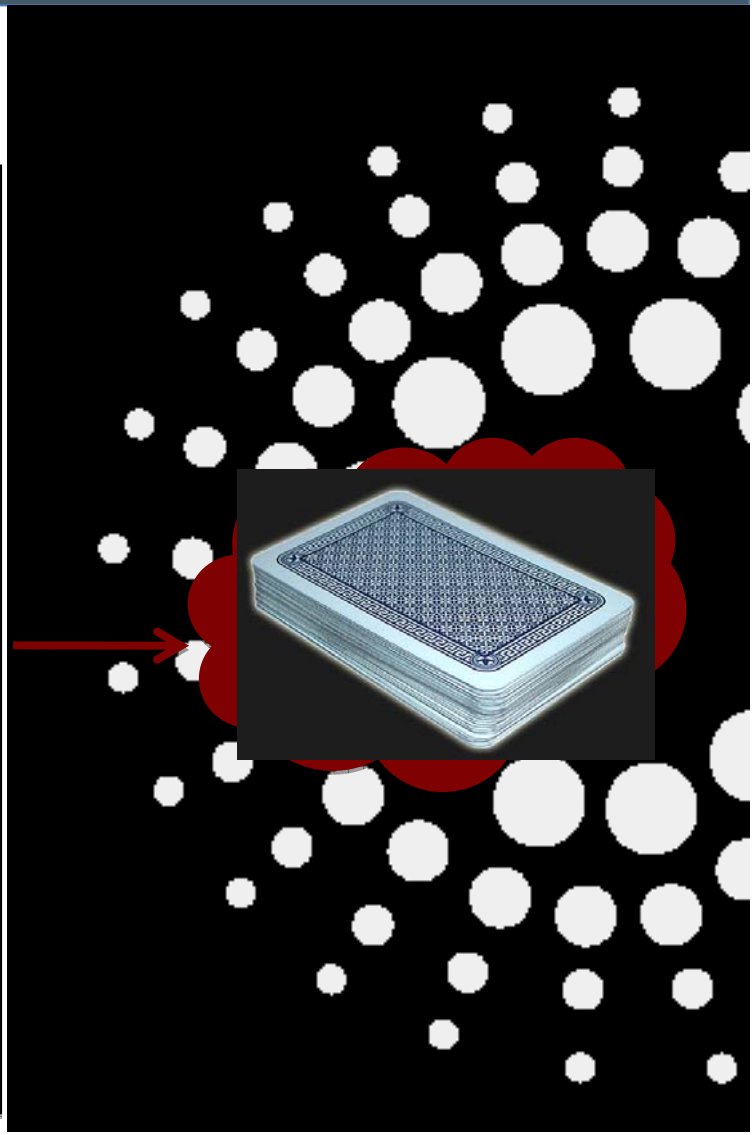
USA
- Univ. of Alabama, Tuscaloosa
- Iowa State Univ., Ames
- Boston Univ., Boston
- California Inst. of Tech., Pasadena
- Carnegie Mellon Univ., Pittsburgh
- Univ. of Illinois at Chicago, Chicago
- Fairfield Univ., Fairfield
- Fermi National Accelerator Lab., Batavia
- Florida State Univ. - HEPG, Tallahassee
- Florida State Univ. - SCRI, Tallahassee
- Univ. of Florida, Gainesville
- The Univ. of Iowa, Iowa City
- Johns Hopkins Univ., Baltimore
- LLNL, Livermore
- Los Alamos Nat. Lab., Los Alamos
- Univ. of Maryland, College Park
- Univ. of Minnesota, Minneapolis
- Univ. of Mississippi, Oxford
- Massachusetts Inst. of Tech., Cambridge
- Univ. of Nebraska-Lincoln, Lincoln
- Northeastern Univ., Boston
- Northwestern Univ., Evanston
- Univ. of Notre Dame, Notre Dame
- The Ohio State Univ., Columbus
- Princeton Univ., Princeton
- Purdue Univ., West Lafayette
- Rice Univ., Houston
- Univ. of California, Riverside
- Univ. of Rochester, Rochester
- Rutgers, the State Univ. of New Jersey, Piscataway
- Texas Tech Univ., Lubbock
- Univ. of Texas at Dallas, Richardson
- Univ.of California at Davis, Davis
- UCLA, Los Angeles
- Univ.of California San Diego, La Jolla
- Virginia Polytech. Inst. and State Univ., Blacksburg
- Univ. of Wisconsin, Madison

UZBEKISTAN
- Inst. of Nucl. Phys. of the Uzbekistan Acad. of Sciences, Tashkent

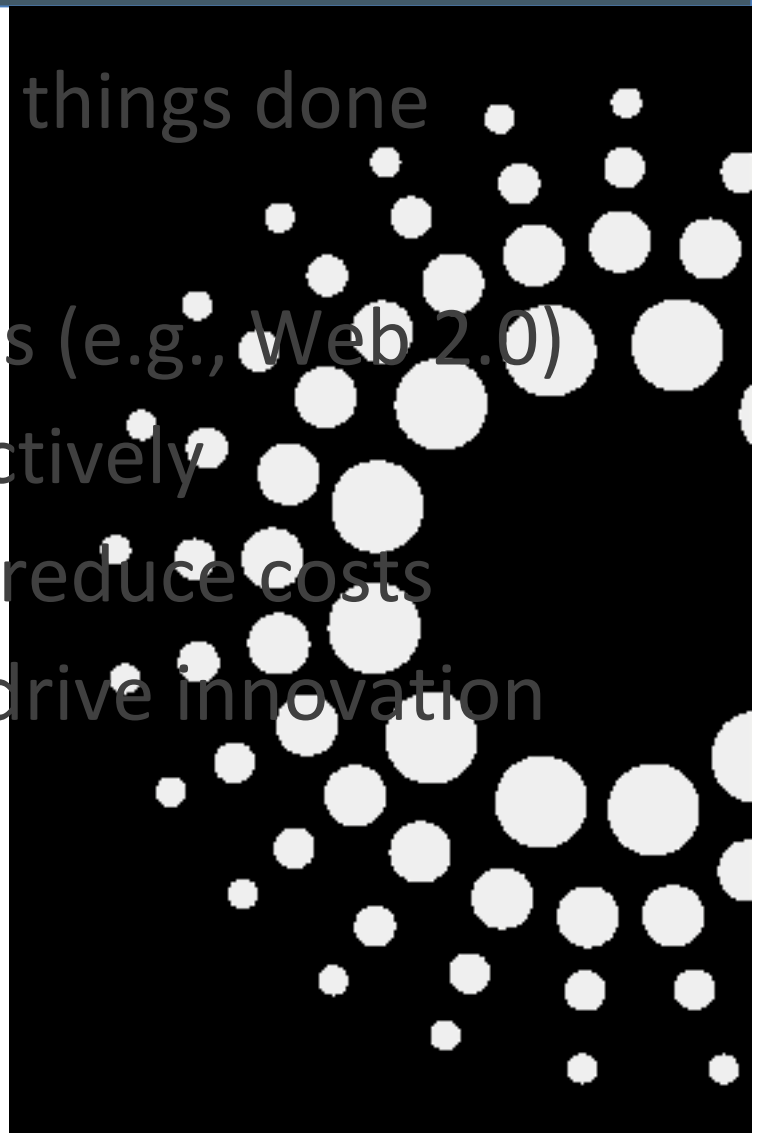
Let's outsource collective services

Move data D from A to B

- A's CRL has expired
- A, B need credentials
- B does not run GridFTP at all
- A's firewall forbids incoming connections
- B has inadequate space for D
- Network from A to B is slow
- …



The outside-the-box cloud thing should:



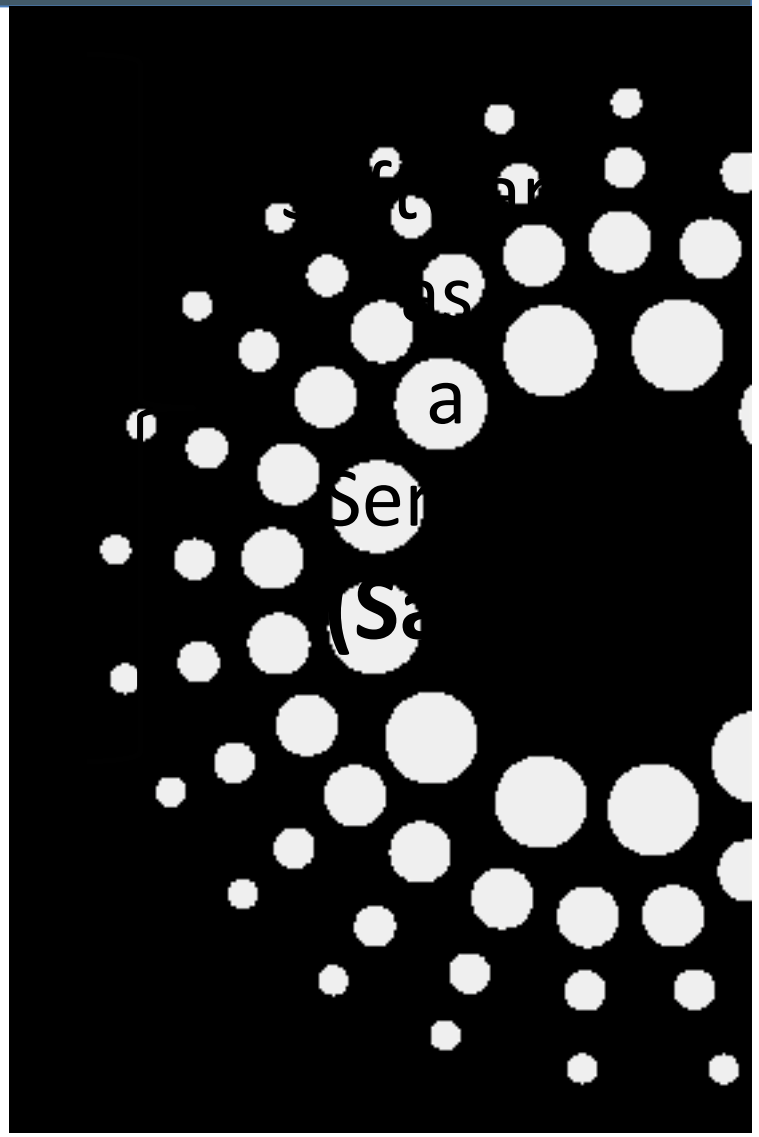
- Take responsibility for getting things done
- Allow for personalization
- Provide nice remote interfaces (e.g., Web 2.0)
- Detect and fix problems proactively
- Exploit economies of scale to reduce costs
- Leverage user community to drive innovation

Information technology at Univa

- Email (hosted Exchange)
- Calendar
- Telephony (hosted VOIP)
- Web presence
- Human resources and payroll (Trinet)
- Accounting
- Customer relationship management (Salesforce.com)
- …

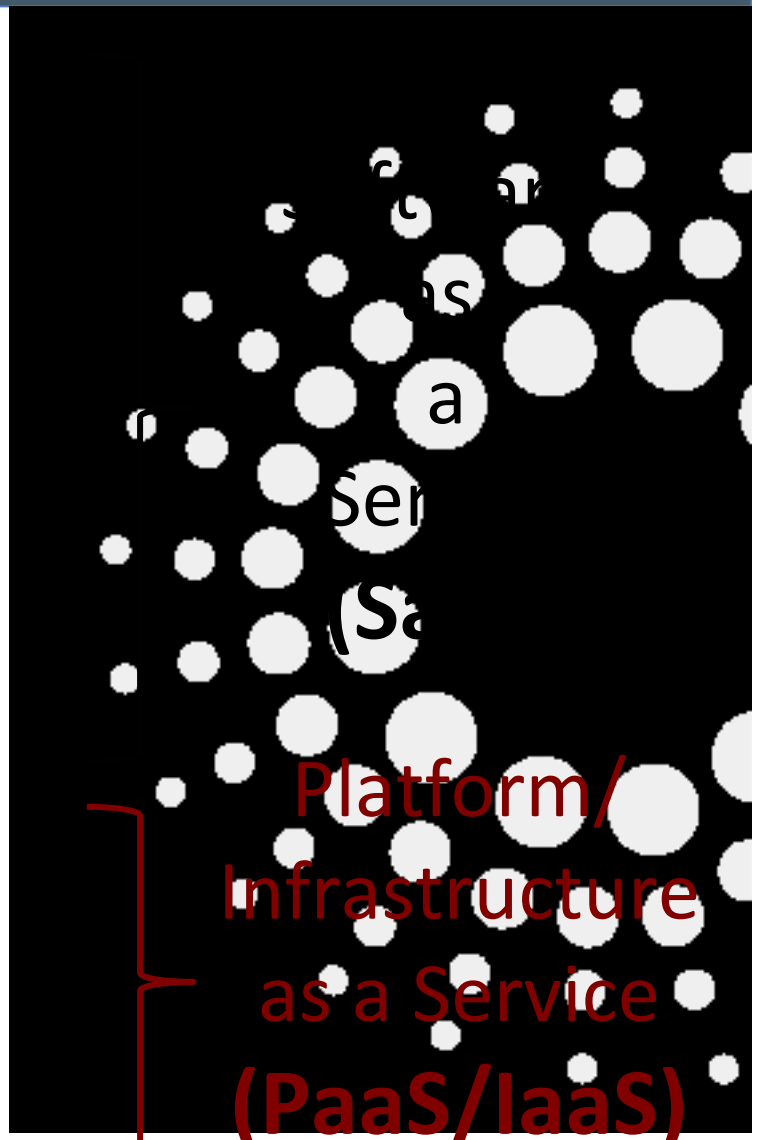
Thinking outside the box for SMB/SMEs

- Web presence
- Email (hosted Exchange)
- Calendar
- Telephony (hosted VOIP)
- Human resources and payroll
- Accounting
- Customer relationship mgmt



Thinking outside the box for SMB/SMEs

- Web presence
- Email (hosted Exchange)
- Calendar
- Telephony (hosted VOIP)
- Human resources and payroll
- Accounting
- Customer relationship mgmt
- Data analytics
- Content distribution
- …



Thinking outside the box for science

- Run experiments
- Collect data
- Manage data
- Move data
- Analyze data
- Run simulations
- Compare experiment with simulation
- Search the literature
- Share results

- Communicate with colleagues
- Publish papers
- Find, configure, install relevant software
- Find, access, analyze relevant data
- Document research
- Order supplies

Globus.org = Sci-SaaS

Thinking outside the box for science

- Run experiments
- Collect data
- Manage data
- **Move data**
- Analyze data
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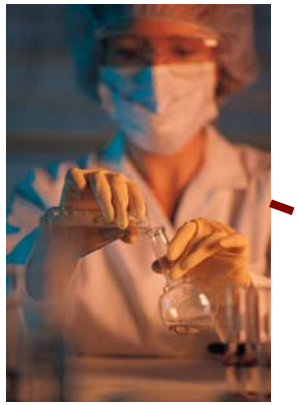
Globus.Org services: Data movement



"Move data from A to B"

Globus. Org

Notificatio n agents

Transfe r agents

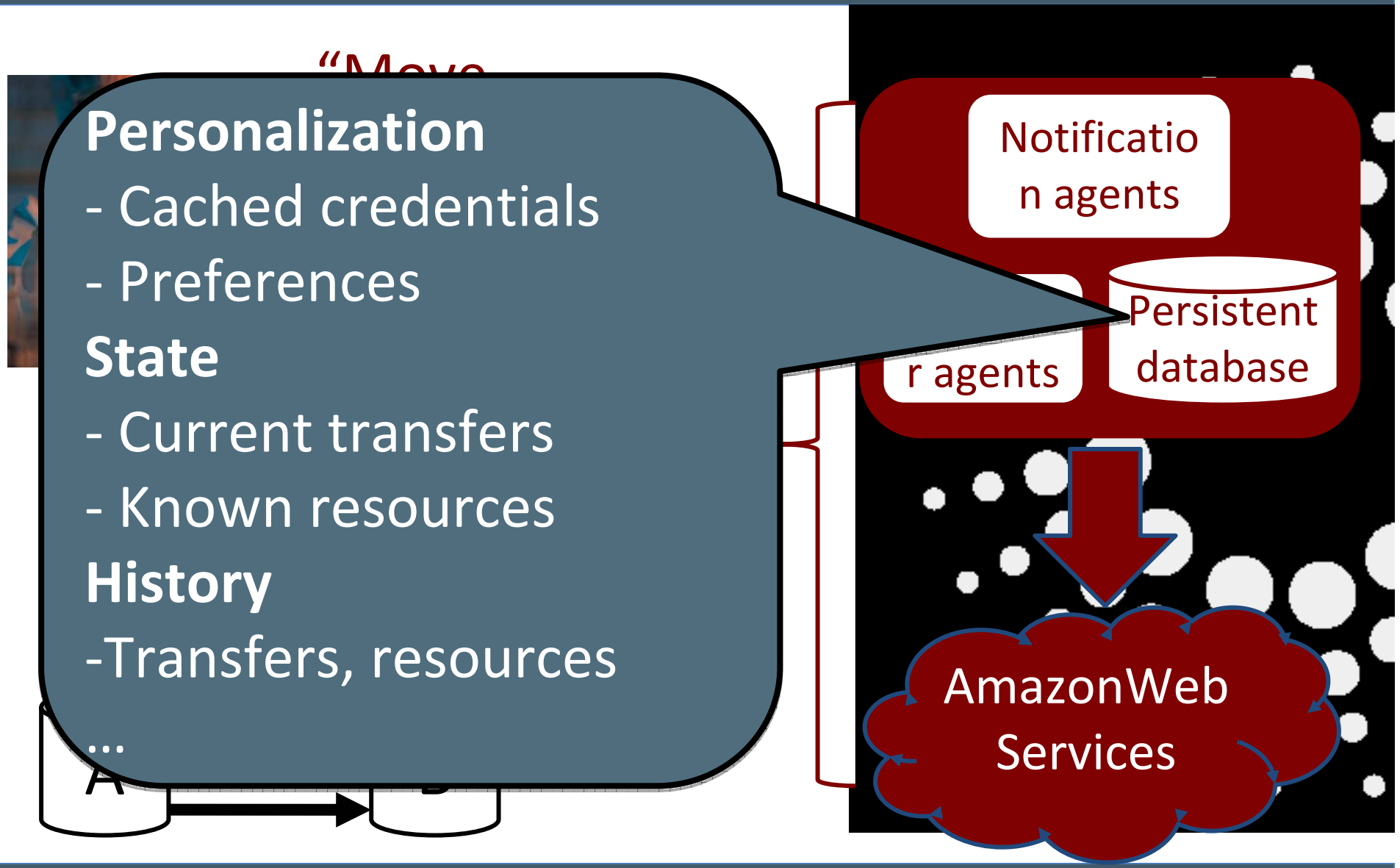
Persistent database

AmazonWeb Services

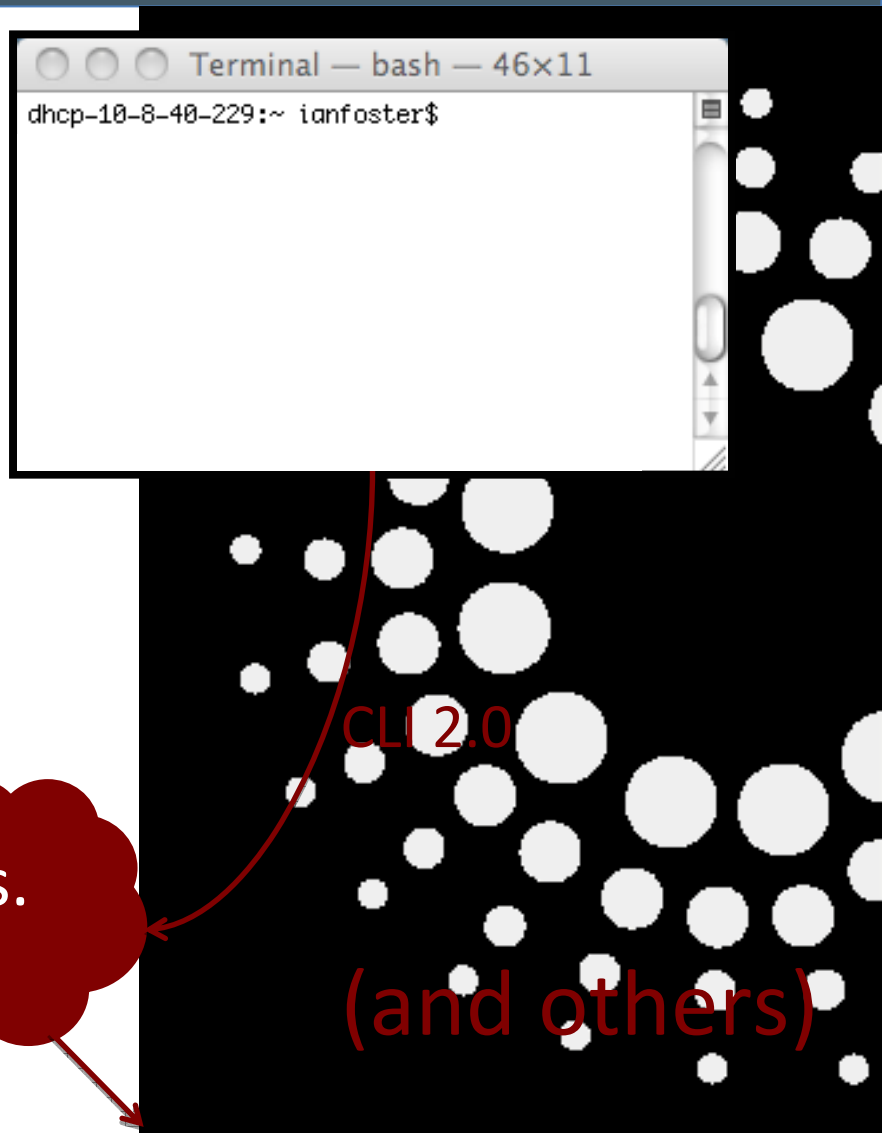
A

B

Globus.Org services: Data replication



Lightweight remote access interfaces



REST

Globus.
Org

CLI 2.0: Lightweight command line interface

CLI 1.0

- Install client library implementing CLI, e.g. Globus libraries
- Write scripts that make CLI calls, e.g.:

  globus_url_copy From To

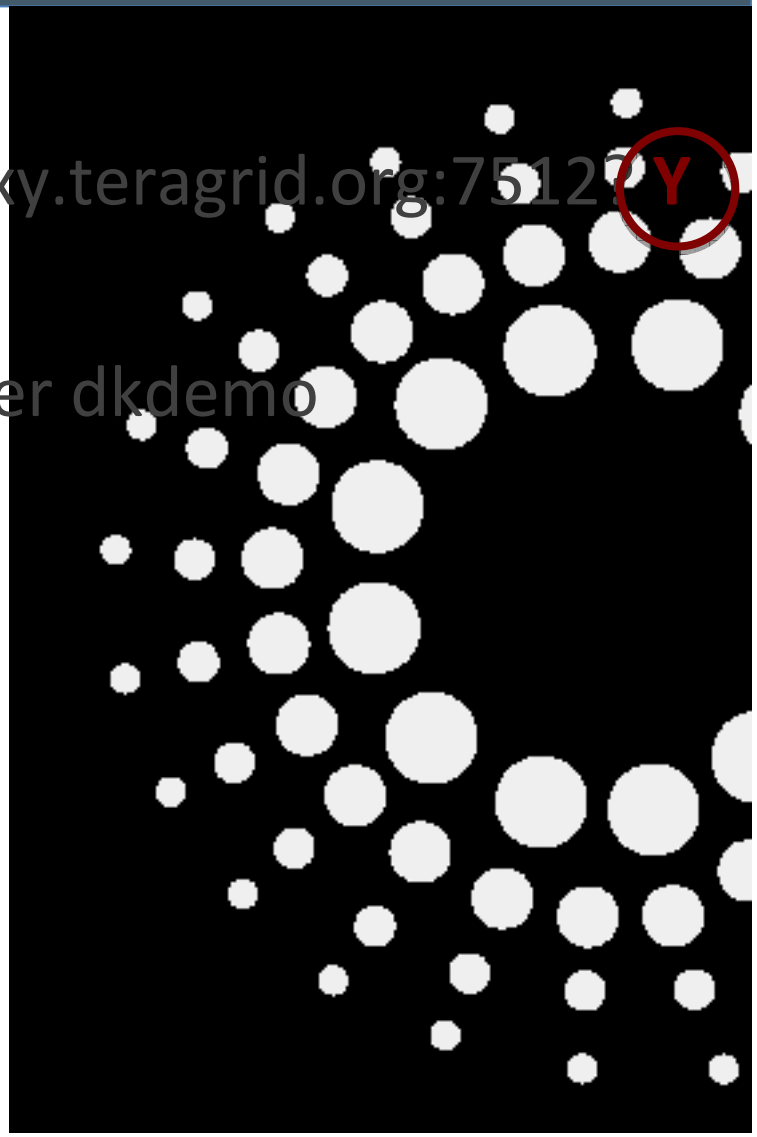
- Updated implementation requires reinstall of library

CLI 2.0

- Write scripts that make CLI calls, e.g.

  **sshdemo.globus.org **
  xfer From To

Using the CLI 2.0 interface



>**ssh -tdemo.globus.org activate**

Do you want to activate using myproxy.teragrid.org:7512? Y

MyProxy pass phrase: **********

A credential has been received for user dkdemo

Using the CLI 2.0 interface

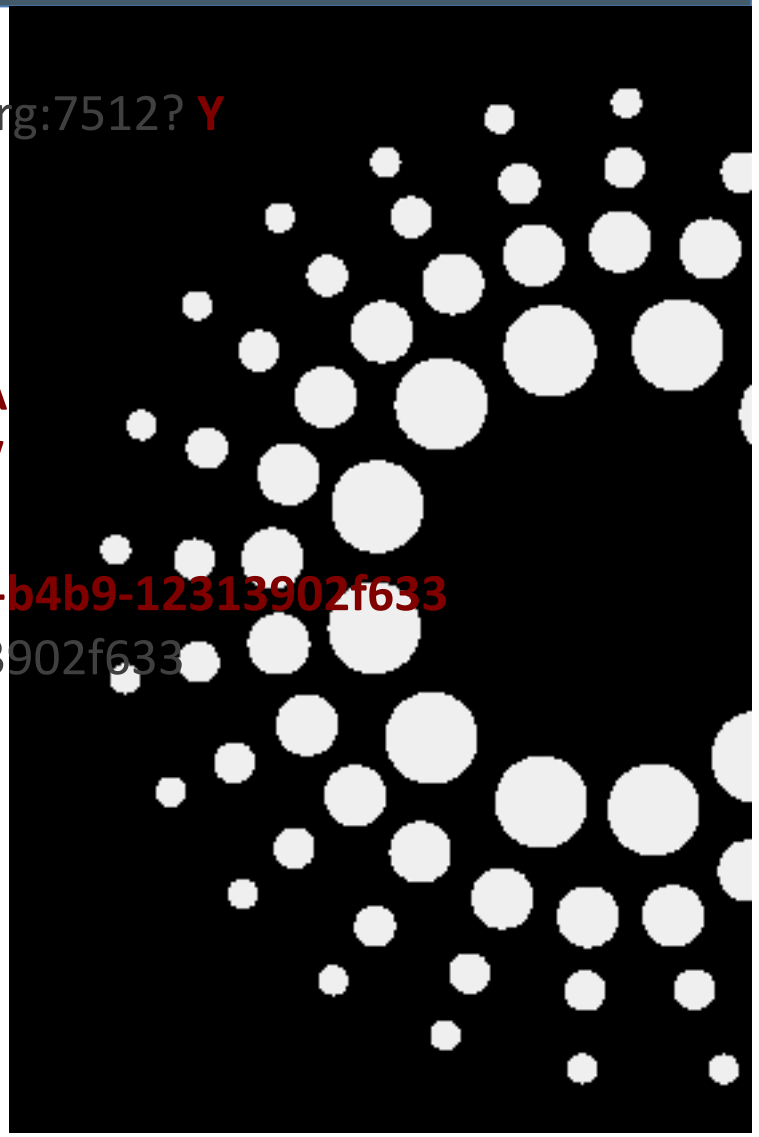
>**ssh -tdemo.globus.org activate**

Do you want to activate using myproxy myproxy.teragrid.org:7512? **Y**
MyProxy pass phrase: **************
A credential has been received for user dkdemo

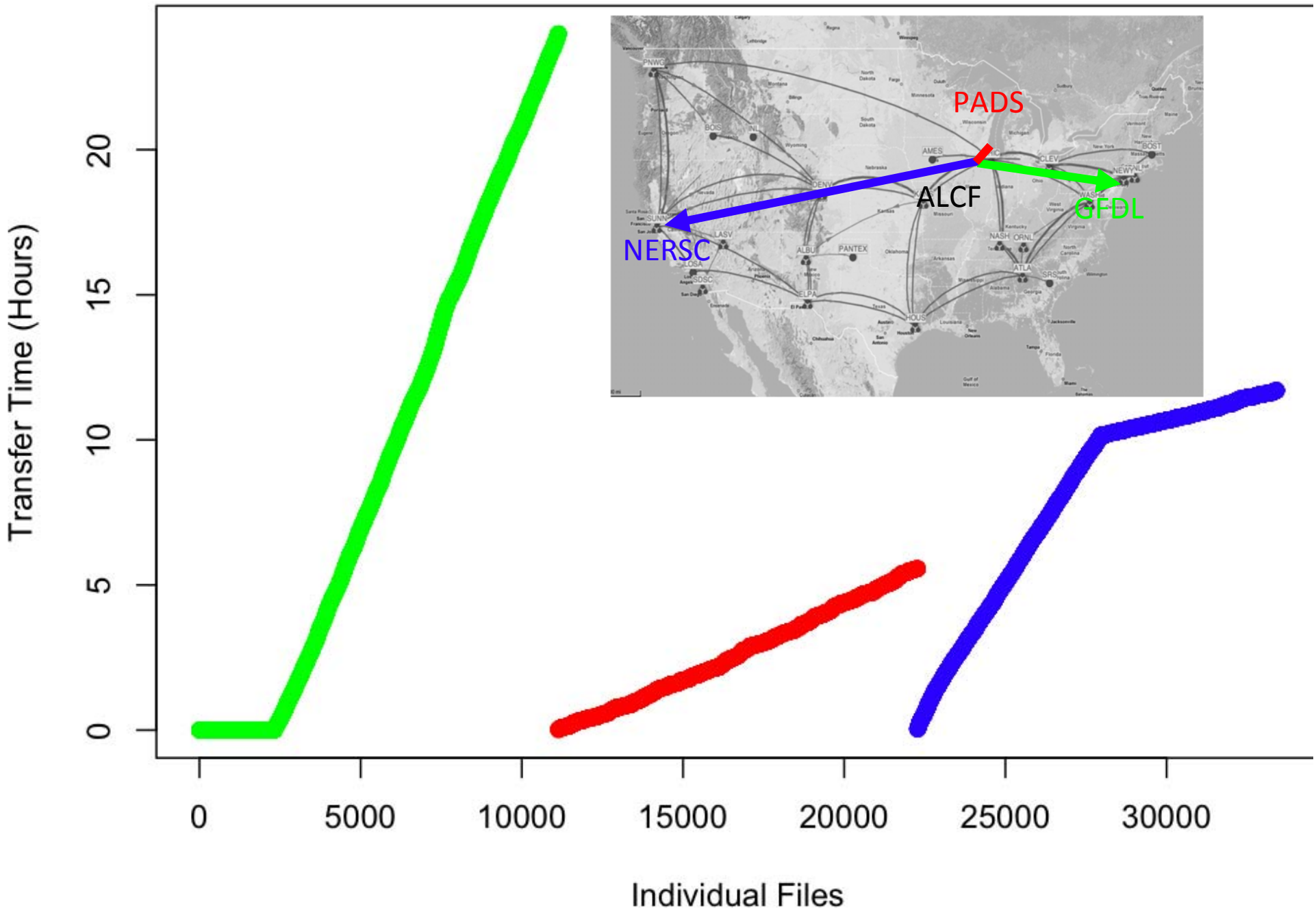
>**sshdemo.globus.orgxfer**
**abe.ncsa.teragrid.org:/u/ncsa/dk/send/train99 **
lonestar.tacc.teragrid.org:/home/01242/dk/recv

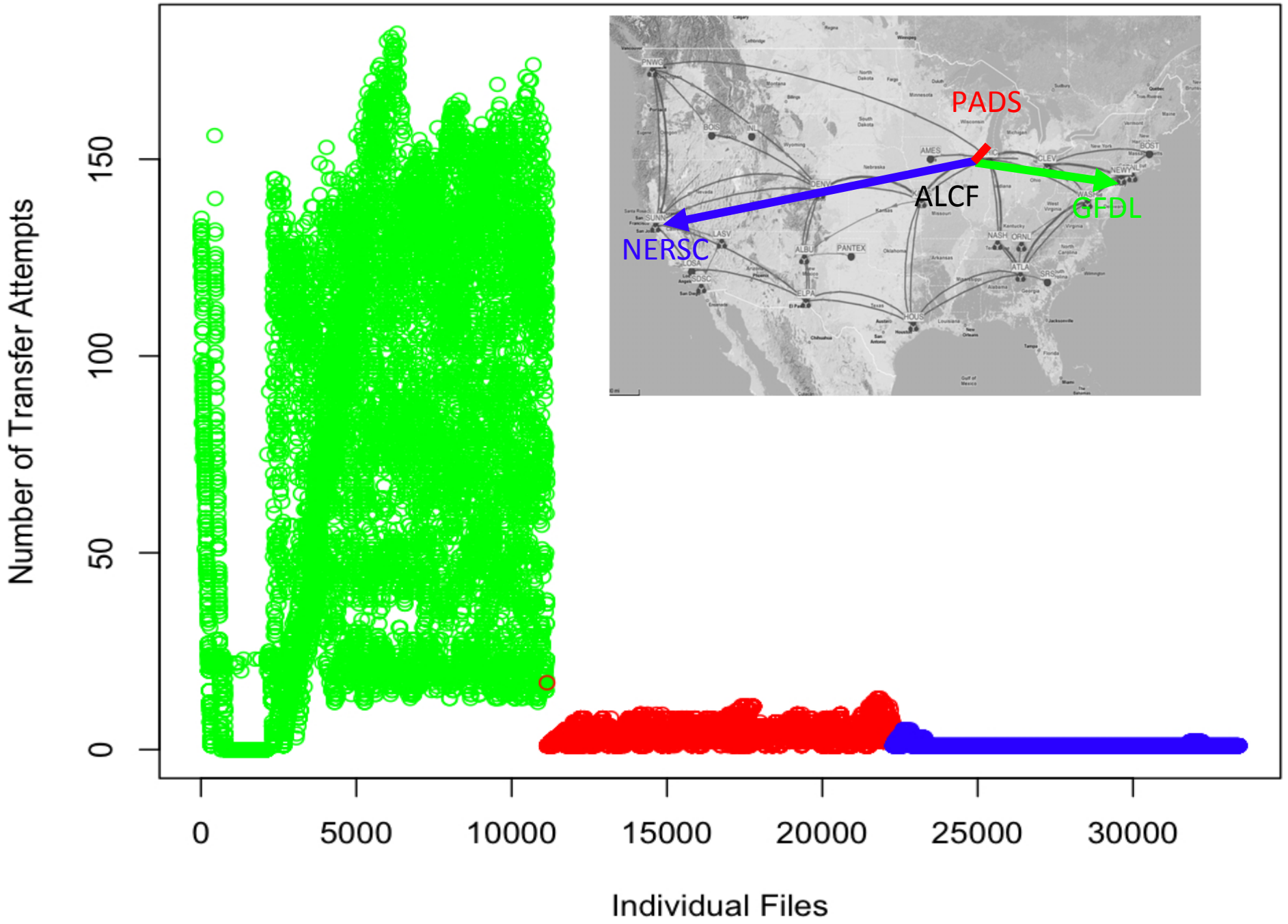
foo30e7b5ef-98bb-11de-b4b9-123139[illegible]02f633

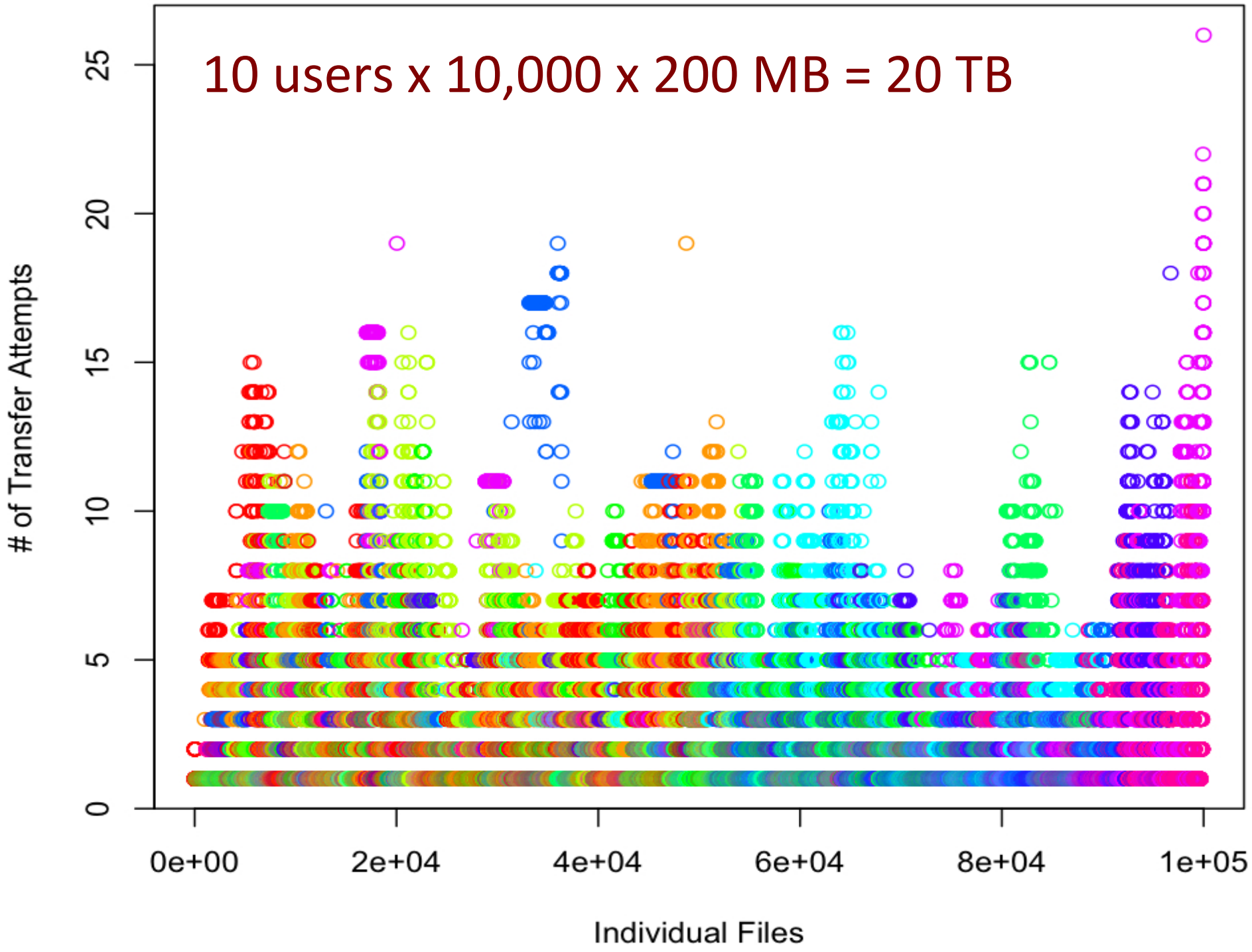
Using the CLI 2.0 interface

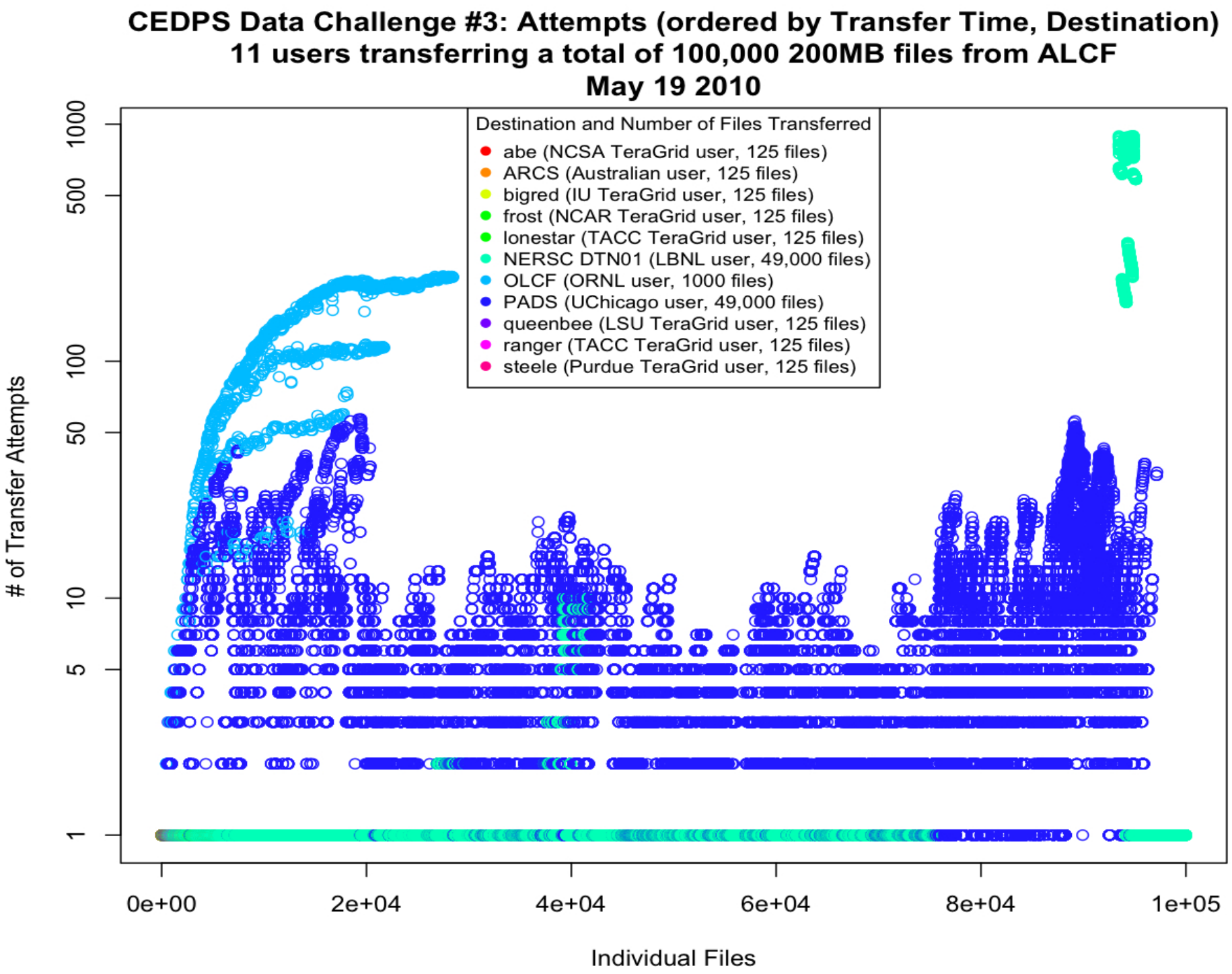


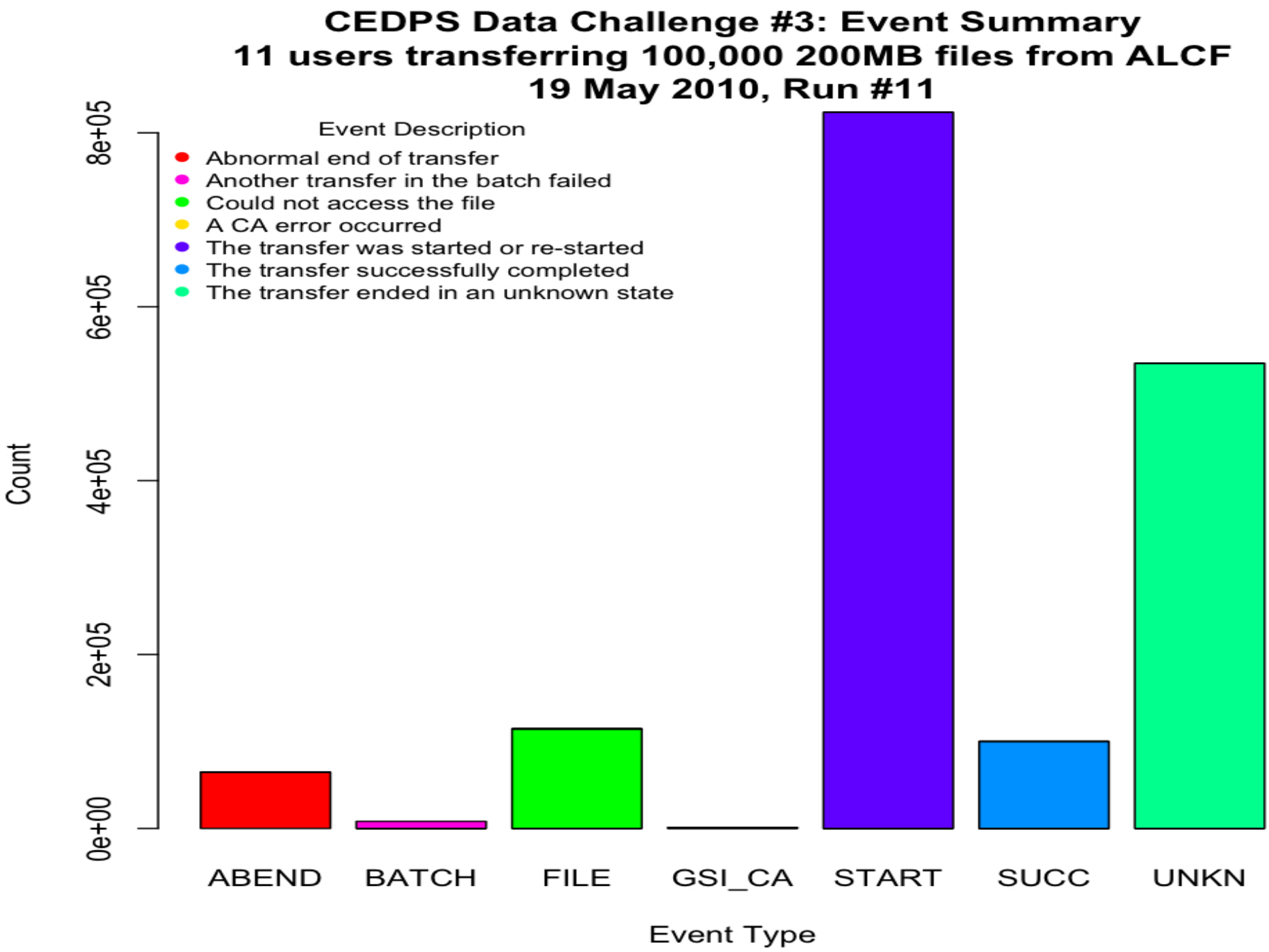
```
>ssh -tdemo.globus.org activate
    Do you want to activate using myproxy.teragrid.org:7512? Y
    MyProxy pass phrase: **********
    A credential has been received for user dkdemo
>sshdemo.globus.orgxfer
    abe.ncsa.teragrid.org:/u/ncsa/dk/send/train99 \
    lonestar.tacc.teragrid.org:/home/01242/dk/recv
    foo30e7b5ef-98bb-11de-b4b9-12313902f633
>ssh -tdemo.globus.org status 30e7b5ef-98bb-11de-b4b9-12313902f633
    uuid            : 3b13a3d4-98bb-11de-b4b9-12313902f633
    status          : COMPLETE
    source_host     : abe.ncsa.teragrid.org
    source_file     : /u/ncsa/dk/send/train99
    dest_host       : lonestar.tacc.teragrid.org
    dest_file       : /home/01242/dk/recv/foo
    last_event      : SUCCEEDED
    deadline        : 2010-05-01 18:54:38
```

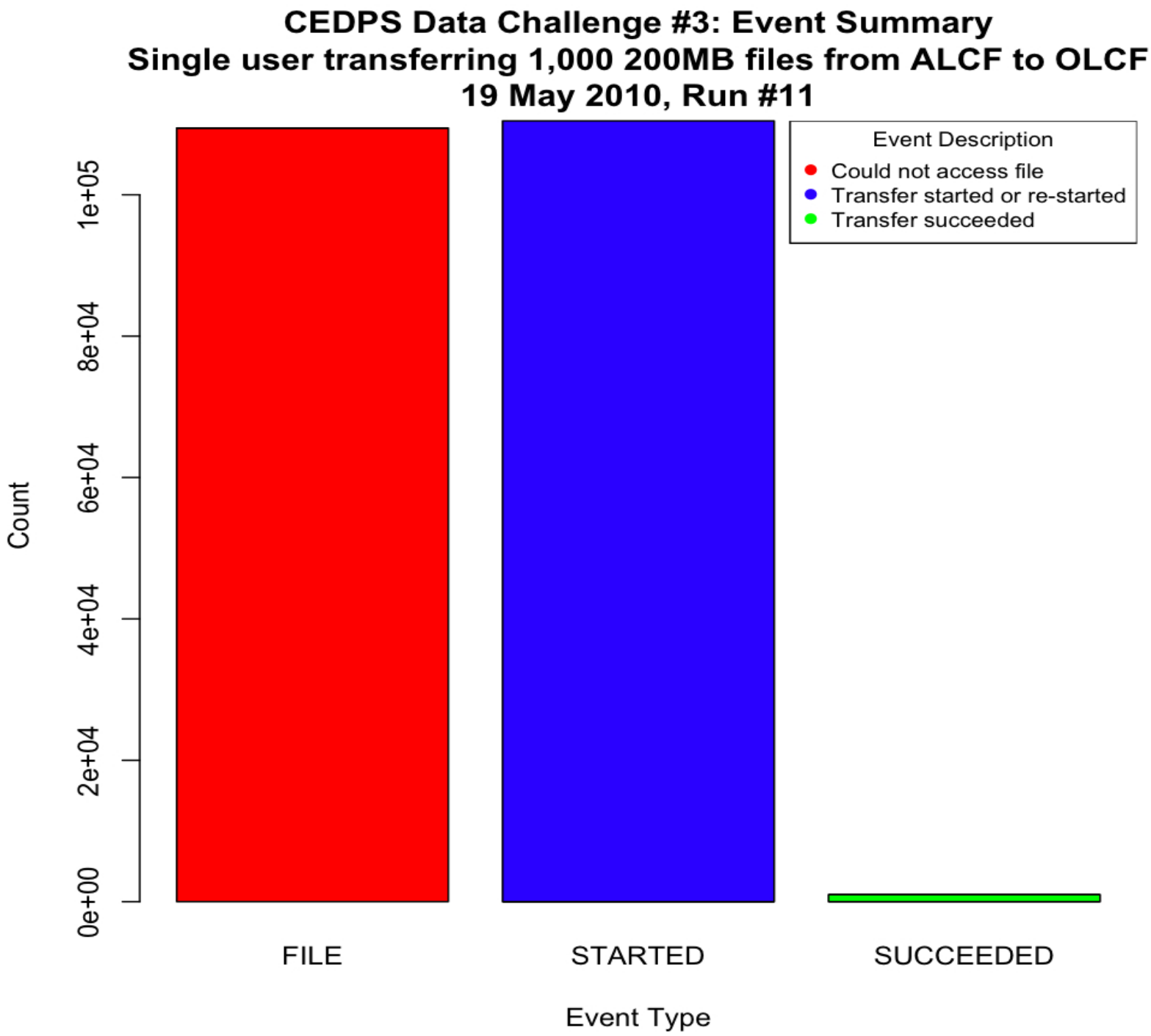

Transfer Time (Hours)
0
5
10
15
20
0
5000
10000
15000
20000
25000
30000
Individual Files
PADS
ALCF
NERSC
GFDL

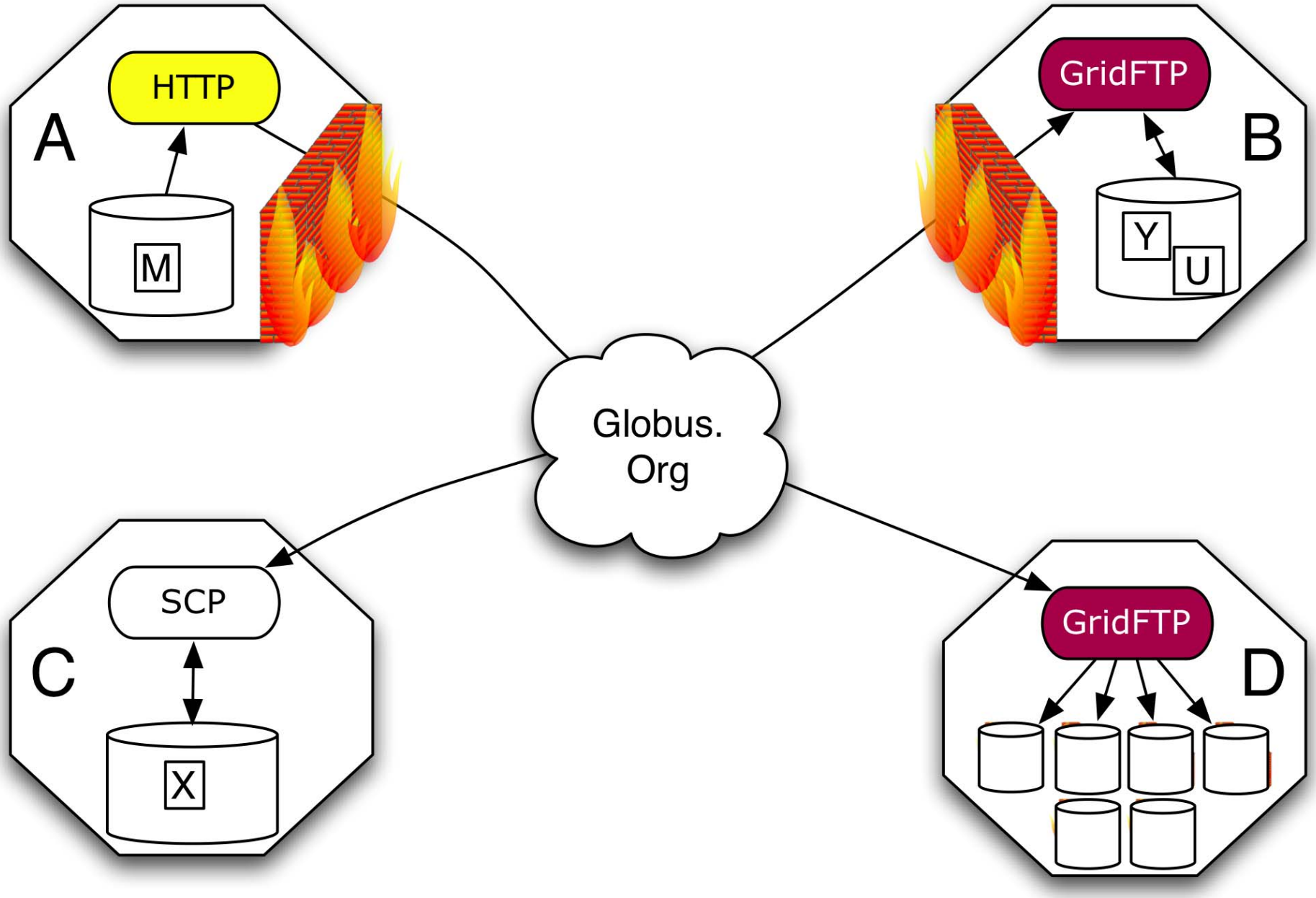

Number of Transfer Attempts
0
50
100
150
0
5000
10000
15000
20000
25000
30000
Individual Files
PADS
ALCF
NERSC
GFDL

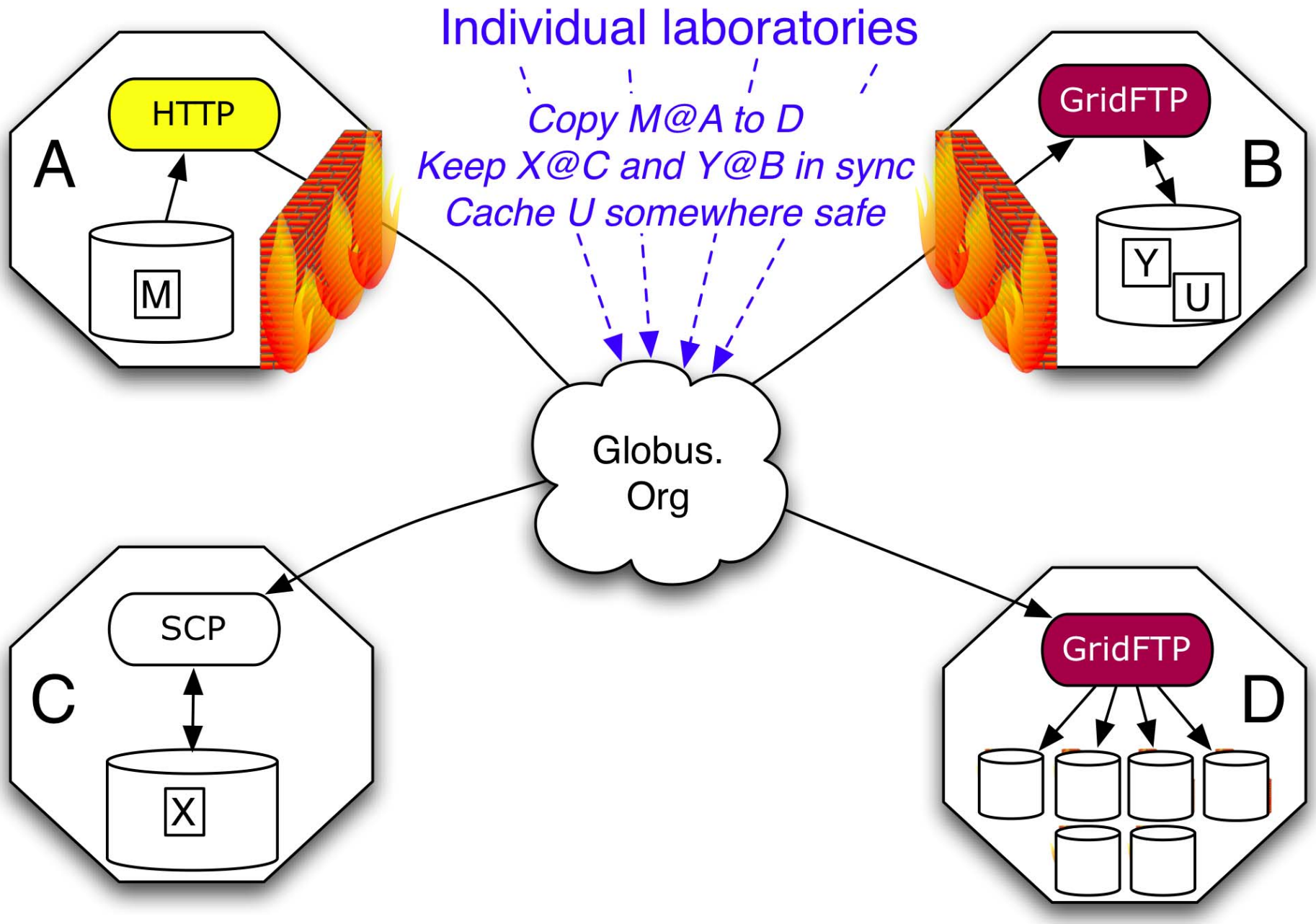

10 users x 10,000 x 200 MB = 20 TB
# of Transfer Attempts
0
5
10
15
20
25
0e+00
2e+04
4e+04
6e+04
8e+04
1e+05
Individual Files


CEDPS Data Challenge #3: Attempts (ordered by Transfer Time, Destination)
11 users transferring a total of 100,000 200MB files from ALCF
May 19 2010
Destination and Number of Files Transferred
abe (NCSA TeraGrid user, 125 files)
ARCS (Australian user, 125 files)
bigred (IU TeraGrid user, 125 files)
frost (NCAR TeraGrid user, 125 files)
lonestar (TACC TeraGrid user, 125 files)
NERSC DTN01 (LBNL user, 49,000 files)
OLCF (ORNL user, 1000 files)
PADS (UChicago user, 49,000 files)
queenbee (LSU TeraGrid user, 125 files)
ranger (TACC TeraGrid user, 125 files)
steele (Purdue TeraGrid user, 125 files)
# of Transfer Attempts
1
5
10
50
100
500
1000
0e+00
2e+04
4e+04
6e+04
8e+04
1e+05
Individual Files


CEDPS Data Challenge #3: Event Summary
11 users transferring 100,000 200MB files from ALCF
19 May 2010, Run #11
Event Description
Abnormal end of transfer
Another transfer in the batch failed
Could not access the file
A CA error occurred
The transfer was started or re-started
The transfer successfully completed
The transfer ended in an unknown state
Count
0e+00
2e+05
4e+05
6e+05
8e+05
ABEND
BATCH
FILE
GSI_CA
START
SUCC
UNKN
Event Type


CEDPS Data Challenge #3: Event Summary
Single user transferring 1,000 200MB files from ALCF to OLCF
19 May 2010, Run #11
Event Description
Could not access file
Transfer started or re-started
Transfer succeeded
Count
0e+00
2e+04
4e+04
6e+04
8e+04
1e+05
FILE
STARTED
SUCCEEDED
Event Type


HTTP
A
M
GridFTP
B
Y
U
Globus.
Org
SCP
C
X
GridFTP
D


Individual laboratories
Copy M@A to D
Keep X@C and Y@B in sync
Cache U somewhere safe
A
HTTP
M
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GridFTP
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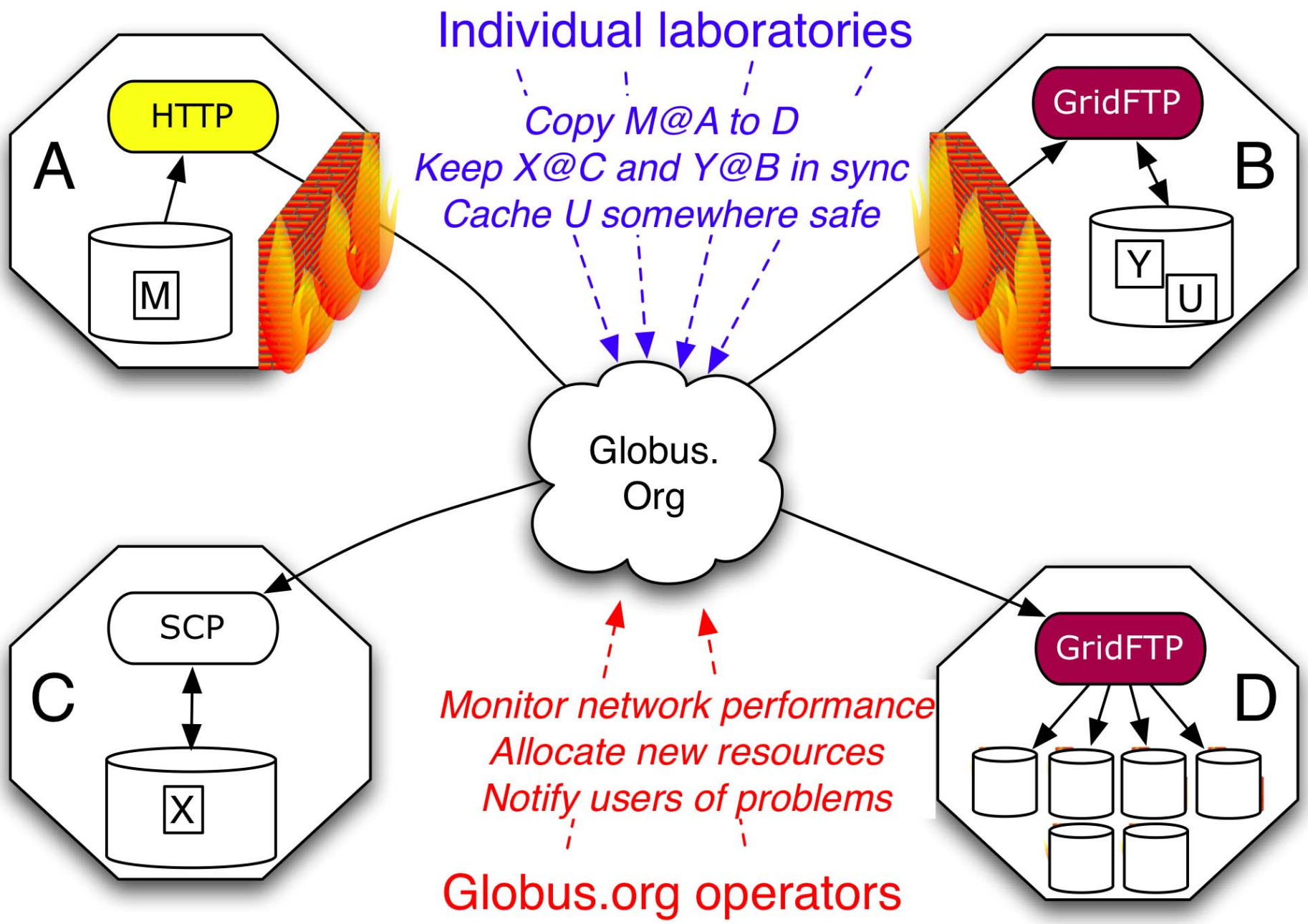
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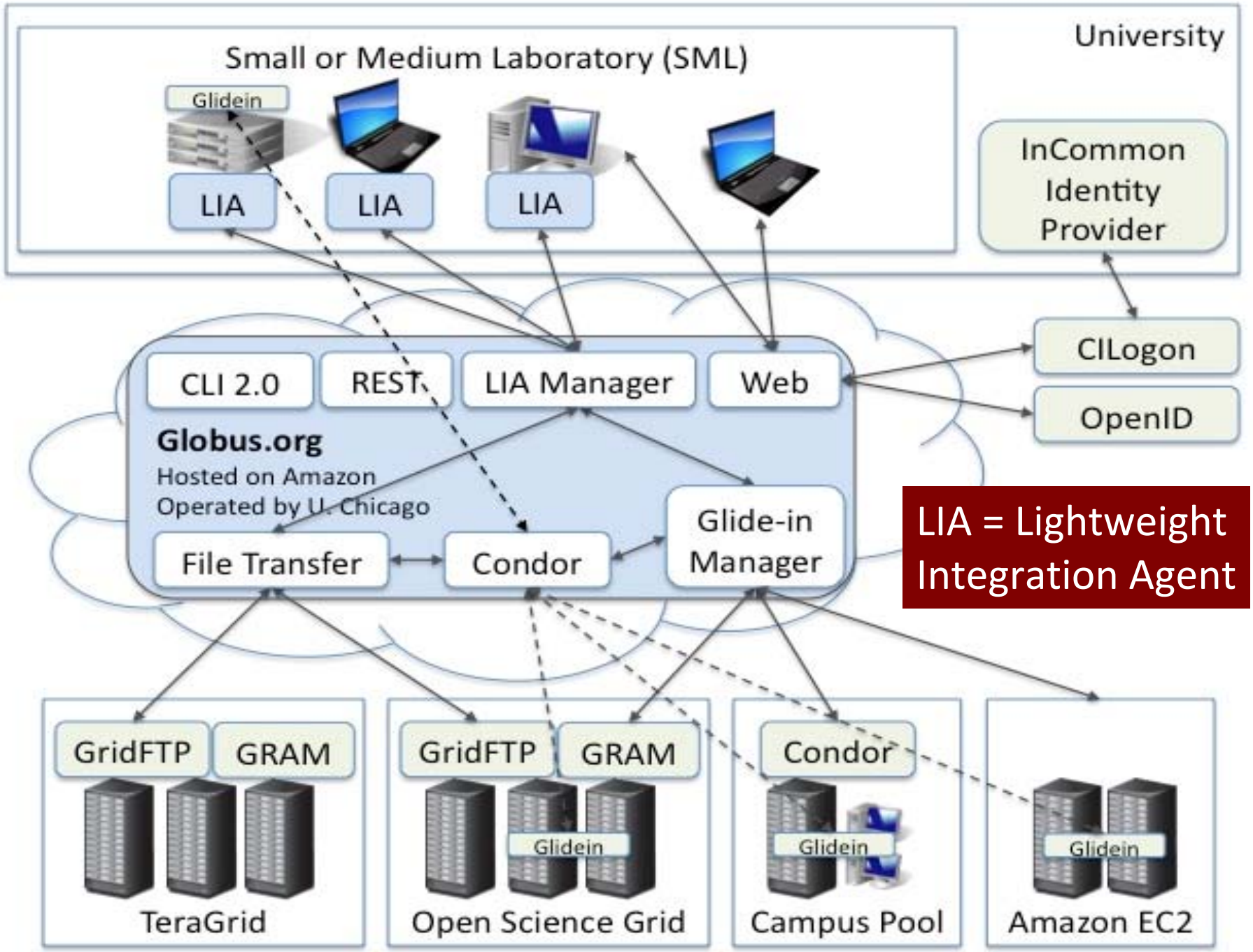
GridFTP
Monitor network performance
Allocate new resources
Notify users of problems
Globus.org operators

Thinking outside the box for science

- Run experiments
- Collect data
- Manage data
- Move data
- Analyze data
- **Run simulations**
- Compare experiment with simulation
- Search the literature
- Share results

- Communicate with colleagues
- Publish papers
- Find, configure, install relevant software
- Find, access, analyze relevant data
- Document research
- Order supplies
- …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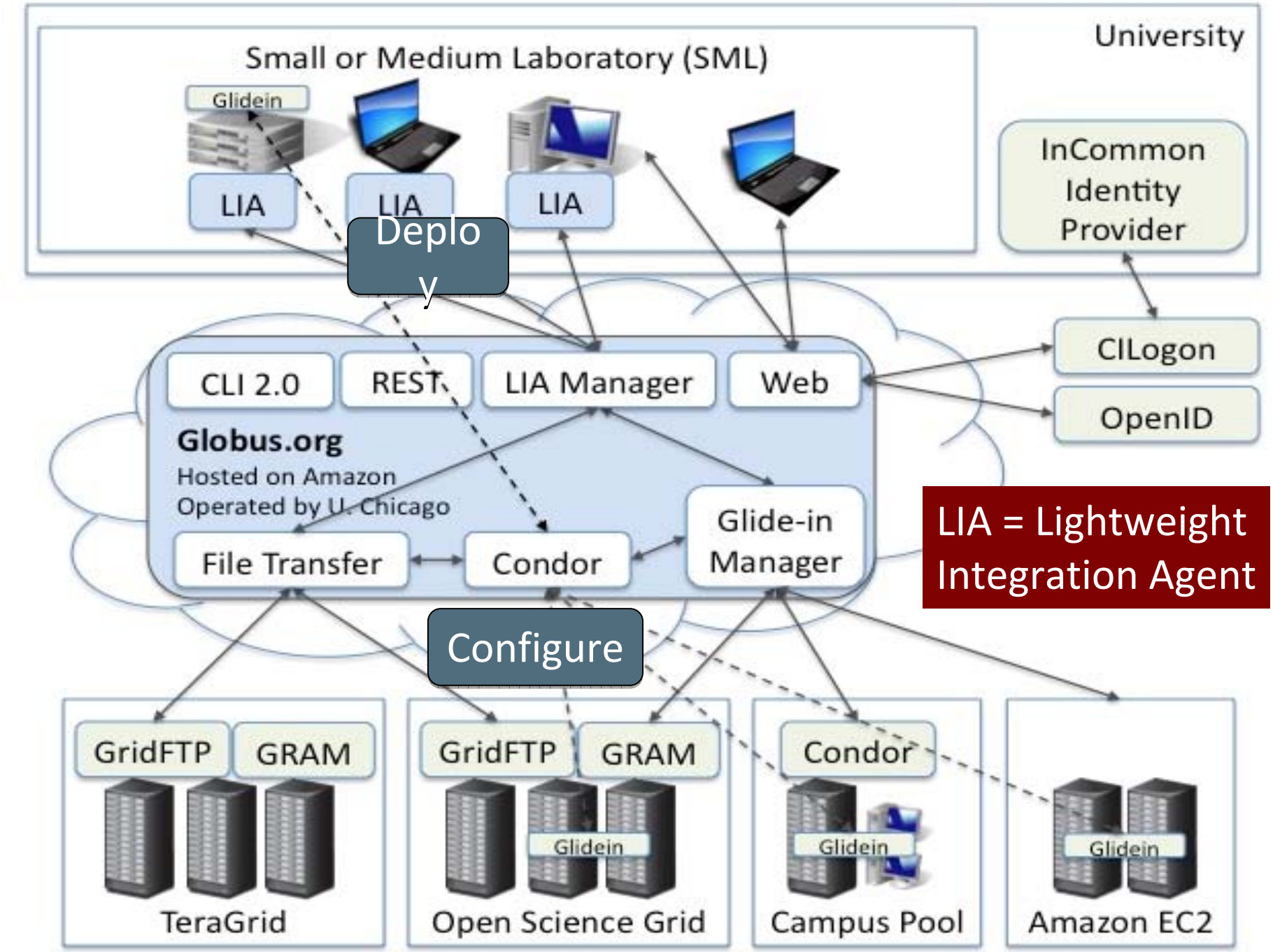
LIA
InCommon Identity Provider
CILogon
OpenID
CLI 2.0
REST
LIA Manager
Web
Globus.org
Hosted on Amazon
Operated by U. Chicago
File Transfer
Condor
Glide-in Manager
LIA = Lightweight Integration Agent
GridFTP
GRAM
TeraGrid
GridFTP
GRAM
Glidein
Open Science Grid
Condor
Glidein
Campus Pool
Glidein
Amazon EC2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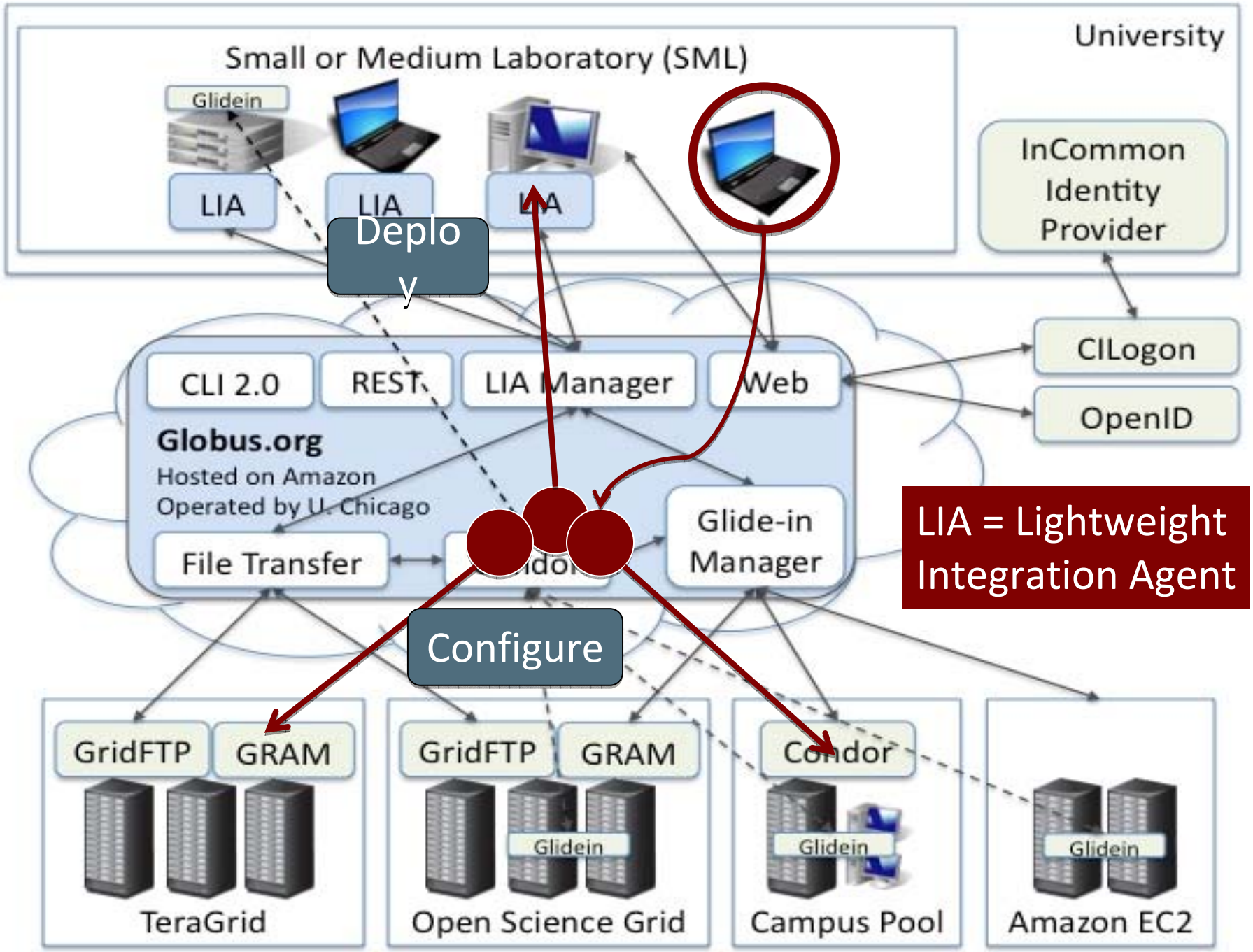
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Other Sci-SaaS services planned

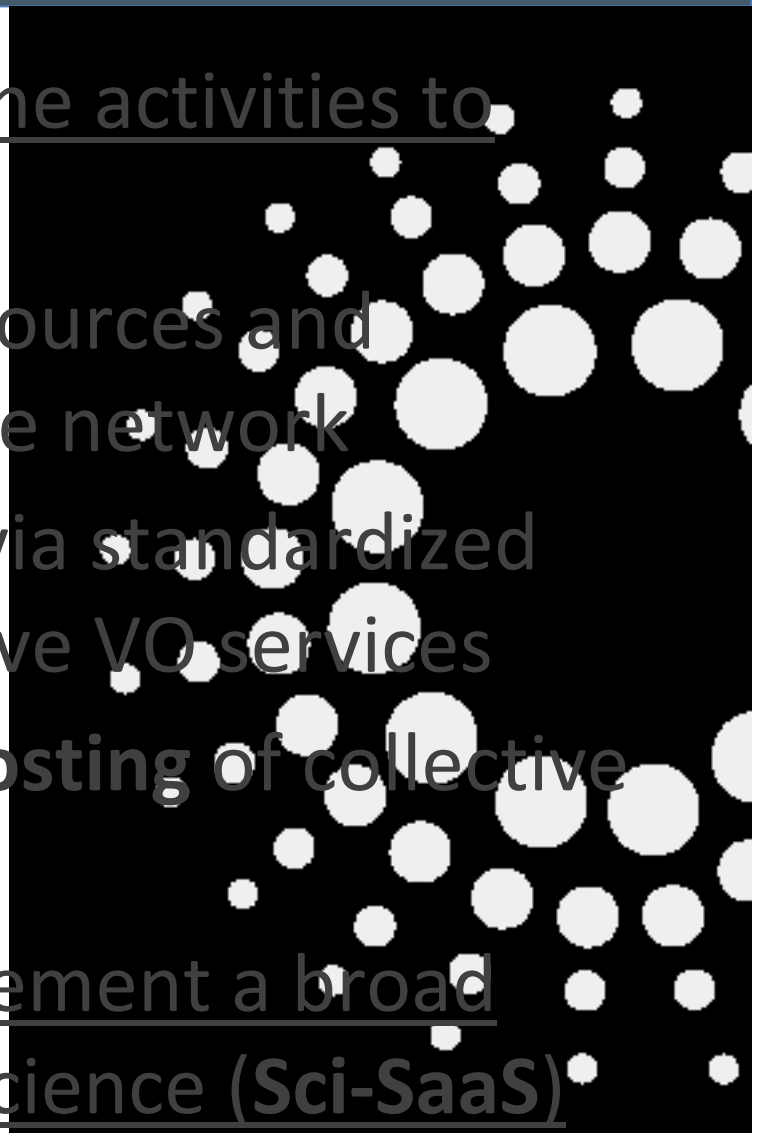
- VO management
  - Groups, membership, policies (via Grouper)
- Computation mgmt
  - Run this computation
  - Analyze any files deposited in directory
- Data management
  - Storage and indexing
  - Archiving and lifecycle
  - Publication and sharing
- Workflow management
  - Data ingest and analysis pipelines
- Meta-computations
  - Uncertainty quantification
  - Optimization

Looking for partners to, e.g.
- Expand set of services
- Host services in other geographies

A few words on Globus

- Use of all components growing
- Many new projects, esp. biomedical
- New software releases and services
  - GRAM5: modernized C-based GRAM2 (now)
  - Crux: next-gen services platform (soon)
  - Native packaging for all components (soon)
  - Globus.org (in alpha)
- Initiative for Globus in Europe (IGE)
  - www.ige-project.eu
- GlobusWorld in Chicago in Feb 2010

Summary: Thinking outside the box



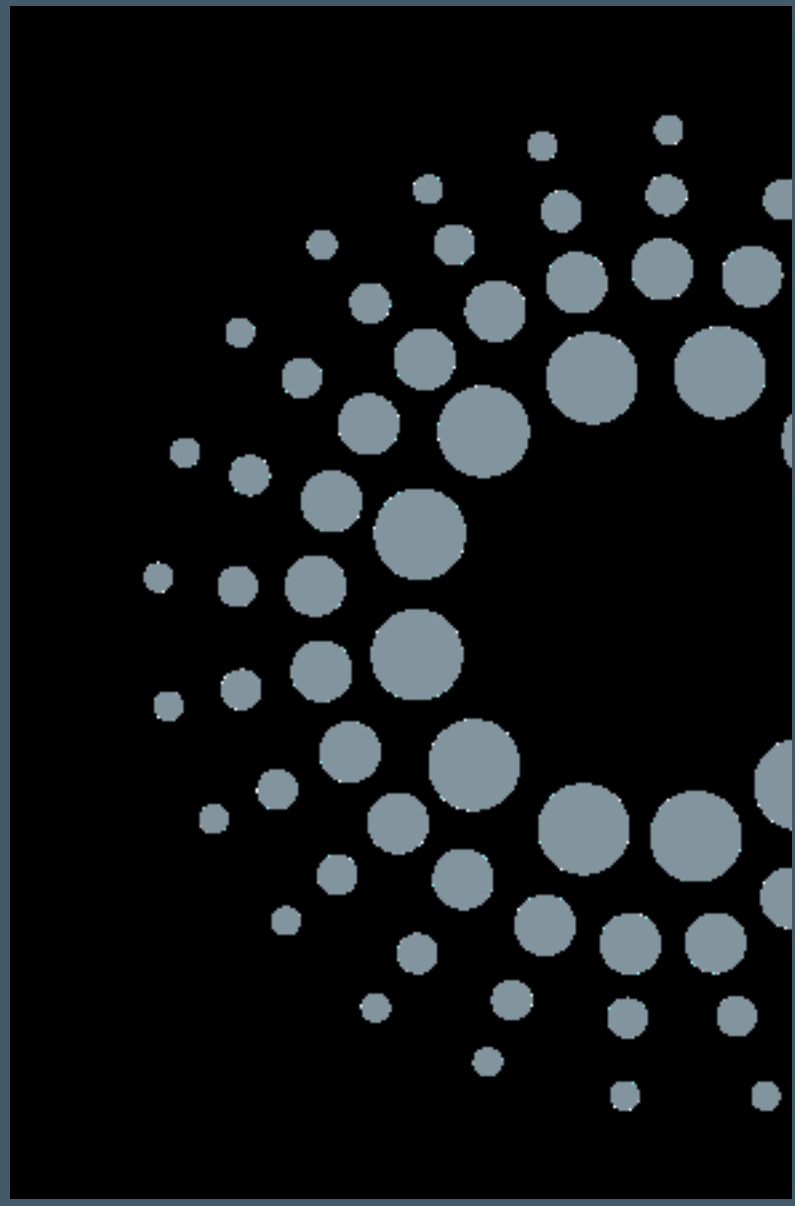
Outsource complex and mundane activities to third parties

- **Services** make distributed resources and capabilities accessible over the network
- **Grid** assists with **integration** via standardized service interfaces and collective VO services
- **Cloud** provides for scalable **hosting** of collective services

Globus.org services aim to implement a broad range of hosted services for science (**Sci-SaaS**)

Computation Institute

Thank you



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