The NASA/GSFC Advanced Data Grid: A Prototype for Future Earth Science Ground System Architectures

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TOPICS

OUTLINE

- Background and Motivation
- Grid Computing Concepts
- Advanced Data Grid (ADG) Prototype Development
- ADG Requirements and Operations Concept
- ADG Architecture
- ADG Implementation
- ADG Test Plans
- ADG Schedule
- Summary and Status

BACKGROUND and MOTIVATION

Science Mission Data Rates and Volumes

- Increased Data Rates (>10Mbps) from Remote Sensing and Earth Science missions
- Overall data volume for a typical 5 year mission duration > 1 peta-Byte (10^{12} bytes)
- Data Reprocessing Requirements can result in throughput as high as 20X real-time

Science Data Segment Workflow Management

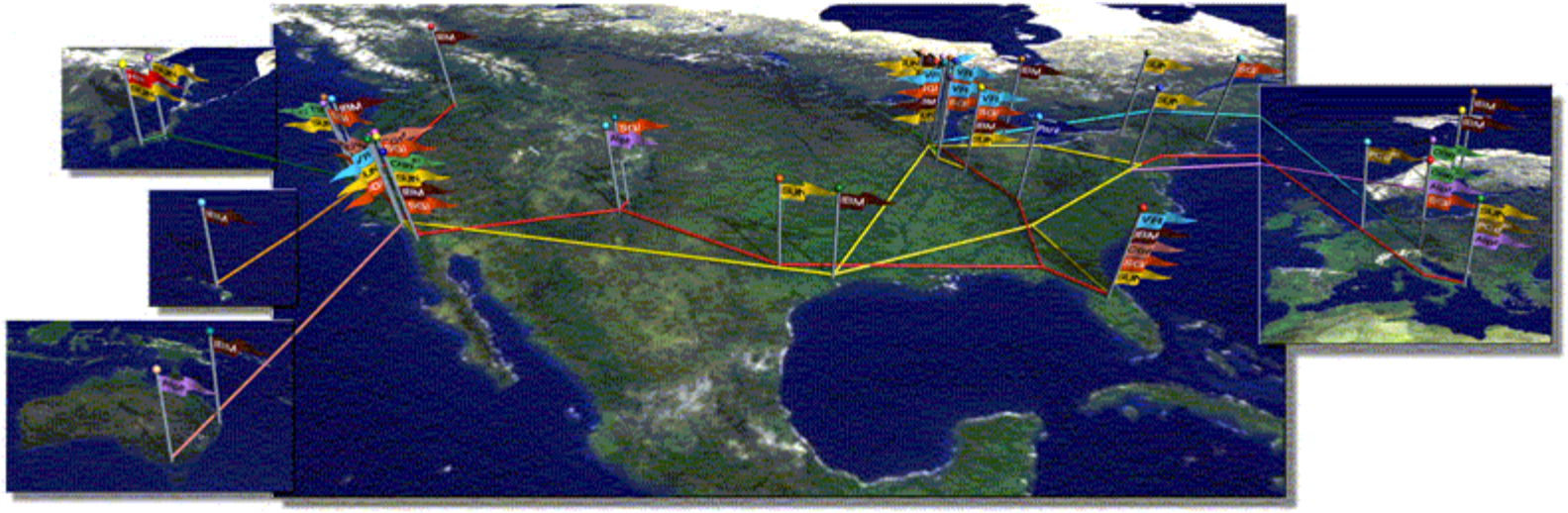
- Management and optimization of multiple data processing streams
- Increased need to provide data discovery and access to large, geographically distributed user community
  - Data discovery becoming more complex; need a solution that is scalable and will interoperate in a highly heterogeneous resource environment
  - Value added products and models are becoming more computationally intensive and data assimilation is becoming mainstream; e.g., climate models that use direct assimilation of satellite data
- Provide long term archive and retrieval of critical measurement data and make this data available for reprocessing

Science Data Segment Architecture and Implementation

- Grid Technology provides a new approach to the development of data system architectures
- New approach to data and computing intensive ground system architectures
- NASA and other large scientific organizations have started development of various types of distributed data processing and storage/retrieval systems using Grid technology
  - Particle Physics Projects, Earth System Modeling, Digital Sky Survey

ADG Prototype Project goal is to address sizing, performance and scalability of grid technology for a peta-byte class Earth Science ground system.

THE GRID COMPUTING CONCEPT



Enable the Sharing of Resources and Data

- **Workflow management beyond web services!**

Standardized resource discovery

- **Where's a machine of the right type and size?**

Standardized performance monitoring

- **What's the current machine and network load?**

Strong authentication with X.509 certificates

- **Are you allowed to use this machine?**

Standardize Information and Data Discovery

- **Maximize use of metadata**

THE GRID COMPUTING CONCEPT

- **Concept arose from the need to manage, large, distributed systems**
  - **The term "Grid" is an analogy with the Electrical Power Grid which made electrical power easy to use and widely available**
  - **Grid computing endeavors to deploy a large-scale infrastructure with distributed services that are easy to use and widely available**
- **Driven by:**
  - **Cost/size reductions in computing H/W to the point of "commodity" components**
  - **Ability to aggregate components to achieve significant performance at modest cost ("supercomputer" for ~$100K)**
  - **Expansion and ubiquity of high-speed networks – *everything is connected***
- **Grid Computing**
  - **A service infrastructure that provides dependable, pervasive and inexpensive access to computation resources**
  - **Heterogeneous, distributed, networked computing**
  - **Flexible integration of all manner of compute resources**
  - **Creation of *Virtual Organizations***
- **Specific Projects**
  - **Globus, Legion, Condor, NASA IPG, Particle Physics Data Grid, Earth System Grid, and many others.**
- **Key Resources for the ADG Prototype**
  - **Data storage, management, discovery and manipulation (sub-setting and retrieval)**
  - **Computational resources for data processing and modeling**

THE GRID COMPUTING CONCEPT

What is a Data Grid?

- Data Grids leverage Grid Computing technology to provide transparent local/remote access to heterogeneous data resources in a Grid environment

Capabilities

- Very large data sets
- Metadata Catalog
- Uniform, abstract view of data
- Multiple storage back-ends
- Local and remote filter/streaming access
- Data replication/caching
- Scalability
- Security

Many Funded Grid and Data Grid Projects

- See www.gridforum.org/Documents/Drafts

GRID COMPUTING TECHNOLOGIES

Grid Computing Requires a variety of enabling technologies

- Distributed Information Services
- Information Metadata Schemas
- Resource Discovery and Scheduling
- Information and Resource Brokers
- Management of Very Large Data Stores
- Event Services
- Messaging Services
- Web-Enabled Services
- Performance Monitoring Tools
- Quality of Service
- Fault Tolerance
- Security: Authentication and Authorization

ADG PROTOTYPE DEVELOPMENT

Development of a Data Grid Prototype

- Address Science Data Segment Ground System Workflow management using Grid Technology
- Address Sizing and Scalability of the Architecture

Approach to ADG Prototype Development

- Develop top-level prototype requirements and Operational Concept (OpsCon)
- Define Architecture based on requirements and Grid Technology
- Define specific prototype design based on this architecture and constrained by:
  - Resource availability
  - Project Duration
  - Cost
- Implement the prototype design
- Perform prototype testing and performance evaluation
- Report Results

REQUIREMENTS AND OPSCON

ADG Project Goal

- **Assess scalability of Grid Technology for Earth Science Data Segment**
  - **Assess performance of specific implementation and identify limitations in various layers of the Grid architecture**
  - **Experiment with different approaches to overcome these limitations**

Requirements

- **Project Goals and Requirements were drawn from several sources**
  - **NPP Requirements provide one example of a near term system that will generate peta-bytes of data during its 5 year mission**
  - **Other studies by NASA and NRC for Earth Science Data Systems (see references**
- **To further specify the prototype we developed several operations concept "scenarios"**
  - **Scenarios describe how the system will be used; Science Data Segment workflow and data life cycles**
  - **Based on NPP OpsCon and current NASA Data Archives**
  - ***Mimic* typical scenarios for future remote sensing and Earth science ground systems**
- **Used to define the prototype architecture**
  - **Map these requirements into a Grid Architecture based on defined services and derived resource requirements**
  - **Architecture should also support testing**

REQUIREMENTS AND OPSCON

Example Requirements

- Data Ingest and Processing (raw and derived products)
- Provide access to derived data products from on-line mission storage
- Provide access to derived products data products from long term archival storage
- Provide search/retrieval access to mission storage for ~20 science team members
- Provide Near-line Storage for ~2.9 pB (5 year mission life)

Example OpsCon Scenarios

- Level 1 Data Ingest
- Cal/Val Data Processing
- Climate Data Processing
- General Science User Data Discovery and Manipulation
- Data Reprocessing

Data Life Cycle Simulations

- 1, 5 and 10 Days
- Match Data Rates and Data volumes (with replay)

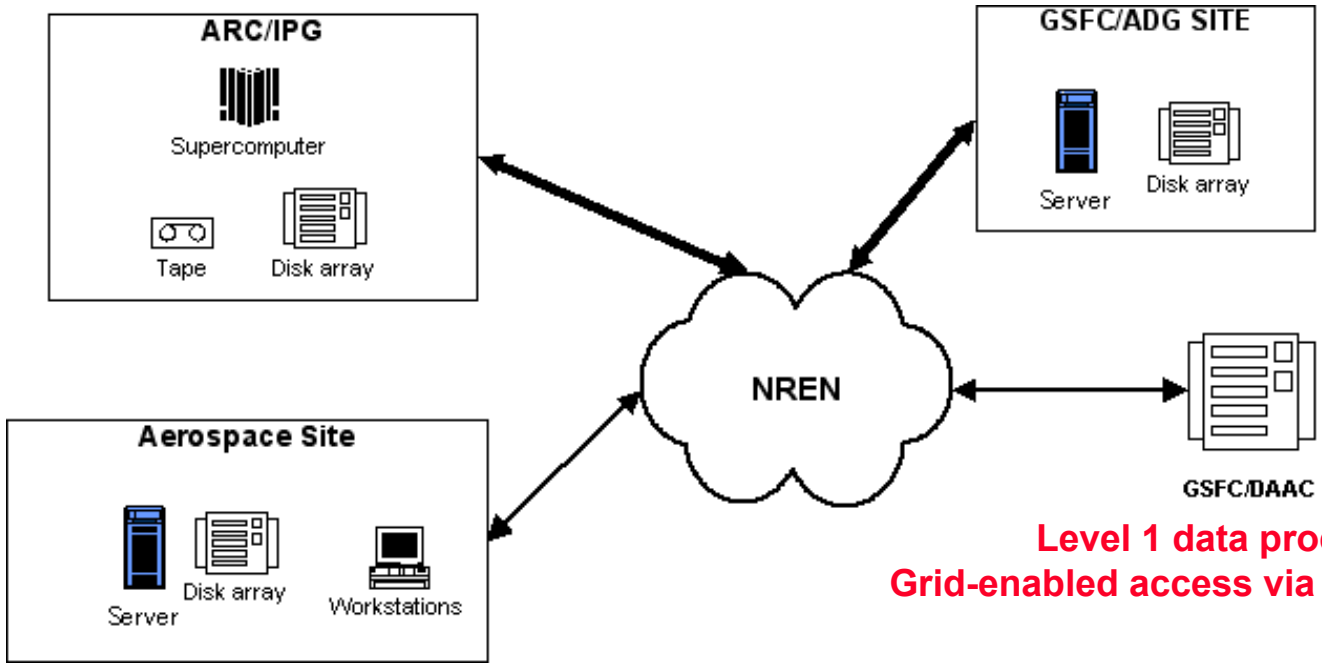
Data Processing Analysis

REAL-TIME PROCESSING				
Data Type	**GB/Day**	**Data Rate (MB/sec)**	**Data Rate + 25% Margin (MB/sec)**	**2 Days of Data (GB)**
L0	300	3.47	4.34	750
L1A	259.2	3.00	3.75	648
L1B	451.2	5.22	6.53	1128
L2	23.3	0.27	0.34	58.25
L3	98	1.13	1.42	245
TEU	15	0.17	0.22	37.5
Ancillary Data	5	0.06	0.07	12.5
	1151.7		**16.66**	**2879.25**
86400	**second/day**			
REPROCESSING				
Reprocessing Ratio =	**20**			
Reprocessing Data Rate (MB/sec)	**333.25**			
Data Volume (2 Days) (TB)	**57.585**			

ADG ARCHITECTURE OVERVIEW

ADG Certificate Authority
Computing Resources
Tape Archive

Primary On-line Data Store
SRB/MCAT Site



Level 1 data processing site
Grid-enabled access via Data Pool prototype

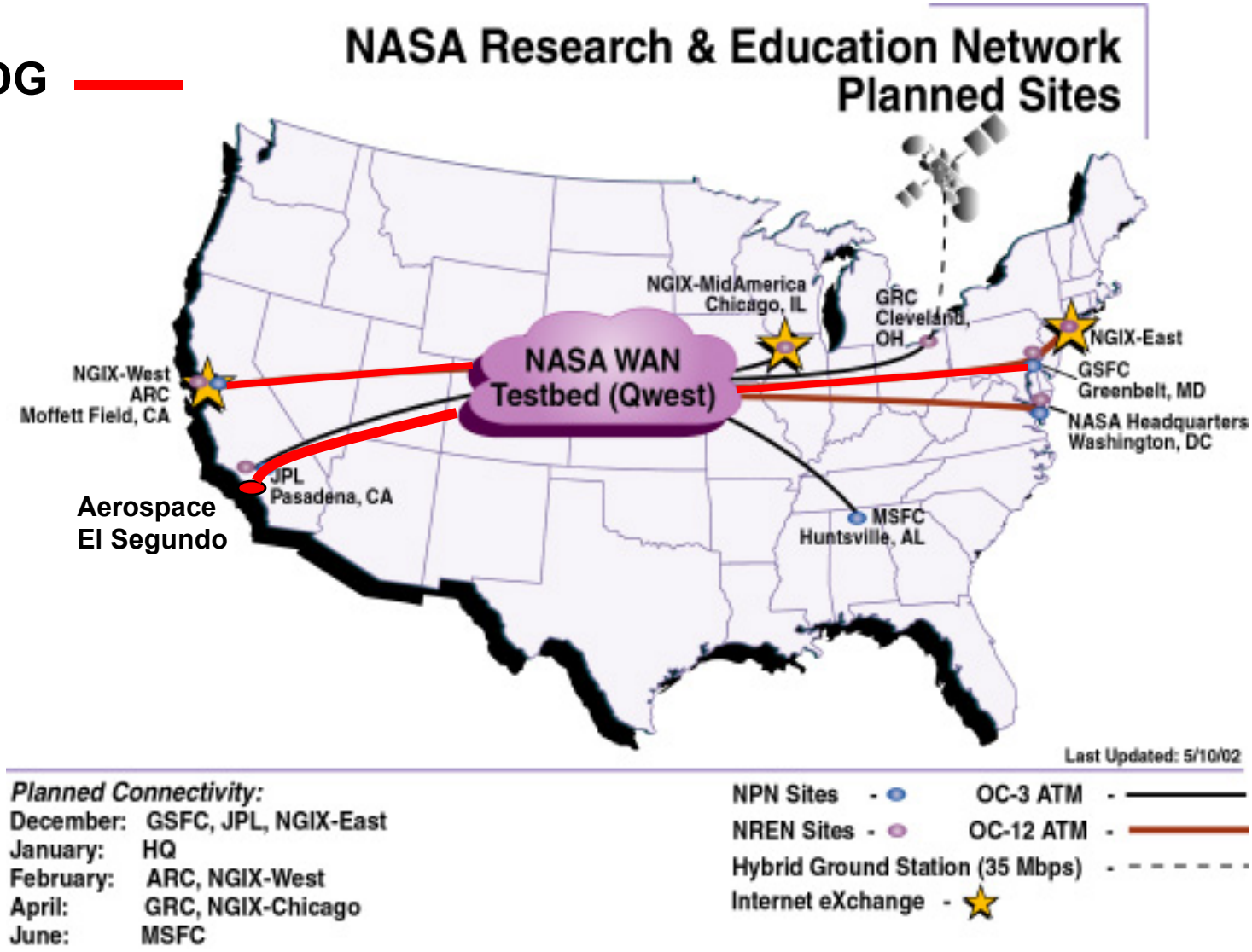
Science User Simulation
Application Development and Testing

All sites include

- **Common grid S/W: Globus, SRB Clients, etc.**
- **Performance monitoring tools**

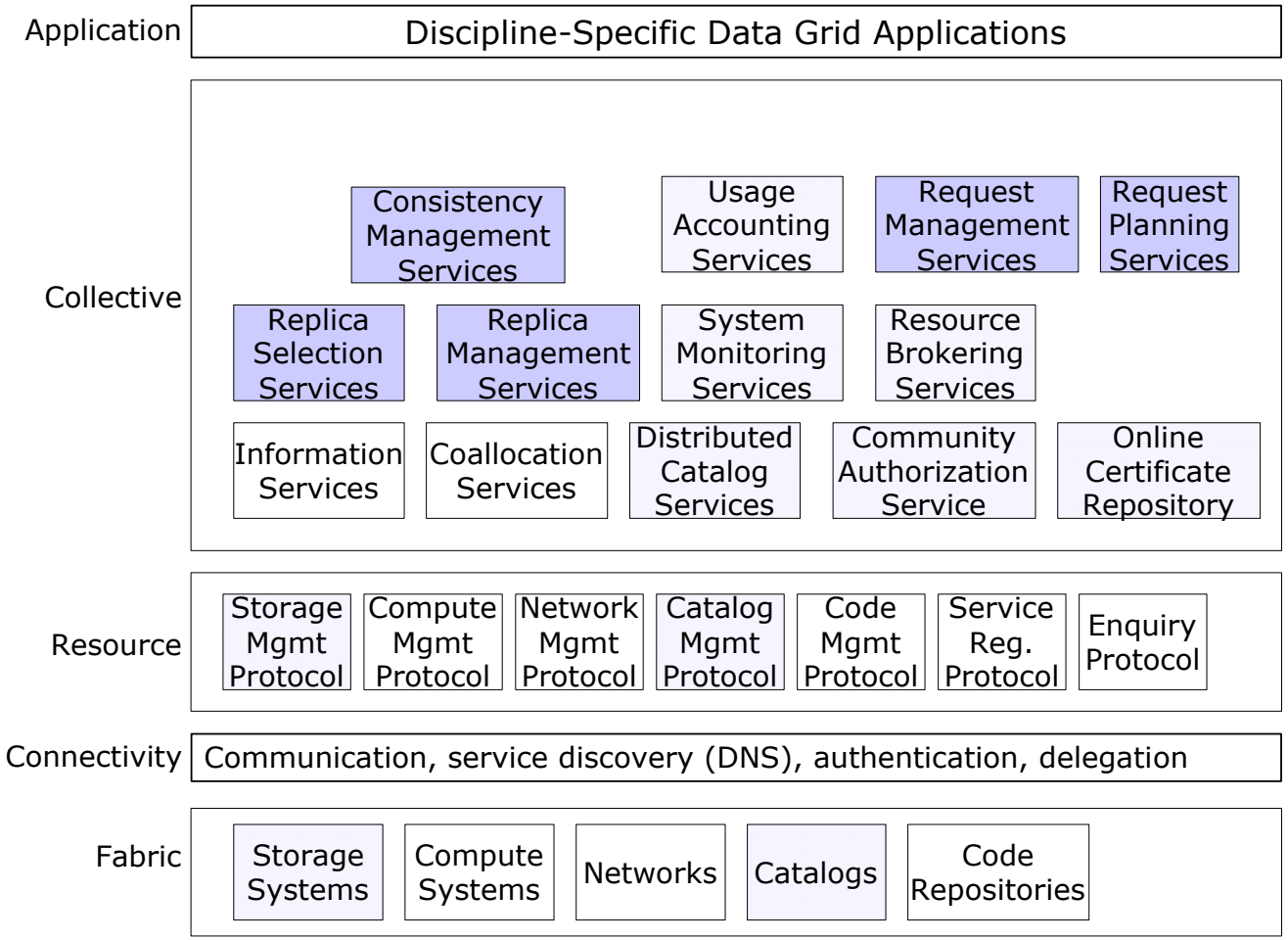
Hosting the ADG on NREN

ADG ——



ADG ARCHITECTURE "Layer" Diagram

–"…Major Data Grid Reference Architecture elements, showing how they relate to other Grid services. Shading indicates some of the elements that must be developed specifically to support Data Grids." – From Ref. 1



From Ref. 1

ADG TEST PLANS

Driven by Requirements and OpsCon Scenarios (Data Life Cycles)

Example Test Plans

- **Level 1 Data Ingest**
  - **Data Pool site is treated as the ADG Level 1 processing site with only short term data storage**
  - **Ingest L1 data from Data Pool short term storage to ADG On-line mission storage [GSFC/ADG]**
  - **Transfer L1 data from on-line mission storage to archive storage [ARC/IPG]**

- **Cal/Val Data Processing**
  - **Cal/Val Process collects satellite data and collocated in-situ measurement for the Calibration and Validation of various data products**
  - **Ingest Calibration Level 1 data from Data Pool; Simulate Field Campaign in-situ data [GSFC/ADG]**
  - **Aerospace Site will act as Science user performing Cal/Val functions**
    - Request sub-set of Calibration Level 1 data that matches up (spatial/temporal) with field campaign in-situ data
    - Transfer sub-set L1 data and field data from mission storage [GSFC/ADG] to Aerospace working data cache

ADG TEST PLANS

Example Test Plans (cont)

- **Climate Application Processing**
  - **Demonstrate an actual application using MODIS data to generate a climate data product (CDP)**
  - **Aerospace Site will act as Science user performing CDP generation functions using ADG resource**
    - Develop CDP application software that can be run on available ADG compute resources
    - CDP Application will request transfer of required data to data cache collocated with compute resources
    - CDP Application results will be transferred back to mission storage [GSFC/ADG] and to archive storage [ARC/IPG]

ADG SCHEDULE

Project Schedule

- Four Phases over 3 years
- Phase I: Initialization
  - Install and test H/W and S/W at each site, as required
  - Local and some interface testing
  - Security implementation; Certificates issued
- Phase II: Baseline
  - Testing of basic Grid interoperability
  - Grid Security Testing
  - ADG Prototype Benchmark testing
  - Data acquisition
- Phase III: Grid Testing
  - Full-up Test and Measurement of the ADG
  - Exercise Science Data Segment Workflow
- Phase IV: Application Demonstration
  - Continued grid testing
  - Demonstration of a grid enabled science application

STATUS and FUTURE POTENTIAL

Status

- ADG is currently in Phase I: Initialization
- ADG Working Group formed from member organizations
  - GSFC, ARC, NREN, Aerospace
- Hardware being installed at GSFC/ADG Site
- SRB/MCAT installation and training expected March 2003
- Data Pool capability expected sometime in 2003
- Aerospace working towards NREN connectivity

Future Potential

- Grid computing technology may become a key architecture and design tool for large-scale, distributed systems
  - Uniform access to very large data stores
  - Share compute power across an enterprise
  - Enable systems to be more easily interoperable
  - Avoid stove piped systems
- All major vendors have announced support for the Globus toolkit
  - Sun Microsystems, IBM, Microsoft, Cray, SGI, Compaq, Fujitsu, Hitachi, NEC, Entropia, Platform Computing
- Commercial web services development will also drive commercial grid development
- ADP is a key demonstration prototype for future ground systems architecture and design

REFERENCES

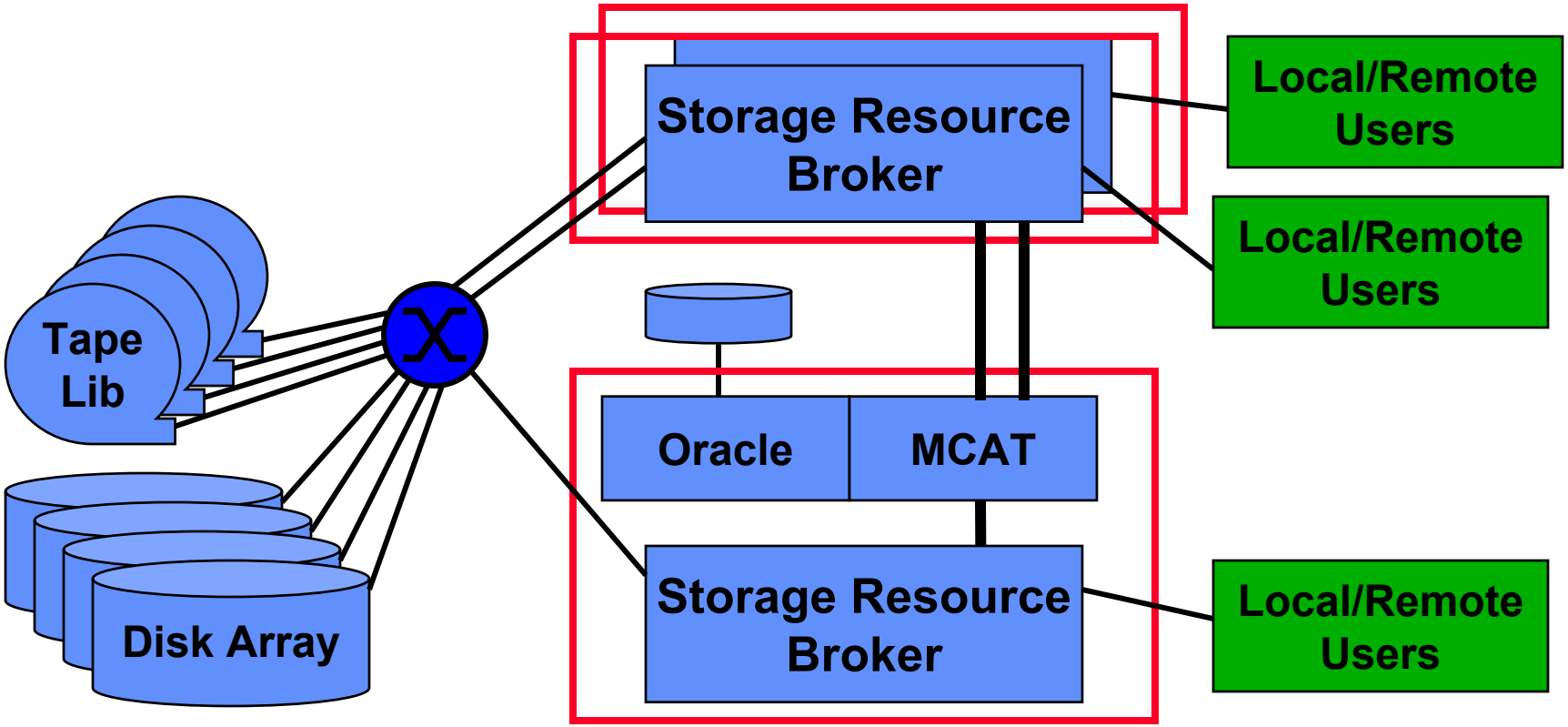
1. *A Data Grid Reference Architecture* (Draft of February 1, 2001), Ian Foster, Carl Kesselman (see http://www.ppdg.net/archives/ppdg/2001/doc00013.doc)
2. Global Grid Forum: http://www.gridforum.org/
3. NPP Web Site: http://jointmission.gsfc.nasa.gov/
4. Globus Web Site: http://www.globus.org/
5. Ensuring the Climate Record from the NPP and NPOESS Meteorological Satellites, Committee on Earth Studies Space Studies Board Division on Engineering and Physical Sciences, National Research Council (2000). See http://www.nas.edu/ssb/cdmenu.htm

Acronyms

ADG	Advanced Data Grid
CEOS	Committee on Earth Observation Satellites
GSFC	Goddard Space Flight Center
ARC	Ames Research Center
IPG	Information Power Grid
NREN	NASA Research and Education Network
NASA	National Aeronautics and Space Administration
NRC	National research Council
MCAT	Metadata Catalog
QoS	Quality of Service
SRB	Storage Resource Broker
H/W	Hardware
S/W	Software

Backup Charts

The Storage Resource Broker -- SDSC



- Data can be stored on any type of device, either locally or remotely

- The SRB provides a uniform view of all data to both local and remote users in a grid environment
- SRBs maintain a Metadata Catalog of all data using a back-end database
- Multiple SRB servers may be federated

Grid Workflow Management

Dynamic organization of computing services

- Applications can be built with organizational decisions "hard-coded"
- Workflow enables this to be decided "on-the-fly"

Creation

- Eager vs. lazy binding of service to physical resources

Discovery

- Eager vs. lazy binding of workflow to service

GSFL -- Grid Services Workflow Language

- An extension over web services

"GSFL: A Workflow Framework for Grid Services"

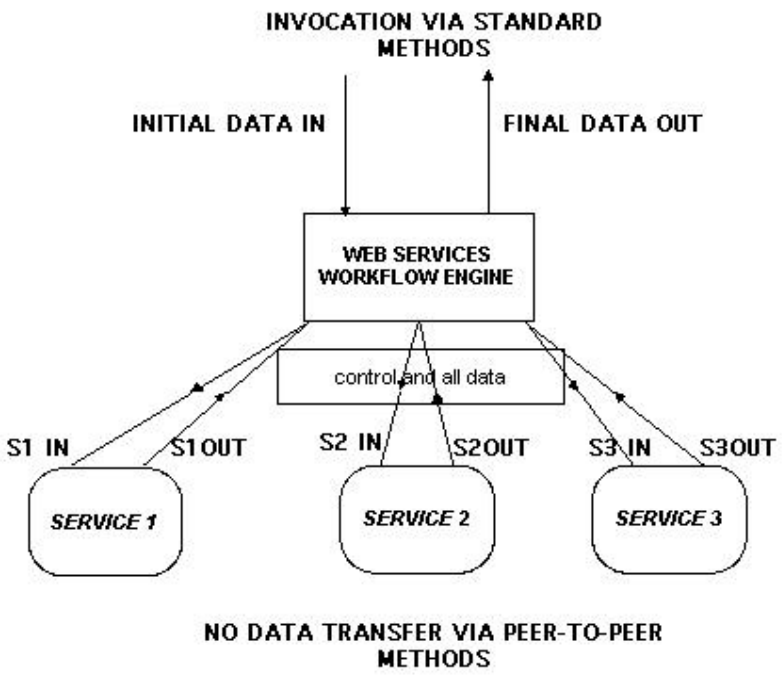
- S. Krishnan, P. Wagstrom, G. von Laszewski
- Argonne National Lab

"A Grid Workflow Management Architecture"

- Dan C. Marinescu
- University of Central Florida

Comparison of Workflow

Web Services Workflow



Grid Services Workflow