Rule-Oriented Data Management Infrastructure

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http://www.sdsc.edu/srb

Funding: NSF ITR / NARA
Distributed Data Management

- Driven by the goal of improving access to data, information, and knowledge
  - Data grids for sharing data on an international scale
  - Digital libraries for publishing data
  - Persistent archives for preserving data
  - Real-time sensor systems for recording data
  - Collections for managing simulation output

- Identified fundamental concepts required by generic distributed data management infrastructure
  - Data virtualization - manage properties of a shared collection independently of the remote storage systems
  - Trust virtualization - manage authentication, authorization, auditing, and accounting independently of the remote storage systems
• After initial design, worked with user communities to meet their data management requirements with the **Storage Resource Broker (SRB)**
  - Used collaborations to fund the continued development
  - Averaged 10-15 simultaneous collaborations for ten years
  - Worked with:
    - Astronomy
    - Bio-informatics
    - Ecology
    - Education
    - Engineering
    - Environmental science
    - High energy physics
    - Humanities
    - Medical community
    - Oceanography
    - Seismology
    - …
History - Scientific Communities

- 1995 - DARPA Massive Data Analysis Systems
- 1997 - DARPA/USPTO Distributed Object Computation Testbed
- 1998 - NSF National Partnership for Advanced Computational Infrastructure
- 1998 - DOE Accelerated Strategic Computing Initiative data grid
- 1999 - NARA Transcontinental Persistent Archive Prototype
- 2000 - NASA Information Power Grid
- 2001 - NLM Digital Embryo digital library
- 2001 - DOE Particle Physics data grid
- 2001 - NSF Grid Physics Network data grid
- 2001 - NSF National Virtual Observatory data grid
- 2002 - NSF National Science Digital Library persistent archive
- 2003 - NSF Southern California Earthquake Center digital library
- 2003 - NIH Biomedical Informatics Research Network data grid
- 2003 - NSF Real-time Observatories, Applications, and Data management Network
- 2004 - NSF ITR, Constraint based data systems
- 2005 - LC Digital Preservation Lifecycle Management
- 2005 - LC National Digital Information Infrastructure and Preservation program
Collaborations - Preservation

1. **MDAS**: 1995-1997, DARPA - SDSC
   Integration of DB and Archival Storage. Support for shared collections

2. **DOCT**: 1997-1998, DARPA/USPTO - SDSC, SAIC, U Va, ODU, UCSD, JPL
   Distributed object computation testbed. Creation of USPTO patent digital library.

3. **NARA**: 1998 - , NARA - U Md, GTech, SLAC, UC Berkeley
   Transcontinental Persistent Archive Prototype based on data grids.

   InterPARES 2 collaboration with UBC on infrastructure independence

5. **PERM**: 2002-2004, NHPRC - Michigan, SDSC
   Preservation of records from an RMA. Interoperability across RMAs.

6. **UK e-Science data grid**: 2003-present, - CCLRC, SDSC
   Federation of independent data grids with a central archive repository

7. **LoC**: 2003-2004, LoC - SDSC, LOC
   Evaluation of use of SRB for storing America Memory collections

   Persistent archive of material retrieved from web crawls of NSDL URLs

9. **ICAP**: 2003-2006, NHPRC - UCSD,UCLA,SDSC
   Exploring the ability to compare versions of records, run historical queries

    Development of a preservation facility that replicates collections

11. **PAT**: 2004-2006, NHPRC - Mi,Mn,Ke,Oh,Slac,SDSC
    Demonstration of a cost-effective system for preserving electronic records.
   Digital library. This is an explicit integration of DSpace with the SRB data grid.
   Assessment criteria for trusted digital repositories.
   Methodologies for preservation & access of software-dependent electronic records.
15. NDIIPP: 2005-2008, LoC - CDL, SDSC
   Preservation of selected web crawls, management of distributed collections.
   Preservation of video workflows.
   Preserving the records of the e-Legislature.
   Preserving the GIS records of the city of Vancouver.
   Develop preservation facility for collections.
   Preserving the geospatial data of the state of California.
21. CASPAR: 2006 - , 17 EU institutions
   Development of representation information for records stored in a SRB data grid.
   Demonstration of the systems needed to manage remote storage of digital data collections.
   California's redlining archives testbed (under consideration for funding).

San Diego Supercomputer Center  University of California, San Diego
## US Academic Institutions (2005)

<table>
<thead>
<tr>
<th>Project</th>
<th>Institution</th>
</tr>
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<td>National Virtual Observatory</td>
<td>Caltech</td>
</tr>
<tr>
<td>Cooperative Institute for Research in Environmental Sciences /Center for Integrated Space Weather Modeling</td>
<td>Colorado University</td>
</tr>
<tr>
<td>Institute for Astronomy</td>
<td>University of California, San Diego</td>
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<tr>
<td>Common Instrument Middleware Architecture, National Middleware Initiative</td>
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<td>Indiana University Cyclotron Facility</td>
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<td>Dspace digital library</td>
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<td>Atmospheric Sciences Data</td>
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<tr>
<td>NOAO data grid</td>
<td>MIT</td>
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<tr>
<td>Web-at-Risk National Digital Information Infrastructure and Preservation Program (CDL)</td>
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<tr>
<td>MPI-IO interface</td>
<td>National Optical Astronomy Observatory</td>
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<td>Computer Science</td>
<td>New York University Libraries</td>
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<td>BioPilot</td>
<td>Ohio State University</td>
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<td>TeraGrid project</td>
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<td>Fusion Portal</td>
<td>Pacific Northwest National Laboratory</td>
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<td>SDSC Production SRB system</td>
<td>Purdue University</td>
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<td>Texas Advanced Computing Center</td>
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<td>Network for Earthquake Engineering Simulation</td>
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<td>NCAR Visualization</td>
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<td>Network for Earthquake Engineering Simulation</td>
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<td>UCAR</td>
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<td>Project</td>
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<td>National Center for Microscopy and Imaging, TeleScience</td>
<td>University of California San Diego</td>
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<td>Library archive</td>
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<tr>
<td>Rapid Unified Generation of Urban Databases (RUGUD)</td>
<td>US Army Research Activity</td>
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<td>P2Tools Design &amp; Development Team Leader</td>
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<td>EPA Data Grid initiative</td>
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<td>Government Agency</td>
<td>US Navy</td>
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<td>Oceanography collections</td>
<td>Woods Hole Oceanographic Institute</td>
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# International Institutions (2005)

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<td>Data management project</td>
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<tr>
<td>eMinerals</td>
<td>Cambridge e-Science Center, UK</td>
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<td>Sickkids Hospital in Toronto</td>
<td>Canada</td>
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<tr>
<td>Welsh e-Science Centre</td>
<td>Cardiff University, UK</td>
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<tr>
<td>Visualization in scientific computing</td>
<td>Chinese Academy of Science, China</td>
</tr>
<tr>
<td>Australian Partnership for Advanced Computing Data Grid</td>
<td>Commonwealth Scientific and Industrial Research Organization, Australia</td>
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<tr>
<td>Consorzio Interuniversitario per il Calcolo Automatico dell'Italia Nord Orientale, HPC-EUROPA project</td>
<td>Italy</td>
</tr>
<tr>
<td>Center for Advanced Studies, Research, and Development</td>
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</tr>
<tr>
<td>LIACS(Leiden Inst. Of Comp. Sci)</td>
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<tr>
<td>Australian Partnership for Advanced Computing Data Grid</td>
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<td>Monash E-Research Grid</td>
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<td>Computational Materials Science</td>
<td>Nanyang Technological University, China</td>
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<td>Virtual Tissue Bank</td>
<td>Osaka University, Japan</td>
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<td>Cybermedia Center</td>
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<td>Belfast e-Science Centre</td>
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<td>Information Technology Department</td>
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<td>Nanyang Centre for Supercomputing</td>
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<td>National University (Biology data grid)</td>
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<td>Swiss Federal Institute (Ecole Polytechnique Federale de Lausanne)</td>
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<td>Project</td>
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<tr>
<td>CERN- GridFTP</td>
<td>Switzerland</td>
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<tr>
<td>Protein structure prediction</td>
<td>Taiwan University, Taiwan</td>
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<tr>
<td>Trinity College High Performance Computing (HPC-Europa)</td>
<td>Trinity College, Ireland</td>
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<tr>
<td>National Environment Research Council</td>
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<td>Universidad Nacionale Autonoma de Mexico Grid</td>
<td>Universidad Nacionale Autonoma de Mexico</td>
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<td>Parallab( HPC-EUROPA project)</td>
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<td>Laboratory for Bioimages and Bioengineering</td>
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<td>School Computing</td>
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<td>Dept. of Computer Science</td>
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<td>Worldwide Universities Network</td>
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<tr>
<td>Large Hadron Collider Computing Grid</td>
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<tr>
<td>Computational Modelling</td>
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<tr>
<td>Instituto do Coracao</td>
<td>University of Sao Paulo, Brazil</td>
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<tr>
<td>White Rose Grid</td>
<td>University of Sheffield, UK</td>
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<td>Australian Partnership for Advanced Computing Data Grid</td>
<td>University of Technology, Australia</td>
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<td>Computational Chemistry environment</td>
<td>University of Zurich, Switzerland</td>
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<tr>
<td>Australian Partnership for Advanced Computing Data Grid</td>
<td>Victoria, Australia</td>
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</table>
Extremely Successful

• **Storage Resource Broker Production Environment**
  - Respond to user requests for help
    - SRB-chat Email
    - Email archive
    - Bugzilla bug/feature request list
    - Hot page for server status
    - Wiki web page with all documentation, user contributed software
  - Continue development of new features, ports
    - CVS repository for all source code changes
    - Daily build and test procedure
    - NMI testbed builds before each release
    - Average of four releases per year
  - Supporting projects now ending or have ended
    - (NSF ITR, DOE, NASA)

• **How can such systems be sustained for use by the academic community?**
Recent SRB Releases

- 3.4.2  June 26, 2006
- 3.4.1  April 28, 2006
- 3.4    October 31, 2005
- 3.3.1  April 6, 2005
- 3.3    February 18, 2005
- 3.2.1  August 13, 2004
- 3.2    July 2, 2004
- 3.1    April 19, 2004
- 3.0.1  December 19, 2003
- 3.0    October 1, 2003
- 2.1.2  August 12, 2003
- 2.1.1  July 14, 2003
- 2.1    June 3, 2003
- 2.0.2  May 1, 2003
- 2.0.1  March 14, 2003
- 2.0    February 18, 2003
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<tr>
<th>Project</th>
<th>Date</th>
<th>GBs of data stored</th>
<th>1000Os of files</th>
<th>GBs of data stored</th>
<th>1000Os of files</th>
<th>Users with ACLs</th>
<th>GBs of data stored</th>
<th>1000Os of files</th>
<th>Users with ACLs</th>
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<td><strong>Data Grid</strong></td>
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<td>17,800</td>
<td>5,139</td>
<td>51,380</td>
<td>8,690</td>
<td>80</td>
<td>106,070</td>
<td>14,001</td>
<td>100</td>
</tr>
<tr>
<td>NSF / NVO</td>
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<td>51,380</td>
<td>8,690</td>
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<td>4,694</td>
<td>380</td>
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<td>Pzone</td>
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<td></td>
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<td>194 TB</td>
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<td>4,635</td>
<td>804 TB</td>
<td>118 mil</td>
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</table>
Standards Effort

• **Global Grid Forum - Grid Interoperability Now**
  • **Organizers:** Erwin Laure (Erwin.Laure@cern.ch)
    Reagan Moore (moore@sdsc.edu)
    Arun Jagatheesan (arun@sdsc.edu) - grid coordination
    Sheau-Yen Chen (sheauc@sdsc.edu) - data grid administrator
    Chien-Yi Hou (chienyi@sdsc.edu) - collection administrator

  • **Goals:**
    ▪ Demonstrate federation of 17 SRB data grids (shared name spaces)
    ▪ Demonstrate replication of a collection

• **Global Grid Forum - Preservation Environments Research Group**
  • **Organizers:** Reagan Moore (moore@sdsc.edu)
    Bruce Barkstrom

  • **Goals:**
    ▪ Demonstrate creation of preservation environments based on data grid technology
    ▪ Demonstrate federation of preservation environments
<table>
<thead>
<tr>
<th>Data Grid</th>
<th>Country</th>
<th>SRB version</th>
<th>Demouser</th>
<th>SRB Zone name</th>
<th>Storage Resource Logical Name</th>
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<td>umiacs</td>
<td>narasrb02-unix1</td>
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</table>
• **Builds on:**
  - **Registry for data grid names** - ensures each data grid has a unique identity
  - **Trust establishment** - explicit registration command issued by the data grid administrator of each data grid
  - **Peer-to-peer server interaction** - each SRB server can respond to commands from any other SRB server, provided trust has been established between the data grids
  - **Administrator controlled registration of name spaces** - each grid controls whether they will share user names, file names, replicate data, replicate metadata or allow remote data storage
  - **Shibboleth style user authentication** - a person is identified by /Zone-name/user-name.domain-name. Authentication is done by the home zone. No passwords are shared between zones.
  - **Local authorization** - operations are under the control of the zone being accessed, including controls on access to files, storage resources, metadata and user quotas. Owners of data can set access controls for other persons
Federation Between Data Grids

Data Access Methods (Web Browser, Scommands, OAI-PMH)

Data Collection A

- Logical resource name space
- Logical user name space
- Logical file name space
- Logical context (metadata)
- Control/consistency constraints

Data Collection B

- Logical resource name space
- Logical user name space
- Logical file name space
- Logical context (metadata)
- Control/consistency constraints

Access controls and consistency constraints on cross registration of name spaces

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Observing Operations Implementation: EarthScope/USArray and ROADNet

Future Proposals

LOOKING Review
Calit2, UCSD
5-7 July 2006

Frank Vernon
UCSD
Real-time Observatory Cyberinfrastructure Challenges

- **Scalability**
  - Dynamic station deployment
  - Data integration with remote archives

- **Extensibility**
  - New sensor types
  - New data types

- **Operational Issues**
  - Multiple communication types
  - Dynamic IP assignment for instruments
  - Intermittent communications

- **Observatory interaction**
  - Real time data integration with other observatories
ROADNet Point Of Presence

- “RPOP”
  - Embedded real-time processing system
  - Integrated with Storage Resource Broker
  - Sophisticated FEDERATION NODE
    - *Data Acquisition tools*
    - *Data concentration and distribution tools*
    - *Data processing tools*
  - Sun Fire server machines
  - Being installed on oceanographic research vessels
RPOP: multiple grid paradigms

Equally effective for the SRB to communicate with any RPOP

Observatory Integration

RPOP: Node in the SRB Federation

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RPOP: Node in the underlying data grid

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Tri-observatory Federation

Southern California Coastal Ocean Observing System

ROADNet

EarthScope / USArray

- Matlab tools
- Observatory-grade analysis tools
- Web access

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From NSF LOOKING Review 7/6/06, Calit2
University of California, San Diego
Cognitive Science Collaboratory

• The NSF-funded Dynamic Learning Center
  ▪ Multi-institution group of scientists and educators
  ▪ Investigate the role of time and timing in learning

• Composed of four center initiatives
  ▪ Dynamics in the external world
  ▪ Dynamics intrinsic to the brain
  ▪ Dynamics of the muscles and body
  ▪ Dynamics of learning

• Data sharing facility
  ▪ Rules to validate enforcement of IRB policies
  ▪ Shared collections
  ▪ Publication of results
  ▪ Archiving of data
Research Agenda

• Require two levels of virtualization for managing operations
  ▪ Map from operations requested by client
  ▪ To micro-services that are implemented by data grid
  ▪ To operations executed on remote storage systems

• Require two levels of virtualization for managing data
  ▪ Map from physical file naming used by storage system
  ▪ To logical name space managed by the shared collection
  ▪ To federated name space managed by federation of shared collections
Fundamental Data Management Concepts

- **Data virtualization**
  - Management of name spaces
    - Logical name space for users
    - Logical name space for storage resources
    - Logical name space for digital entities (files, URLs, SQL, tables, …)
    - Logical name space for metadata (user defined attributes)
  - Decoupling of access mechanisms from storage protocols
    - Standard operations for interacting with storage systems (80)
      - Posix I/O, bulk operations, latency management, registration, procedures, …
    - Standard client level operations for porting preferred interface (22)
      - C library calls, Unix commands, Java class library
      - Perl/Python/Windows load libraries, Perl/Python/Java/Windows web browsers, WSDL, Kepler workflow actors, DSpace and Fedora digital libraries, OAI-PMH, GridSphere portal, I/O redirection, GridFTP, OpenDAP, HDF5 library, Semplar MPI I/O, Cheshire
  - Management of state information resulting from standard operations
Fundamental Data Management Concepts

- **Trust virtualization**
  - Collection ownership of all deposited data
  - Users authenticate to collection, collection authenticates to remote storage system
  - Collection management of access controls
    - Roles for administration, read, write, execute, curate, audit, annotate
    - ACLs for each object
    - ACLs on metadata
    - ACLs on storage systems
    - Access controls remain invariant as data is moved within shared collection
  - Audit trails
  - End-to-end encryption
Research Objectives

• What additional levels of virtualization are required to support advanced data management applications?

• Observe that each community imposes different management policies.
  ▪ Different criteria for data disposition, access control, data caching, replication
  ▪ Assertions on collection integrity and authenticity
  ▪ Assertions on guaranteed data transport

• Need the ability to characterize the management policies and validate their application
Levels of Virtualization

• Require metadata (state information, descriptive metadata) for six name spaces
  ▪ Logical name space for users
  ▪ Logical name space for digital entities (files, tables, URLs, SQL, …)
  ▪ Logical name space for resources (storage systems, ORB, archives)
  ▪ Logical name space for metadata (user defined metadata, extensible schema)
  ▪ Logical name space for rules (assertions and constraints)
  ▪ Logical name space for micro-services (data grid actions)

• Associate state information and descriptive information with each name space

• Virtualization of management policies
integrated Rule-Oriented Data System

• Integrate a rule engine with a data grid
• Map management policies to rules
• Express operations within the data grid as micro-services
• Support rule sets for each collection and user role

• On access to the system:
  ▪ Select rule set (Collection : user role : desired operation)
  ▪ Load required metadata (state information) into a temporary metadata cache
  ▪ Evaluate rule input parameters and perform desired actions
    ▪ Rules cast as Event:Condition:Action sets
      ▪ Rules invoke both micro-services and rules
    ▪ Provide recovery mechanism for each micro-service
  ▪ On completion, load changed state information back into persistent metadata repository
iRODS - integrated Rule-Oriented Data System

Client Interface

Admin Interface

Resources

Rule Invoker

Rule

Engine

Current State

Service Manager

Rule Modifier Module

Config Modifier Module

Metadata Modifier Module

Consistency Check Module

Consistency Check Module

Consistency Check Module

Rule Base

Confs

Metadata Persistent Repository

Metadata-based Services

Resource-based Services

Micro Service Modules

Micro Service Modules

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Example Rules

0 ON register_data
IF $objPath like /home/collections.nvo/2mass/fits-images/*
DO cut [nop]
AND check_data_type(fits image) [nop]
AND get_resource(nvo-image-resource) [nop]
AND registerData [recover_registerData]
AND addACLForDataToUser(2massusers.nvo,write) [recover_addACLForDataToUser]
AND extractMetadataForFitsImage [recover_extractMetadataForFitsImage]

1 ON register_data
IF $objPath like /home/collections.nvo/2mass/*
DO get_resource(2mass-other-resource) [nop]
AND registerData [recover_registerData]
AND addACLForDataToUser(2massusers.nvo,write) [recover_addACLForDataToUser]

2 ON register_data
DO get_resource(null) [nop]
AND registerData [recover_registerData]
Emerging Preservation Technology

• NARA research prototype persistent archive demonstrated use of data grid technology to manage authenticity and integrity
  ▪ Federated data grids

• Current challenge is the management of preservation policies
  ▪ Characterize policies as rules
  ▪ Apply rules on each operation performed by the data grid
  ▪ Manage state information describing the results of rule application
  ▪ Validate that the preservation policies are being followed

• Same challenge exists in grid services
  ▪ Characterize and apply rules that govern grid service application
ERA Capabilities

- **List of 854 required capabilities:**
  - Management of disposition agreements describing how record retention and disposal actions
  - Accession, the formal acceptance of records into the data management system
  - Arrangement, the organization of the records to preserve a required structure (implemented as a collection/sub-collection hierarchy)
  - Description, the management of descriptive metadata as well as text indexing
  - Preservation, the generation of Archival Information Packages
  - Access, the generation of Dissemination Information Packages
  - Subscription, the specification of services that a user picks for execution
  - Notification, the delivery of notices on service execution results
  - Queuing of large scale tasks through interaction with workflow systems
  - System performance and failure reports. Of particular interest is the identification of all failures within the data management system and the recovery procedures that were invoked.
  - Transformative migration, the ability to convert specified data formats to new standards. In this case, each new encoding format is managed as a version of the original record.
  - Display transformation, the ability to reformat a file for presentation.
  - Automated client specification, the ability to pick the appropriate client for each user.
Summary of Mapping to Rules

• Multiple systems need to be integrated:
  ▪ PAWN submission pipeline - 34 operations
  ▪ Cheshire indexing system - 13 operations
  ▪ Kepler workflow - 53 operations
  ▪ iRODS data management - 597 operations
  ▪ Operations facility - the remaining capabilities

• The 597 operations are executed by 174 generic rules

• The analysis identified five types of metadata attributes:
  ▪ Collection metadata - 11 attributes
  ▪ File metadata - 123 attributes
  ▪ User metadata - 38 attributes
  ▪ Resource metadata - 9 attributes
  ▪ Rule metadata - 32 attributes
File Operations

- List files
- Display file (template)
- Set number of items per display page
- Format file
- Delete file
- Delete file authorized
- Delete file copies
- Delete file versions
- Erase file
- Replace file
- Set file version
- Create soft link
- Replicate file
- Synchronize replicas
- Physmove file
- Annotate file
- Access URL
- Regenerate system metadata
- Check vault
- Monitor space used
- Output file
- Register file
- Register collection hierarchy

- Delete collection
- Bulk move files (new hierarchy)
- Queue file for transfer
- Queue file for encrypted transfer
- Output file to media
- Modify file
- Redact file
- Edit file
- Replicate archives
- Monitor resources - hot page
- Track usage
- Set system parameter
- Predict resource requirements
- Inventory resources
- Log event
- Delete event log entry
- Identify data type
- Create access role
- Modify access control
- Generate notification
- Subscribe
- Delete subscription

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Data Management Rules

- Execute rule
- Suspend rule
- Add rule
- Modify rule
- List rules
- List rule metadata
- Validate rule set
- Approve rule
- Queue rule
- List queued rules
- Set queued rule priority
- Adjust max run time
- Estimate service resources
- List metadata
- Get metadata
- Set metadata
- Bulk metadata load
- Delete metadata
- Define extensible schema
- Load extensible schema
- Export metadata

- Query metadata
- Save query
- Select saved query
- Run saved query
- Modify query
- Modify running query
- Save query result set
- Modify query result set
- Delete search results
- Annotate search result
- Sinit - set default workbench interface
- Register user
- Self-registration
- Delete user
- Suspend user
- Activate user
- Add resource
- Remove resource
- Set resource offline
- Set resource online
- Input file
Example Rules - Templates

- DIP format template
- Disposition agreement format template
- Disposition action format template
- Physical location report template
- Inventory report template
- Data movement summary report template
- Access report template
- File migration report template
- Document internal access control template
- AIP format template
- Transfer format template
- Access review determination rule template
- Access review determination report template
- Validate access classification rule template
- File transfer discrepancy report template
- Notification review report template
- Redaction rule template
- Search display template
- File display template (file type)
- Format conversion format template
- Workbench display template
- Request help format template
- System message format template
- Event log display template
- System report format template
- Monitor hot page format template
- Hot page report template
- Create DIP
- Modify DIP
- Application hot page report template
- COTS hot page report template
- Usage workflow report template
- System configuration display template
- Logistics report format template
- Inventory report format template
- Description extraction rule template
- Accounting report rule template
- Accounting report format template
Example Rules - Templates

- Identify template use
- Create template
- Modify template
- Delete template
- List templates
- Approve template
- Check template
- Assign template
- Template-based default setting
- Parse file
- Generate report
- Modify report
- Export record
- Export records
- Create disposition agreement
- Disposition record check
- Modify disposition agreement
- Compare disposition agreements
- Compare access review determinations
- Change review determination
- List review history
- Preservation assessment rule template
- Preservation assessment report format template

- Lifecycle parsing rules template
- Authenticity validation rule template
- Assess preservation
- Modify workbench
- Select workbench
- Create description
- Validate description
- Modify description
- Update description
- Approve description
- Create unique identifier
- Approve disposition agreement
- Validate transfer request
- Validate access classification
- Queue record for destruction
- Certify deletion of records
- Set disposition hold
- Unset disposition hold
- Record disposition action
- Compare disposition agreements
- Compare access review determinations
- Change review determination
- List review history
- Preservation assessment rule template
- Preservation assessment report format template

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The assessment criteria can be mapped to management policies. The management policies can be mapped to a set of rules whose execution can be automated. The rules require definition of input parameters that define the assertion being implemented. The execution of the rules generates state information that can be evaluated to verify the assertion result. The types of rules that are needed include:

- Specification of assertions (setting rule parameters - flags and descriptive metadata)
- Deferred consistency constraints that may be applied at any time
- Periodic rules that execute defined procedures
- Atomic rules applied on each operation (access controls, audit trails)

The rules determine the metadata attributes that need to be managed.
<table>
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<tr>
<th>#</th>
<th>Policy layers/types</th>
<th>TDR</th>
<th>Rule or procedure</th>
<th>State info (result of rule application)</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>4.2</td>
<td>Format</td>
<td>ų</td>
<td>Periodic rule - check consistency with required formats</td>
<td>List of supported formats and flag for SLA support level for each</td>
<td>Whether file format is accepted, preservation SLA for each accepted format; Also any requirements for quality within format (e.g. compliance with TIFF 6.0 acceptance specs)</td>
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<tr>
<td>ų ų</td>
<td></td>
<td>A5.1</td>
<td>Consistency rule - check that deposit agreement exists</td>
<td>Deposit agreement for storage of data specifying access, replicas, consistency checks</td>
<td>If repository manages, preserves, and/or provides access to digital materials on behalf of another organization, it has and maintains appropriate contracts or deposit agreements.</td>
</tr>
<tr>
<td>ų ų</td>
<td></td>
<td>B2.1</td>
<td>Consistency rule that AIP definition exists</td>
<td>Statement of characteristics of each AIP</td>
<td>Repository has an identifiable, written definition for each AIP or class of information preserved by the repository</td>
</tr>
<tr>
<td>ų ų</td>
<td></td>
<td>B2.2</td>
<td>Consistency rule - check allowed transformative migration is performed</td>
<td>Criteria for allowed transformative migrations</td>
<td>Repository has a definition of each AIP (or class) that is adequate to fit long-term preservation needs</td>
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<td>B3.9</td>
<td>Set / Update descriptive metadata: Consistency check for changes to allowed transformative migrations</td>
<td>Procedure for updating transformative migration strategy: Audit trail of changes; Consistency check for changes to migration strategy</td>
<td>Repository has mechanisms to change its preservation plans as a result of its monitoring activities</td>
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<tr>
<td>ų ų</td>
<td></td>
<td>B4.2</td>
<td>Consistency rule - check required metadata</td>
<td>Validation that minimum descriptive metadata is present</td>
<td>Repository captures or creates minimum descriptive metadata and ensures that it is associated with the AIP</td>
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iRODS Development

• Open source software
  ▪ 48,000 lines of “C” code
  ▪ Implemented 50 remote storage operations
  ▪ Implemented 13 client level operations
  ▪ Implemented client server model, with improved protocol

• Standard build procedure
  ▪ Built entire system on NMI testbed at University of Wisconsin

• Rule engine
  ▪ Nested Event-Condition-Action sets with recovery procedures for each action
  ▪ Named rule sets
  ▪ Logical name space for rules
  ▪ Logical name space for micro-services
  ▪ Logical name space for metadata
Rule Engine

- **Declarative Programming** - through a Rule-based Approach along with rule-consistency checks performed to verify rule execution for cycles and other consistency checks.

- **Transparent Processing & Agile Programming** - similar to Business Rules Logic.

- **Event Condition Action (ECA) Paradigm** - similar to active databases.

- **Transactional & Atomic Operations** - Similar to ACID properties of RDBMS. Each rule either succeeds completely or does not change the operational data (both transient and persistent metadata).

- **WorkFlow Paradigm** for defining a sequence of tasks.

- **Service oriented paradigm** based on micro-services and rules.

- **New Programming paradigms** - based on coding micro services and developing workflows (rules) and stitching the microservices at runtime to the requested operation.

- **Abstraction and logical naming at multiple levels**: data, collections, resources, users, metadata, methods, attributes, rules and micro-services

- **Novel management of version control in the execution architecture**. All versions can coexist. Users can apply their versions and rules at the same time to achieve their tasks.

- **Data grid paradigm** providing standard distributed data management functions:

- **Digital library paradigm** providing standard digital library functions:

- **Persistent archive paradigm** providing standard preservation functions:
iRODS Collaboration Areas

- Shibboleth-SRB/iRODS-Cheshire-uK eScience integration
- GSI support
- Time-limited sessions via the one-way hash authentication
- Python Client library
- Java Client library
- A GUI Browser (Java, or Python, or other)
- A driver for HPSS
- A driver for SAM-QFS
- Other drivers?
- Porting to many versions of Unix/Linux
- Porting to Windows
- Support for Oracle as the database
- Support for MySQL as the database
- A way for users to influence rules
- More extensive installation and test scripts
- AIP to aggregate small files
- MCAT to RCAT migration tools
- Extensible Metadata From the client level, User-defined metadata does not appear distinct from system or extensible metadata.
- Query condition/select clustering. Zones/Federation
Research Collaborations - UCSD

• Creation of custom web interfaces to shared collections
  ▪ Yannis Katsis
  ▪ Yannis Papakonstantinou
  ▪ App2you collections and displays data
    ▪ Template driven interface development
    ▪ https://app2you.org/video/tutorial.html

• Validation of rule set consistency
  ▪ Dayou Zhou
  ▪ Alin Deutsch
  ▪ Assert temporal properties of rule execution
More Information

moore@sdsc.edu

SRB:
http://www.sdsc.edu/srb

iRODS:
http://www.sdsc.edu/srb/future/index.php/Main_Page