Overview:
Data Management & iRODS

Center for Data Intensive Cyber Environments
University of North Carolina at Chapel Hill

UNC School of Information and Library Science (SILS)
Renaissance Computing Institute (RENCI)
Institute for Neural Computation (INC) at UC San Diego

diceresearch.org irods.org

Data Management & iRODS

- **Motivation**: Problems in Digital Data
- **Introduction** to iRODS, the Integrated Rule-Oriented Data System
- **Use Cases**
  - Research, Preservation, Humanities, etc.
- iRODS – more details

Motivation: Core Problem

- **Collaborative Research & Education**
  - Sharing data by "connecting the dots" of
    - *Different groups, projects*
    - *Different institutions, locations*
    - *Different disciplines*
    - *Diverse types of data*
    - *Diverse hardware, software infrastructure*

How is data managed now?

- The widely used "oops" method...
  - Oops, we should have…
    - Migrated/backed up our data…
    - Before our server died, that format changed, application disappeared, we ran out of storage…
    - It's one way to get rid of too much data…
      - *Note: Data backups are not preservation.*
- Toward a more conscious data system
  - Where you decide what to add, keep, discard, share, when and with whom…

Some questions to ask…

- How will you **share Data Collections**?
  - Throughout your collaboration and beyond
  - Regardless of where the data is
  - Including diverse data from collaborators, while
  - Controlling access in nuanced ways
  - Adding/removing data, users, partners, different infrastructure, etc.
  - Using the Data Collections with your applications to analyze, visualize, create derived works, etc.
  - **Some challenges** in Digital Data
    - Ephemeral; technology obsolescence; exploding size (10 times larger 2006–2011); Babel - proliferating proprietary formats, etc.

Toward a Unified Data Space

- **Sharing data across space**
  - Multiple spaces: geographic, institutional, disciplinary...
  - Infrastructure spaces (h.w./s.w.)
  - Harness power of cyber technologies
    - ***Virtual Collections*** *of distributed data*
      - Global Name Spaces (data, users, storage, etc.)
    - Beyond single-site repository model (hard copy based)
  - Also known as a "Data Grid"

Toward a Unified Data Space

- **Sharing data across time**
  - A "memory" for your project
    - Communicating with the future
    - Long-term preservation
  - Need automated policies that govern a life cycle workflow from ingestion to disposition, access, validate authenticity, access, etc.
- **Sharing in space and time** require related capabilities, architecture
  - Trend: people realizing they need to both share and preserve

Another question to ask…

- Does your system design let data be "born" in a comprehensive environment?
  - From fragmented, ad hoc to intentional
    - Your decide Policies for managing, when to discard
  - Cheaper: "A stitch in time saves nine"
    - Automation for mushrooming data collections
    - Avoids generating more "legacy data" that must be harvested later (difficult, expensive)
  - Trend toward annotation at creation
    - Upstream collaboration between data creators and data professionals

Introduction to iRODS

- The Integrated Rule-Oriented Data System
- Design priorities
  - Enable collaboration
  - Flexible - "Swiss Army Knife"
  - Comprehensive - full life cycle
  - "Real world" software
    - 12+ years of user-driven collaborative research and production use in diverse communities
    - Easy to install, configure, use, extend
    - Scalable - keep up with exploding data
    - Extensible - keep up with evolving s.w./h.w.

iRODS Community

- iRODS is open source, BSD license
- Core developers: DICE Center
  - Development wiki: https://irods.org
- Collaborations with community who contribute code
  - Accelerating in US and internationally
- Data Intensive Cyberinfrastructure Foundation
  - Home for iRODS open source community


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iRODS User Community

- iRODS Development Collaborations
  - NARA TPAP Transcontinental Persistent Archive Prototype (NARA funded)
  - NSF SDCI Research in Adaptive Middleware Architecture Systems
  - SHAMAN Sustaining Heritage Access through Multivalent ArchiviNg
  - UK e-Science data grid
- Communities Using DICE Technologies, including Biology, Environment, Psychology, Human Subjects
  - BIRN Biomedical Informatics Research Network (NIH funded)
  - ROADNet Real-time Observatories, Applications, and Data management Network (NSF funded)
  - SEEK Science Environment for Ecological Knowledge (NSF funded)
  - TDLC Temporal Dynamics of Learning Center (NSF funded) – Overview
- Physical Sciences Uses
  - CADAC Computational Astrophysics Data Analysis Center (NSF funded)
  - BaBar high energy physics data grid (DOE funded)

iRODS User Community

- Physical Sciences (continued)
  - NOAO National Optical Astronomy Observatories data grid (NSF funded)
  - NVO National Virtual Observatory (NSF funded)
  - Observatoire de Strasbourg, France, VOSpace Interface
- Persistent Archives and Digital Preservation / Humanities Uses
  - NARA TPAP Transcontinental Persistent Archive Prototype
  - e-Legacy Preserving the Geospatial Data of the State of California
  - DCPC Distributed Custodial Preservation Center (NHPRC funded)
  - DIGARCH UCTV NSF Digital Archiving and Long-Term Preservation (LoC)
  - T-RACES Testbed for Redlining Archives of CA Exclusionary Spaces (IMLS)
- Geosciences Uses
  - OOI Ocean Observatories Initiative (NSF funded)
  - SCEC Southern California Earthquake Center (NSF funded)
- High Performance and Grid Computing
  - NSF TeraGrid
- Plus many international users.
- And growing all the time…

Introduction to iRODS Data System

You, Researchers, Students, etc.

Want to easily Find, Access, Use, Move, Share Data, and more…

With your Interfaces, your Applications, your Workflows

iRODS Data System – "Middleware"

A "layer" that "connects the dots" while masking and automating your interactions with diverse infrastructure.

The "World of Infrastructure"

Your and other's Storage, Networks, Admin. Domains, Computing Services, Web Services, etc.

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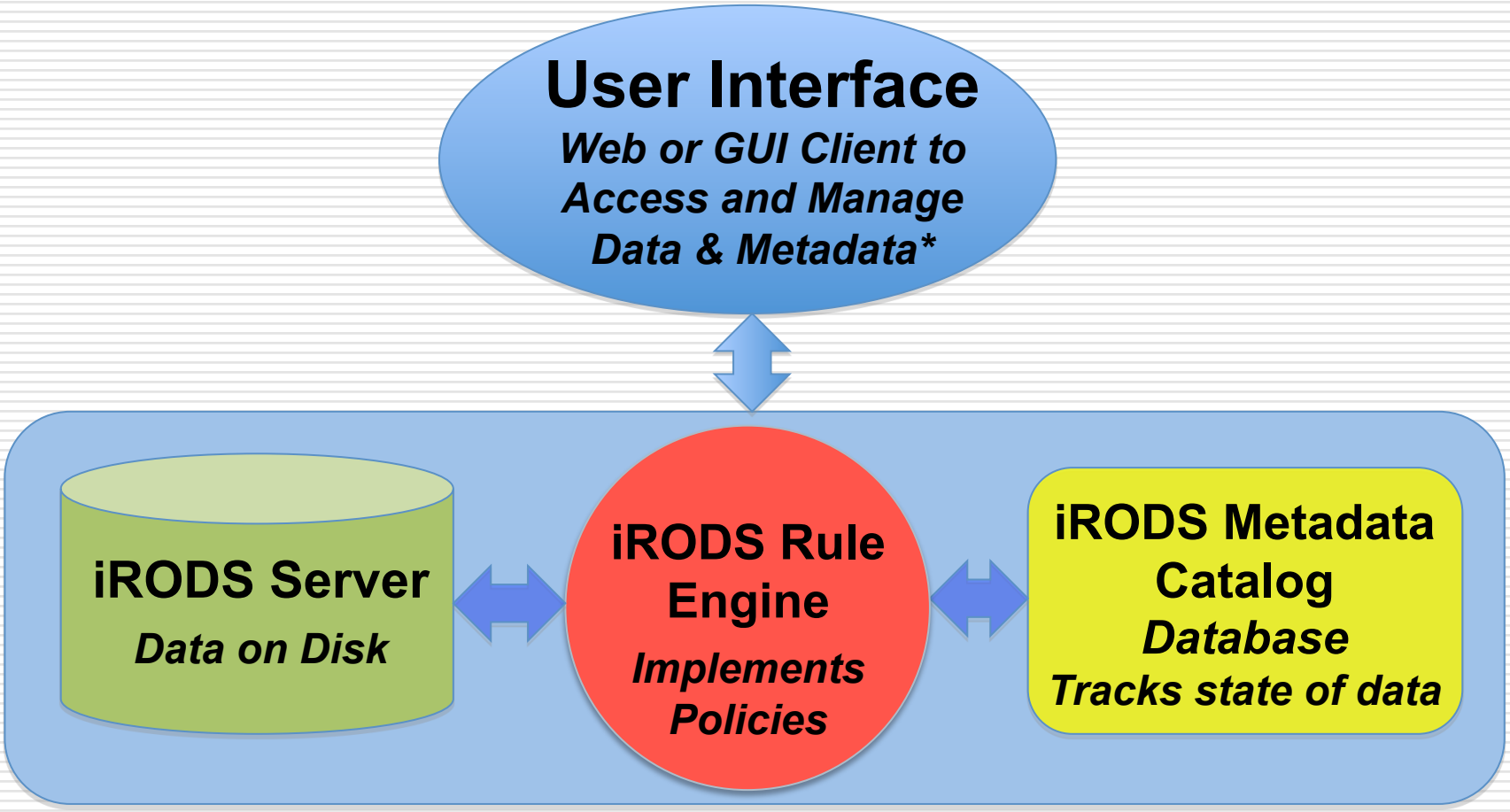
Overview of iRODS Components

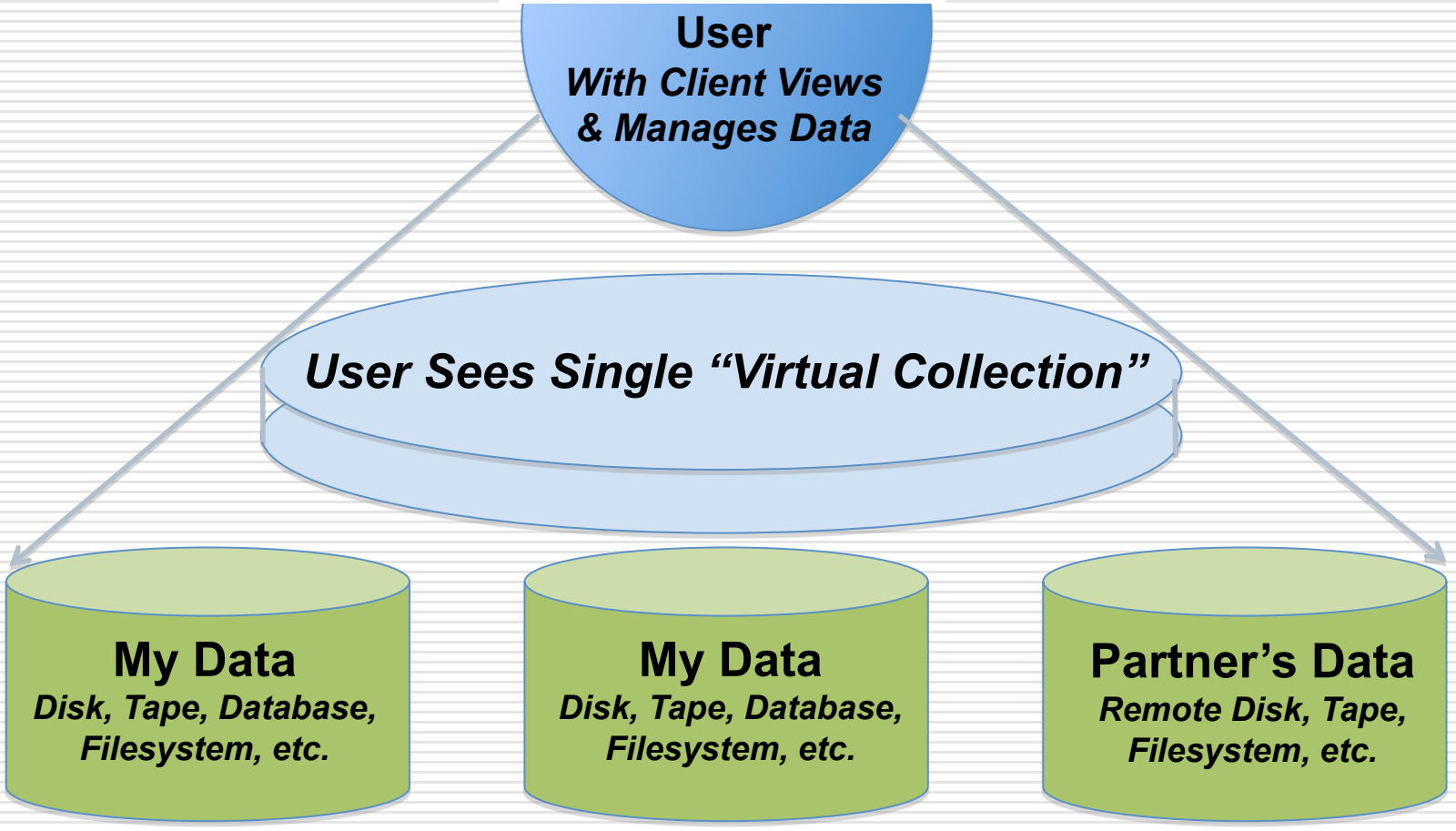


*Access data with: Web-based Browser, iRODS GUI, Command Line clients, Dspace, Fedora, Kepler workflow, WebDAV, user level file system, etc.

iRODS Interfaces and Portals

- Davis WebDAV interface to iRODS
  - No client needed, iPhone access to your data
- Many interfaces, including
  - Windows Explorer for iRODS
  - Java Universal eXplorer
  - i-Commands (UNIX-like command line)
  - Integration with Fedora, Dspace, etc.
- Web Portals with iRODS
  - ARCS HERMES portal using iRODS
  - EnginFrame portal using iRODS

iRODS Shows Unified "Virtual Collection"



The iRODS Data System can install in a "layer" over existing or new data, letting you view, manage, and share part or all of diverse data in a unified Collection.

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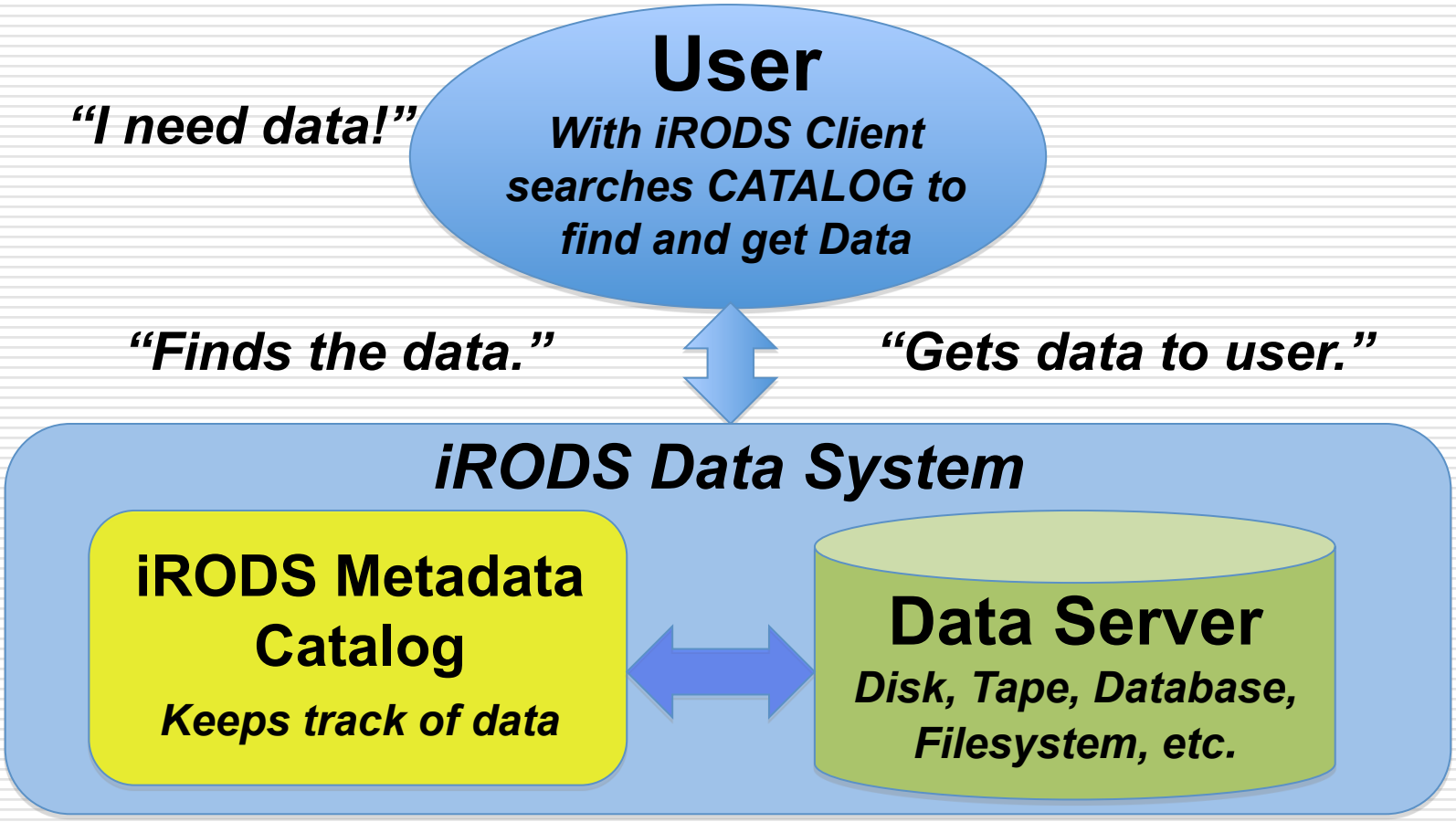
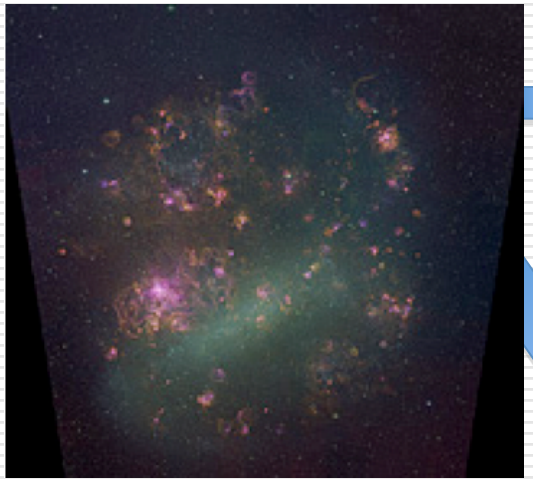
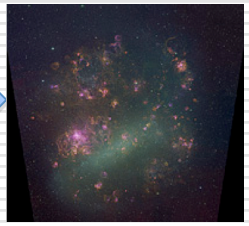
Accessing Data in the iRODS System



Users can search for, access, add/extract metadata, annotate, analyze & process, replicate, copy, share data, manage & track access, subscribe, and more.

Adding Data to iRODS Data System





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Astronomers
Set iRODS Rules to automate Data Workflow

iRODS Data System

iRODS Metadata Catalog
Keeps info. for File

iRODS Server
File at Observatory In Chile

3

Data Archive
Copy in Archive in Illinois

Rules can tell iRODS to automatically 1) Register photo from telescope in Chile into Metadata Catalog and write to Data Server, 2) Make thumbnail, 3) Make copy in US Archive.

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Sharing Data in iRODS Data System

Scientist A
Adds data to Shared Collection

Scientist B
Accesses and analyzes shared Data

iRODS Data System

- ***Brain*** **Data Server, CA**
- ***Audio*** **Data Server, NJ**
- ***Video*** **Data Server, TN**
- **iRODS Metadata Catalog**

Scientists can use iRODS as a "data grid" to share multiple types of data, near and far. iRODS Rules also enforce and audit human subjects access restrictions.

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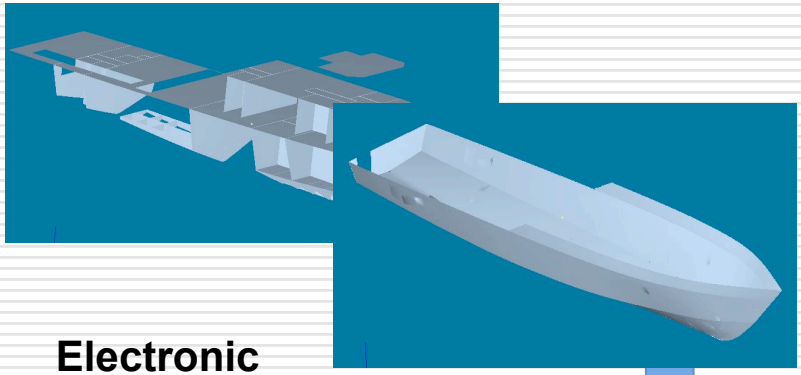
Preserving Electronic Records with iRODS



Electronic
Engineering Drawings

Archivists
Use iRODS in Preservation Workflow

iRODS Data System

iRODS Metadata Catalog
Includes audit trails

Data Archive
Holds Electronic Records Collection

Dark Archive
Secure Backup

Archivists can use iRODS for preserving Electronic Records, from Appraisal to Access, with Rules enforcing trustworthy respository criteria with audits.

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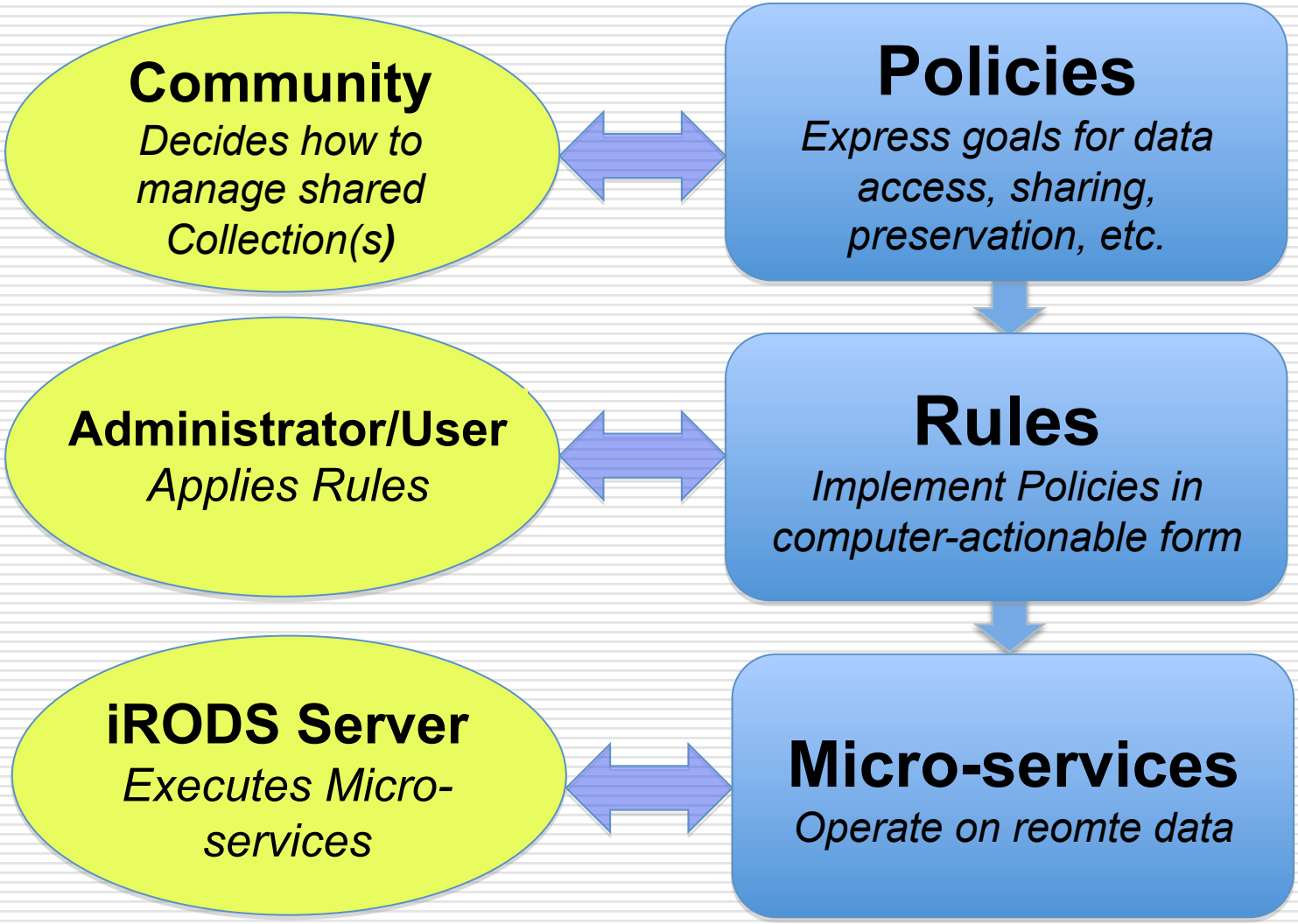
"Layers" in iRODS: From Users to Storage



More Information about iRODS

1. **Shared collections** assembled from data distributed across different groups, remote storage locations
2. **Workflow environment** executed where data is (server-side on remote storage)
3. **Policy enforcement engine**, with computer actionable Rules applied at remote storage
4. **Validation environment** for assessment criteria (audit trails)
5. **Consensus building system** for establishing collaboration (policies, data formats, semantics, shared collection, etc.)

Use Case: Dissertation Collection

- Support for Student Dissertation data in Health Sciences Library (UNC)
  - Organize collection of student simulation data
    - Input files, output files
  - Use iRODS Rules to periodically synchronize student's work area with Collection, registering new files into Collection, and replicating files to tape archive
  - Build templates to describe required metadata for registered files
  - Use iRODS Rule to verify compliance of metadata for each file with template

Use Case: Digital Humanities

- T-RACES: Testbed for the Redlining Archives of California's Exclusionary Spaces
  - A digital humanities collaborative between UNC and UCHRI
  - Building iRODS Data Grid for the digital humanities
  - Provides integrated map, text, and database interfaces
  - Extend to redlined cities of North Carolina

Use Case: NARA Archiving

- NARA Transcontinental Persistent Archive Prototype
  - **Federates** 7 independent iRODS data grids: Each manages own Storage resources and Metadata Catalog, applies own Policies
  - Use iRODS federation to establish Policies for sharing data between sites.
  - Control operations a remote user can do within your data grid.
  - Extensible Environment, can federate with additional research and education sites. Each data grid uses different vendor products.

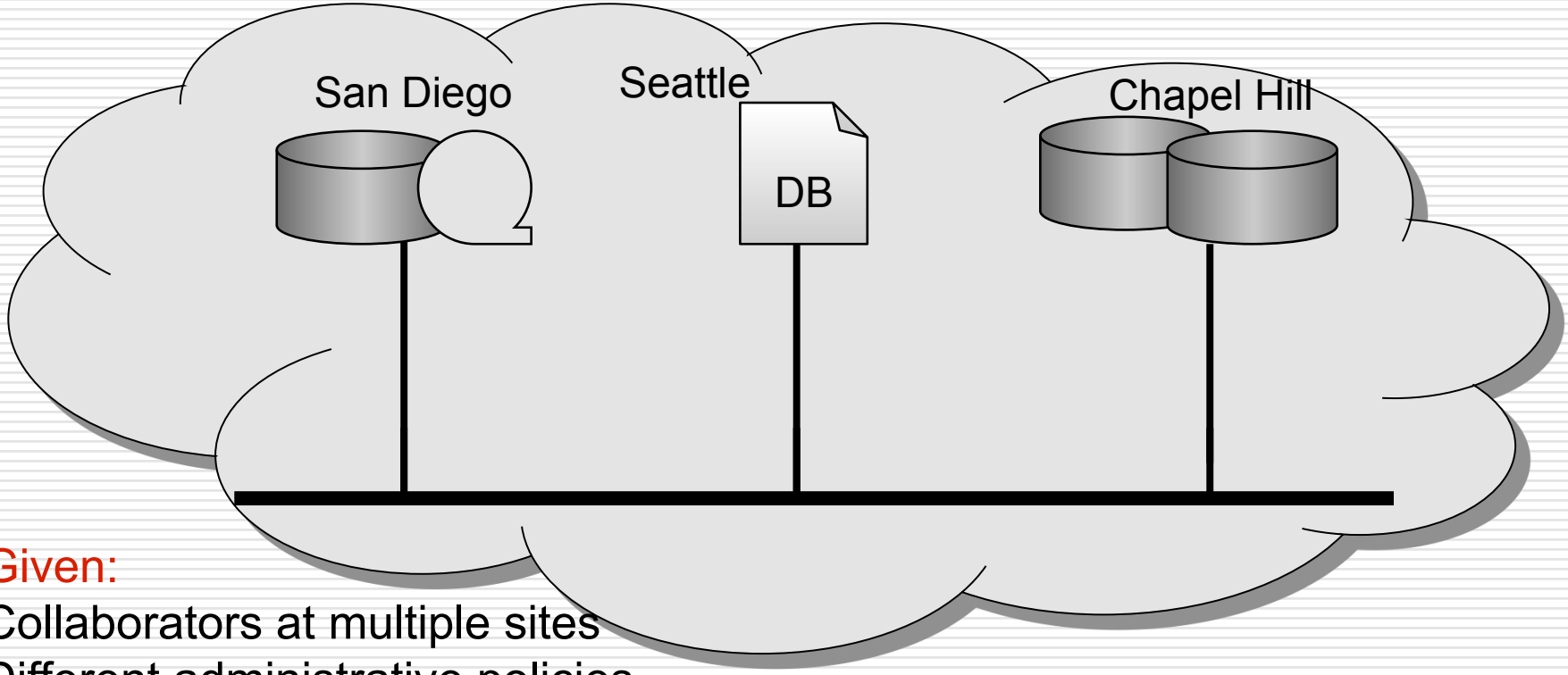
Use Case: Social Science

- ODUM Institute social science data
  - Replicate XML-based data collection into iRODS Data Grid
  - Create XML file holding all the data
  - Load XML file into iRODS Data Grid
  - Apply XLST transformation on data to derive the attributes to register into the iRODS Metadata Catalog to support discovery
  - Bulk load the metadata attributes
  - Use iRODS micro-service to access a remote URL defined by the metadata to retrieve a given survey

iRODS – more details

- **A data grid system - data virtualization**
  - A distributed file system, based on a client-server architecture.
  - Allows users to access files seamlessly across a distributed environment, based upon their attributes rather than just their names or physical locations.
  - It replicates, syncs and archives data, connecting heterogeneous resources in a logical and abstracted manner.
- **A distributed workflow system - policy virtualization**
  - Policies can be coded as functions (micro-services)
  - Remote micro-services can be chained
  - The chains (workflows) are interpreted at run-time
  - Chains can be triggered on an event and condition (Rules)
    - They can also be recursive.
  - Micro-services communicate through parameters, shared contexts, and out-of-band message queues.

Building a Shared Collection



Given:

Collaborators at multiple sites

Different administrative policies

Different types of storage systems

Different naming conventions

Challenge: Assemble a self-consistent, persistent distributed shared collection

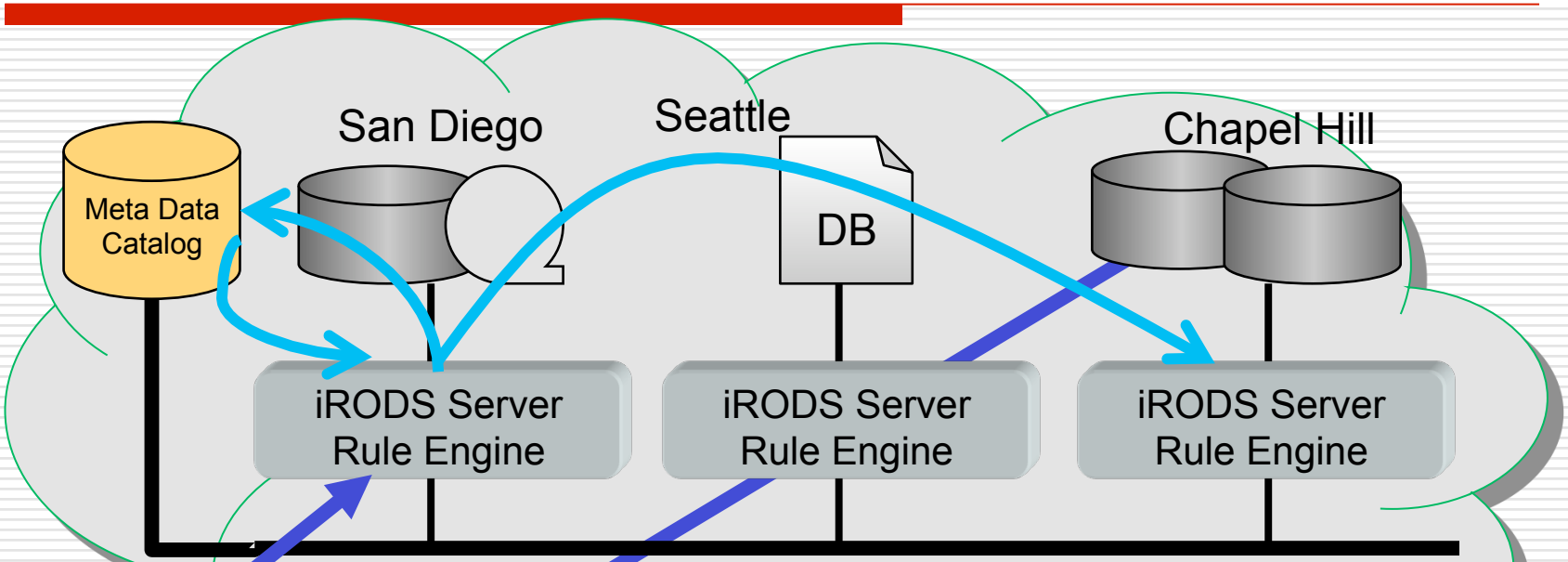
Shared Collection Challenges

- Need common naming conventions to identify
  - Collaborators
  - Shared data and their types & methods
  - Shared data resources & access policies
- Need discovery metadata
  - Assign attributes to each name space
    - State information (metadata)
- Assign policies between name spaces
  - Access constraints, disposition policy, integrity
- Mediate across site and project policies

Discovery: Metadata

- System Metadata
  - User name space
    - Address / e-mail / telephone number
    - Role (administrator, curator, user)
  - File name space
    - Creation date / size / location / checksum
    - Owner / access controls
  - Storage resource name space
    - Capacity / quotas / Type (archive, disk, fast cache)
- Domain Metadata
  - User-given metadata
    - Key-Value-Unit Triplets, Annotations
    - Relational / XML Metadata
    - Domain-specific Schemas
      - Dublin Core, Darwin Core, FITS, DICOM, …

Under the hood - a glimpse



- User asks for data (using logical properties)
- Data request goes to 1st Server
- Server looks up information in catalog
- Catalog tells 2nd federated server has data
- 1st server asks 2nd server for data
- 2nd server applies Rules and serves data

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Policies in iRODS

- **Policies**: Express community goals for data access and sharing, management, long-term preservation, uses, etc.
- **Policy Examples**
  - Run a particular workflow when a "set of files" is ingested into a collection (e.g. make thumbnails of images, post to website).
  - Automatically replicate a file added to a collection into 3 geographically distributed sites.
  - Automatically extract metadata for a file of a certain type and store in metadata catalog.
  - Periodically check integrity of files in a Collection and repair/replace if needed/possible.
  - Automatically pick a certain storage location based on user or collection or size or type.
  - Let a user access a collection only if using certificate-based login.
  - Send a notification when a certain file is ingested.
  - etc.

iRODS Rules

- Implement Policies
- Verify enforcement (audit trails)
- Automate management of exploding data
  - Let you handle petabytes in hundreds of millions of files
- Each Rule defines
  - Event, Condition, Action chains (micro-services, other Rules), Recovery chains
- Rule types
  - Atomic (immediate), Deferred, Periodic
- Rules are executed by Micro-services
  - Applied where data is (server-side)

Micro-services

- Function snippets – perform a small, well-defined operation/semantics, e.g.
  - computeChecksum
  - replicateFile
  - integrityCheckGivenCollection
  - zoomImage
  - getSDSSImageCutOut
  - searchPubMed
- Chained to implement iRODS Rules (workflows)
- Invoked by the iRODS Rule Engine
- Recovery micro-services provide roll-back upon failure
- Currently C functions; PHP, Java coming soon
- Can wrap Web-services

Summary

- **Motivation**: Problems iRODS Addresses
  - Collaborative Research & Education
    - *"Connecting the dots"*
  - Long-term Preservation
- **Introduction** to iRODS, the Integrated Rule-Oriented Data System
- **Use Cases**
  - Research, Preservation, Humanities, etc.
- iRODS – more details

DICE Center

- Center for Data Intensive Cyber Environments
  - University of North Carolina at Chapel Hill (UNC)
    - UNC School of Information and Library Science (SILS)
    - Renaissance Computing Institute (RENCI)
      - Reagan Moore
      - Richard Marciano
      - Arcot Rajasekar
      - Antoine de Torcy, Chien-Yi Hou
  - UC San Diego
    - Institute for Neural Computation (INC)
      - Mike Wan
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  - iRODS development is supported by
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