# Storage Tiering

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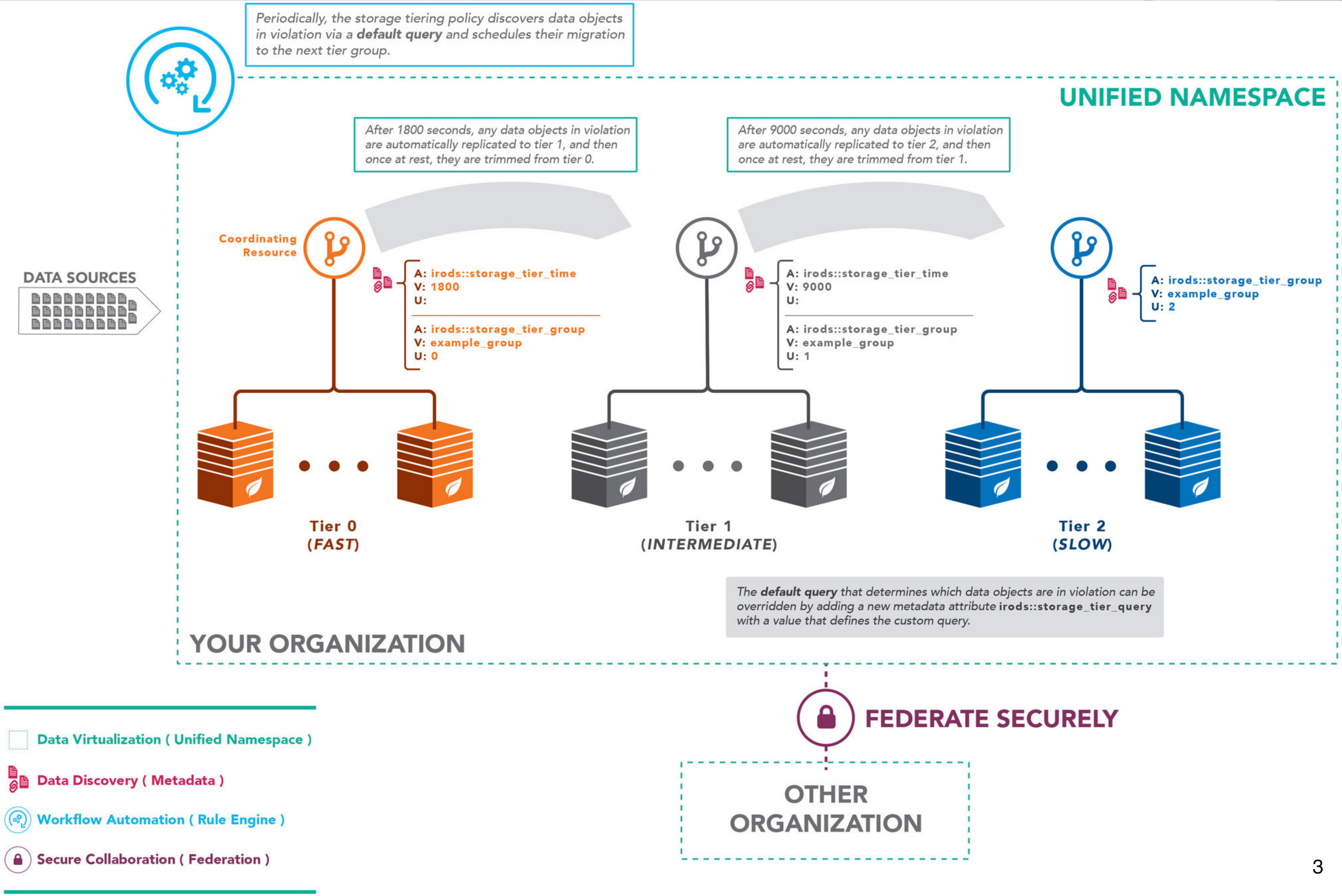
## iRODS Capabilities

- Packaged and supported solutions
- Require configuration not code
- Derived from the majority of use cases observed in the user community

| | |
|---|---|
| Storage Tiering | Automated Ingest |
| Auditing | Indexing |
| Provenance | Compliance |
| Data Integrity | Publishing |

# Storage Tiering Overview



Periodically, the storage tiering policy discovers data objects in violation via a **default query** and schedules their migration to the next tier group.

After 1800 seconds, any data objects in violation are automatically replicated to tier 1, and then once at rest, they are trimmed from tier 0.

After 9000 seconds, any data objects in violation are automatically replicated to tier 2, and then once at rest, they are trimmed from tier 1.

```
A: irods::storage_tier_time
V: 1800
U:

A: irods::storage_tier_group
V: example_group
U: 0
```

```
A: irods::storage_tier_time
V: 9000
U:

A: irods::storage_tier_group
V: example_group
U: 1
```

```
A: irods::storage_tier_group
V: example_group
U: 2
```

The **default query** that determines which data objects are in violation can be overridden by adding a new metadata attribute **irods::storage_tier_query** with a value that defines the custom query.

## Data Object Access Time

The default policy for tiering is based on the last time of access for a given data object which is applied as metadata

```
irods::access_time <unix timestamp>
```

Dynamic Policy Enforcement Points for RPC API are used to apply the metadata

```
pep_api_data_obj_close_post
pep_api_data_obj_put_post
pep_api_data_obj_get_post
pep_api_phy_path_reg_post
```

## Configuring a Tier Group

Tier groups are entirely driven by metadata

- The attribute identifies the resource as a tiering group participant
- The value defines the group name
- The unit defines the position within the group

```
imeta set -R <resc0> irods::storage_tiering::group example_group 0
imeta set -R <resc1> irods::storage_tiering::group example_group 1
imeta set -R <resc2> irods::storage_tiering::group example_group 2
```

- Tier position, or index, can be any value - order will be honored
- Configuration must be performed at the root of a resource composition
- A resource may belong to many tiering groups

## Configuring Tiering Time Constraints

Tiering violation time is configured in seconds

Configure a tier to hold data for 30 seconds

```
imeta set -R <resc> irods::storage_tiering::time 30
```

Configure a tier to hold data for 30 days

```
imeta set -R <resc> irods::storage_tiering::time 2592000
```

The final tier in a group does not have a storage tiering time
  - it will hold data indefinitely

## Verification of Data Migration

When data is found to be in violation:

- Data object is replicated to the next tier
- New replica integrity is verified (in one of three ways)
- Source replica is trimmed

'catalog' is the default verification for all resources

```
imeta set -R <resc> irods::storage_tiering::verification catalog
```

For verification, this setting will determine if the replica is properly registered within the catalog after replication.

## Verification of Data Migration

Filesystem verification is more expensive as it involves a potentially remote file system stat.

```
imeta add -R <resc> irods::storage_tiering::verification filesystem
```

This option will stat the remote replica on disk and compare the file size with that of the catalog.

## Verification of Data Migration

Checksum verification is the most expensive as file sizes may be large

```
imeta add -R <resc> irods::storage_tiering::verification checksum
```

Compute a checksum of the data once it is at rest, and compare with the value in the catalog.

Should the source replica not have a checksum one will be computed before the replication is performed

## Configuring the restage resource

When data is in a tier other than the lowest tier, upon access the data is restaged back to the lowest tier.

This flag identifies the tier for restage:

```
imeta add -R <resc> irods::storage_tiering::minimum_restage_tier true
```

Users may not want data restaged back to the lowest tier, should that tier be very remote or not appropriate for analysis.

Consider a storage resource at the edge serving as a landing zone for instrument data.

## Preserving Replicas

Some users may not wish to trim a replica from a tier when data is migrated, such as to allow data to be archived and also still available on fast storage.

To preserve a replica on any given tier, attach the following metadata flag to the root resource.

```
imeta set -R <resc> irods::storage_tiering::preserve_replicas true
```

## Custom Violation Query

Admins may specify a custom query which identifies violating data objects

```
imeta set -R <resc> irods::storage_tiering::query "SELECT
DATA_NAME, COLL_NAME, DATA_RESC_ID WHERE META_DATA_ATTR_NAME =
'irods::access_time' AND META_DATA_ATTR_VALUE <
'TIME_CHECK_STRING' AND DATA_RESC_ID IN ('10021', '10022')"
```

Any number of queries may be attached to a resource in order provide a range of criteria by which violating data may be identified

- could include user applied metadata
- could include externally harvested metadata

## Custom Violating Specific Query

More complex SQL may be required to identify violating objects.  Users may configure Specific Queries and attach those to a given tier within a group.

### Create a specific query in SQL

```
iadmin asq "select distinct R_DATA_MAIN.data_name, R_COLL_MAIN.coll_name,
R_DATA_MAIN.resc_id from R_DATA_MAIN, R_COLL_MAIN, R_OBJT_METAMAP r_data_metamap,
R_META_MAIN r_data_meta_main where R_DATA_MAIN.resc_id IN (10021, 10022) AND
r_data_meta_main.meta_attr_name = 'archive_object' AND r_data_meta_main.meta_attr_value
= 'true' AND R_COLL_MAIN.coll_id = R_DATA_MAIN.coll_id AND R_DATA_MAIN.data_id =
r_data_metamap.object_id AND r_data_metamap.meta_id = r_data_meta_main.meta_id order by
R_COLL_MAIN.coll_name, R_DATA_MAIN.data_name" archive_query
```

### Configure the specific query

```
imeta set -R <resc> irods::storage_tiering::query archive_query specific
```

## Limiting violating query results

When working with large sets of data, throttling the amount of data migrated at one time can be helpful.

In order to limit the results of the violating queries attach the following metadata attribute with the value set as the query limit.

```
imeta set -R <resc> irods::storage_tiering::object_limit LIMIT_VALUE
```

## Logging data transfer

In order to record the transfer of data objects from one tier to the next, the storage tiering plugin on the ICAT server can be configured by setting "data_transfer_log_level" : "LOG_NOTICE" in the plugin_specific_configuration.

In /etc/irods/server_config.json add the configuration to the storage_tiering plugin instance:

```
{
    "instance_name": "irods_rule_engine_plugin-storage_tiering-instance",
    "plugin_name": "irods_rule_engine_plugin-storage_tiering",
    "plugin_specific_configuration": {
        "data_transfer_log_level" : "LOG_NOTICE"
    }
},
```

## Storage Tiering Metadata Vocabulary

All default metadata attributes are configurable

```
"plugin_specific_configuration": {
    "access_time_attribute" : "irods::access_time",
    "storage_tiering_group_attribute" : "irods::storage_tiering::group",
    "storage_tiering_time_attribute" : "irods::storage_tiering::time",
    "storage_tiering_query_attribute" : "irods::storage_tiering::query",
    "storage_tiering_verification_attribute" : "irods::storage_tiering::verification",
    "storage_tiering_restage_delay_attribute" : "irods::storage_tiering::restage_delay",
    "default_restage_delay_parameters" : "<PLUSET>1s</PLUSET><EF>1h DOUBLE UNTIL SUCCESS OR 6 TIMES</EF>",
    "time_check_string" : "TIME_CHECK_STRING"
}
```

Should there be a preexisting vocabulary in your organization, it can be leveraged by redefining the metadata attributes used by the storage tiering framework.

## Example Implementation

Getting Started

## Installing Tiered Storage Plugin

As the **ubuntu** user

Install the package repository

```
wget -qO - https://packages.irods.org/irods-signing-key.asc | sudo apt-key add -
echo "deb [arch=amd64] https://packages.irods.org/apt/ $(lsb_release -sc) main" | \
  sudo tee /etc/apt/sources.list.d/renci-irods.list
sudo apt-get update
```

Install the storage tiering package

```
ubuntu@hostname:~$ sudo apt-get install irods-rule-engine-plugin-storage-tiering
```

## Configuring the rule engine plugin

As the **irods** user

Edit /etc/irods/server_config.json

```
"rule_engines": [
    {
         "instance_name": "irods_rule_engine_plugin-storage_tiering-instance",
         "plugin_name": "irods_rule_engine_plugin-storage_tiering",
         "plugin_specific_configuration": {
         }
    },
    {
        "instance_name": "irods_rule_engine_plugin-irods_rule_language-instance",
        "plugin_name": "irods_rule_engine_plugin-irods_rule_language",
        "plugin_specific_configuration": {
            <snip>
        },
        "shared_memory_instance": "irods_rule_language_rule_engine"
    },
    ...
]
```

Note - Make sure **storage_tiering** is the only rule engine plugin listed above **irods_rule_language**.

## Example Implementation

Three Tier Group with Random Resources

## Make some resources

As the **irods** user

```
iadmin mkresc rnd0 random
iadmin mkresc rnd1 random
iadmin mkresc rnd2 random
iadmin mkresc st_ufs0 unixfilesystem `hostname`:/tmp/irods/st_ufs0
iadmin mkresc st_ufs1 unixfilesystem `hostname`:/tmp/irods/st_ufs1
iadmin mkresc st_ufs2 unixfilesystem `hostname`:/tmp/irods/st_ufs2
iadmin mkresc st_ufs3 unixfilesystem `hostname`:/tmp/irods/st_ufs3
iadmin mkresc st_ufs4 unixfilesystem `hostname`:/tmp/irods/st_ufs4
iadmin mkresc st_ufs5 unixfilesystem `hostname`:/tmp/irods/st_ufs5
iadmin addchildtoresc rnd0 st_ufs0
iadmin addchildtoresc rnd0 st_ufs1
iadmin addchildtoresc rnd1 st_ufs2
iadmin addchildtoresc rnd1 st_ufs3
iadmin addchildtoresc rnd2 st_ufs4
iadmin addchildtoresc rnd2 st_ufs5
```

## Make some resources

### Check the results

```
irods@hostname:~$ ilsresc
demoResc:unixfilesystem
rnd0:random
├── st_ufs0:unixfilesystem
└── st_ufs1:unixfilesystem
rnd1:random
├── st_ufs2:unixfilesystem
└── st_ufs3:unixfilesystem
rnd2:random
├── st_ufs4:unixfilesystem
└── st_ufs5:unixfilesystem
```

## Create a Tier Group

Create a tier group named example_group, adding the metadata to the root resources

```
imeta set -R rnd0 irods::storage_tiering::group example_group 0
imeta set -R rnd1 irods::storage_tiering::group example_group 1
imeta set -R rnd2 irods::storage_tiering::group example_group 2
```

## Set the Tiering Time Constraints

Configure tier 0 to hold data for 30 seconds

```
imeta set -R rnd0 irods::storage_tiering::time 30
```

Configure tier 1 to hold data for 60 seconds

```
imeta set -R rnd1 irods::storage_tiering::time 60
```

Tier 2 does not have a storage tiering time as it will hold data indefinitely

## Testing the tiering

### Stage some data into storage tier 0

```
iput -R rnd0 /tmp/stickers.jpg
```

### Check the results

```
irods@hostname:~$ imeta ls -d stickers.jpg
AVUs defined for dataObj stickers.jpg:
attribute: irods::access_time
value: 1526134799
units:
```

```
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              0 rnd0;st_ufs0      2157087 2018-05-11.11:51 &
stickers.jpg
```

## Sample Tiering rule

JSON ingested by the Tiering Plugin

- run once until success or six failures

```
{
   "rule-engine-instance-name": "irods_rule_engine_plugin-tiered_storage-instance",
   "rule-engine-operation": "apply_storage_tiering_policy",
   "delay-parameters": "<PLUSET>1s</PLUSET><EF>1h DOUBLE UNTIL SUCCESS OR 6 TIMES</EF>",
   "storage-tier-groups": [
       "example_group_g2",
       "example_group"
   ]
}
INPUT null
OUTPUT ruleExecOut
```

In production this would be persistently on the delay queue

## Launching the sample Tiering rule

### Run the rule from the terminal

```
irule -r irods_rule_engine_plugin-storage_tiering-instance -F example_tiering_invocation.r
```

### Check the delay queue

```
irods@hostname:~$ iqstat
id     name
10038 {"rule-engine-operation":"apply_storage_tiering_policy","storage-tier-groups":["example_group_g2","example_group"]}
```

### Wait for the delay execution engine to fire...

### Check the resource for stickers.jpg

```
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              2 rnd1;st_ufs2      2157087 2018-05-12.10:22 &
stickers.jpg
```

## Launching the Tiering rule once more

The time for violation is 60 seconds for rnd1

```
irule -r irods_rule_engine_plugin-storage_tiering-instance -F example_tiering_invocation.r
```

Check the delay queue

```
irods@hostname:~$ iqstat
id     name
10038 {"rule-engine-operation":"apply_storage_tiering_policy","storage-tier-groups":["example_group_g2","example_group"]}
```

Wait for the delay execution engine to fire...

Check the resource for stickers.jpg

```
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              3 rnd2;st_ufs4      2157087 2018-05-12.10:22 & stickers.jpg
```

## Restaging Data

Fetching data when it is not in the lowest tier will automatically trigger a restaging of the data

```
irods@hostname:~$ iget -f stickers.jpg


irods@hostname:~$ iqstat
id name
10035 {"rule-engine-operation":"apply_storage_tiering_policy","storage-tier-groups":["example_group_g2","example_group"]}
```

The object will be replicated back to the lowest tier, honoring the verification policy

```
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              4 rnd0;st_ufs1      2157087 2018-05-12.10:22 & stickers.jpg
```

## Setting a Minimum Restage Tier

In order to flag a resource as the target resource for restaging data, we add metadata

```
imeta set -R rnd1 irods::storage_tiering::minimum_restage_tier true
```

The object will be replicated to this tier instead of the lowest tier

```
irods@hostname:~$ !irule
irods@hostname:~$ !irule
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              6 rnd2;st_ufs5          2157087 2018-05-15.15:10 &
stickers.jpg
irods@hostname:~$ iget -f stickers.jpg
irods@hostname:~$ iqstat
id     name
10044 {"destination-resource":"rnd1","object-
path":"/tempZone/home/rods/stickers.jpg","preserve-replicas":false,"rule-engine-
operation":"migrate_object_to_resource","source-resource":"rnd2","verification-
type":"catalog"}
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              7 rnd1;st_ufs2          2157087 2018-05-15.15:10 &
stickers.jpg
```

## Preserving replicas on a given storage tier

If we want to preserve replicas on a tier we can set a metadata flag

```
imeta set -R rnd1 irods::storage_tiering::preserve_replicas true
```

When the staging rule is invoked the replica on the rnd1 tier will not be trimmed after replication

```
irods@hostname:~$ !irule
irule -r irods_rule_engine_plugin-storage_tiering-instance -F
example_tiering_invocation.r
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              1 rnd1;st_ufs2          2157087 2018-05-15.15:28 &
stickers.jpg
  rods              2 rnd2;st_ufs5          2157087 2018-05-15.15:28 &
stickers.jpg
```

A replica is preserved for analysis while another is safe in the archive tier

## Custom violation queries

Any number of queries may be attached to a tier to identify violating objects.

The resource ids of the leaf resources are necessary for the query, not the root.

```
irods@hostname:~$ ilsresc -l st_ufs0
resource name: ufs0
id: 10019
...
irods@hostname:~$ ilsresc -l st_ufs1
resource name: ufs1
id: 10020
....
```

## Custom violation queries

Craft a query that replicates the default behavior

```
imeta set -R rnd0 irods::storage_tiering::query "SELECT DATA_NAME,
COLL_NAME, DATA_RESC_ID WHERE META_DATA_ATTR_NAME = 'irods::access_time'
AND META_DATA_ATTR_VALUE < 'TIME_CHECK_STRING' AND DATA_RESC_ID IN
('10019', '10020')" [general]
```

- Compare data object access time against TIME_CHECK_STRING
- TIME_CHECK_STRING macro is replaced with the current time by the plugin before the query is submitted
- Check DATA_RESC_ID against the list of child resource ids
- Columns DATA_NAME, COLL_NAME, DATA_RESC_ID must be queried in that order
- By default all queries are of the type general, which is optional

## Custom violation queries

Identify the leaf resource ids for the middle tier

```
irods@hostname:~$ ilsresc -l st_ufs2
resource name: ufs2
id: 10021
...
irods@hostname:~$ ilsresc -l st_ufs3
resource name: ufs3
id: 10022
....
```

## Custom violation queries

Craft a query that uses metadata to identify violating objects

Add a Specific Query to iRODS, using new resource ids

```
iadmin asq "select distinct R_DATA_MAIN.data_name, R_COLL_MAIN.coll_name,
R_DATA_MAIN.resc_id from R_DATA_MAIN, R_COLL_MAIN, R_OBJT_METAMAP r_data_metamap,
R_META_MAIN r_data_meta_main where R_DATA_MAIN.resc_id IN (10021, 10022) AND
r_data_meta_main.meta_attr_name = 'archive_object' AND r_data_meta_main.meta_attr_value =
'true' AND R_COLL_MAIN.coll_id = R_DATA_MAIN.coll_id AND R_DATA_MAIN.data_id =
r_data_metamap.object_id AND r_data_metamap.meta_id = r_data_meta_main.meta_id order by
R_COLL_MAIN.coll_name, R_DATA_MAIN.data_name" archive_query
```

Attach the query to the middle tier

```
imeta set -R rnd1 irods::storage_tiering::query archive_query specific
```

This query must be labeled specific via the units

## Testing the queries

### Starting over with stickers.jpg

```
irods@hostname:~$ irm -f stickers.jpg
irods@hostname:~$ iput -R rnd0 /tmp/stickers.jpg
```

### Wait for it...

```
irods@hostname:~$ irule -r irods_rule_engine_plugin-storage_tiering-instance -F
example_tiering_invocation.r

irods@hostname:~$ iqstat
id      name
10065 {"rule-engine-operation":"apply_storage_tiering_policy","storage-tier-groups":
["example_group_g2","example_group"]}
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              1 rnd1;st_ufs3      2157087 2018-05-18.13:38 & stickers.jpg
```

## Testing the queries

The file stopped at rnd1 as the time-based default query is now overridden

```
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              1 rnd1;st_ufs3      2157087 2018-05-18.13:38 & stickers.jpg
```

Now set the metadata flag to archive the data object

```
irods@hostname:~$ imeta set -d /tempZone/home/rods/stickers.jpg archive_object true
```

## Testing the queries

The metadata is set, run the tiering rule

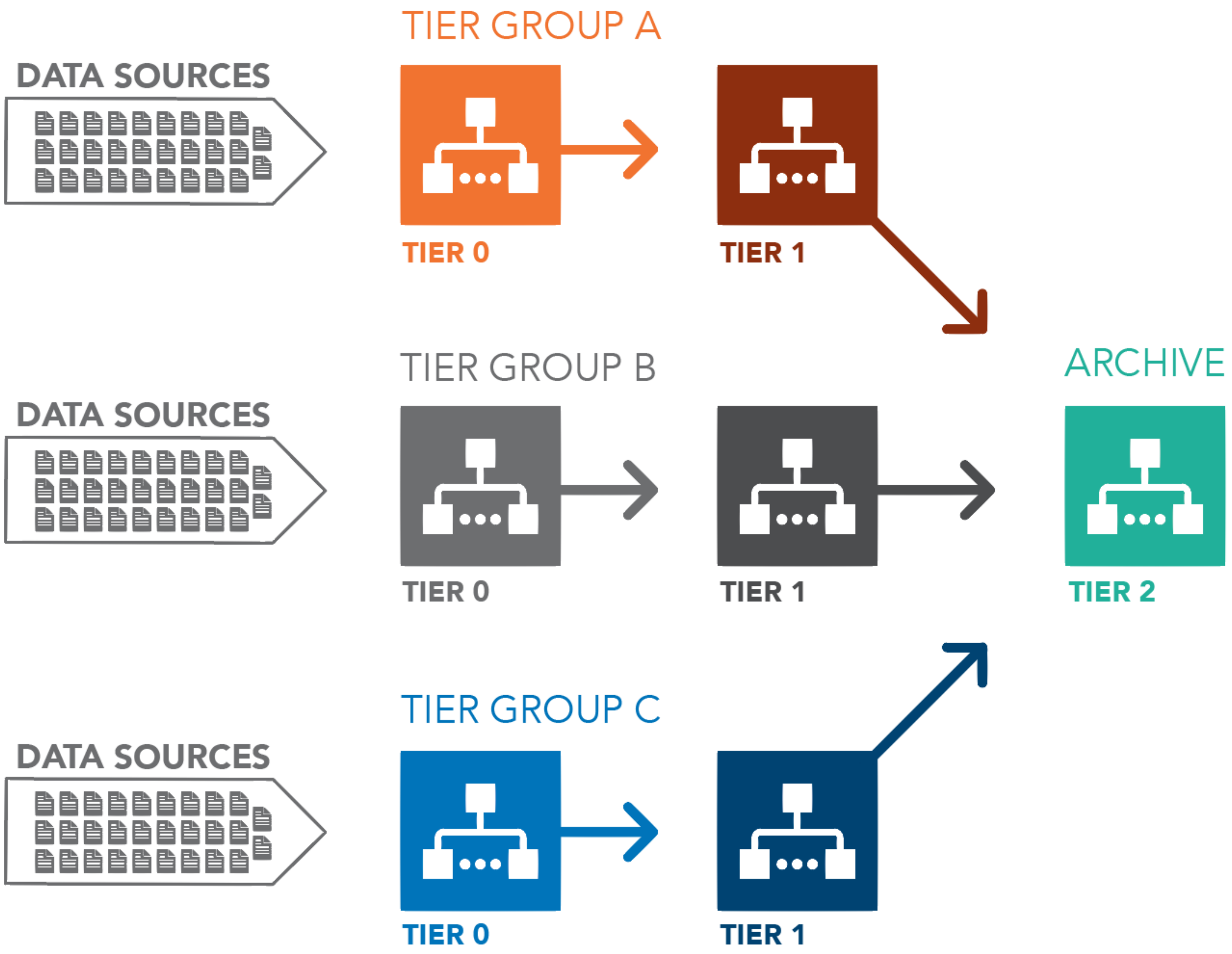
```
irods@hostname:~$ irule -r irods_rule_engine_plugin-storage_tiering-instance -F
example_tiering_invocation.r
irods@hostname:~$ iqstat
id     name
10065 {"rule-engine-operation":"apply_storage_tiering_policy","storage-tier-groups":
["example_group_g2","example_group"]}
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              1 rnd1;st_ufs3      2157087 2018-05-18.13:38 & stickers.jpg
  rods              2 rnd2;st_ufs4      2157087 2018-05-18.14:16 & stickers.jpg
```

The preservation flag is still set so we have two replicas

## Another example

Three Tier Groups with Common Archive

# We will create data flow from instrument to archive



## Create some more resources

```
iadmin mkresc tier2 unixfilesystem `hostname`:/tmp/irods/tier2

iadmin mkresc tier0_A unixfilesystem `hostname`:/tmp/irods/tier0_A
iadmin mkresc tier1_A unixfilesystem `hostname`:/tmp/irods/tier1_A

iadmin mkresc tier0_B unixfilesystem `hostname`:/tmp/irods/tier0_B
iadmin mkresc tier1_B unixfilesystem `hostname`:/tmp/irods/tier1_B

iadmin mkresc tier0_C unixfilesystem `hostname`:/tmp/irods/tier2_C
iadmin mkresc tier1_C unixfilesystem `hostname`:/tmp/irods/tier1_C
```

## Create Tier Groups

### Tier Group A

```
imeta set -R tier0_A irods::storage_tiering::group tier_group_A 0
imeta set -R tier1_A irods::storage_tiering::group tier_group_A 1
imeta add -R tier2   irods::storage_tiering::group tier_group_A 2
```

### Tier Group B

```
imeta set -R tier0_B irods::storage_tiering::group tier_group_B 0
imeta set -R tier1_B irods::storage_tiering::group tier_group_B 1
imeta add -R tier2   irods::storage_tiering::group tier_group_B 2
```

### Tier Group C

```
imeta set -R tier0_C irods::storage_tiering::group tier_group_C 0
imeta set -R tier1_C irods::storage_tiering::group tier_group_C 1
imeta add -R tier2   irods::storage_tiering::group tier_group_C 2
```

## Set Tier Time Constraints

### Tier 0

```
imeta set -R tier0_A irods::storage_tiering::time 30
imeta set -R tier0_B irods::storage_tiering::time 45
imeta set -R tier0_C irods::storage_tiering::time 15
```

### Tier 1

```
imeta set -R tier1_A irods::storage_tiering::time 60
imeta set -R tier1_B irods::storage_tiering::time 120
imeta set -R tier1_C irods::storage_tiering::time 180
```

### Tier 2 has no time constraints

## Creating an automated periodic rule

Create a new rule file to periodically apply the storage tiering policy - foo.r

```
{
   "rule-engine-instance-name": "irods_rule_engine_plugin-storage_tiering-instance",
   "rule-engine-operation": "apply_storage_tiering_policy",
   "delay-parameters": "<PLUSET>1s</PLUSET><EF>REPEAT FOR EVER</EF>",
   "storage-tier-groups": [
       "tier_group_A",
       "tier_group_B",
       "tier_group_C"
   ]
}
INPUT null
OUTPUT ruleExecOut
```

Launch the new rule

```
irods@hostname:~$ irule -r irods_rule_engine_plugin-storage_tiering-instance -F foo.r

irods@hostname:~$ iqstat
id     name
10096 {"rule-engine-operation":"apply_storage_tiering_policy","storage-tier-groups":
["tier_group_A","tier_group_B","tier_group_C"]}
```

## Stage data into all three tiers and watch

```
irods@hostname:~$ iput -R tier0_A /tmp/stickers.jpg stickers_A.jpg
irods@hostname:~$ iput -R tier0_B /tmp/stickers.jpg stickers_B.jpg
irods@hostname:~$ iput -R tier0_C /tmp/stickers.jpg stickers_C.jpg

irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              0 tier0_A       2157087 2018-05-18.21:03 & stickers_A.jpg
  rods              0 tier0_B       2157087 2018-05-18.21:08 & stickers_B.jpg
  rods              0 tier0_C       2157087 2018-05-18.21:13 & stickers_C.jpg
  rods              1 rnd1;st_ufs3     2157087 2018-05-18.13:38 & stickers.jpg
  rods              2 rnd2;st_ufs4     2157087 2018-05-18.14:16 & stickers.jpg
```

## Wait for it...

```
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              0 tier2          2157087 2018-05-18.22:03 & stickers_A.jpg
  rods              1 tier1_B        2157087 2018-05-18.22:00 & stickers_B.jpg
  rods              2 tier0_C        2157087 2018-05-18.21:13 & stickers_C.jpg
  rods              1 rnd1;st_ufs3      2157087 2018-05-18.13:38 & stickers.jpg
  rods              2 rnd2;st_ufs4      2157087 2018-05-18.14:16 & stickers.jpg
```

## And then again...

```
irods@hostname:~$ ils -l
/tempZone/home/rods:
  rods              2 tier2          2157087 2018-05-18.22:03 & stickers_A.jpg
  rods              2 tier2          2157087 2018-05-18.24:00 & stickers_B.jpg
  rods              2 tier2          2157087 2018-05-18.25:45 & stickers_C.jpg
  rods              1 rnd1;st_ufs3      2157087 2018-05-18.13:38 & stickers.jpg
  rods              2 rnd2;st_ufs4      2157087 2018-05-18.14:16 & stickers.jpg
```

All newly ingested stickers_X all now reside in tier2

## Questions?