DAOS: A New Storage Paradigm

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Notices

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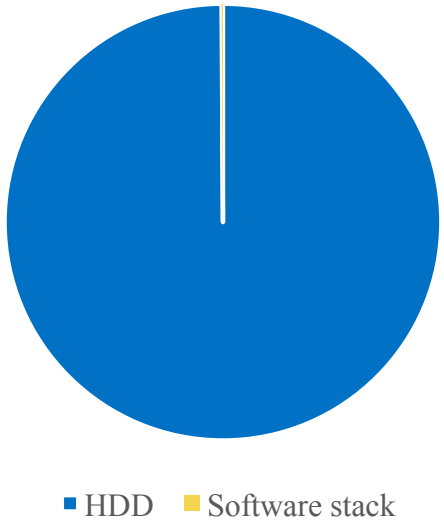
Agenda

- Storage Challenges and DAOS overview
- Next Gen HPC Storage Vision
- Next Gen Storage Stack
- Middleware I/O & Applications
- DAOS/Lustre Integration

Today's HPC Storage System Pain Points

- HPC storage systems perform poorly with random, unaligned or small I/Os
  - Require larger & larger well-aligned sequential I/Os
- Scientific data models limited by POSIX
  - One-size-fits-all POSIX data model
  - **Worst-case** concurrency control mechanism
- Hitting scalability limits of traditional PFS

Challenge: I/O Latency & IOPS



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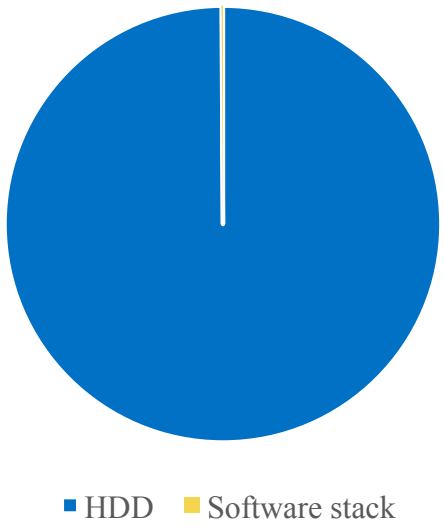

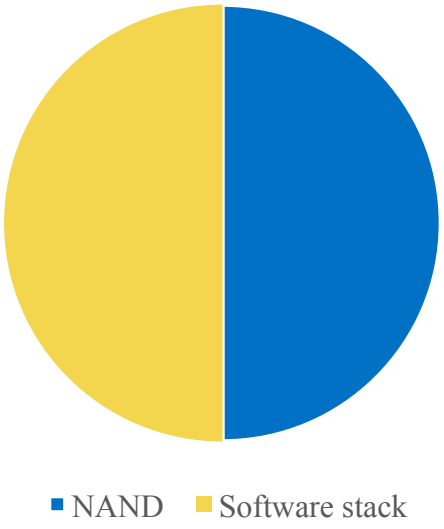

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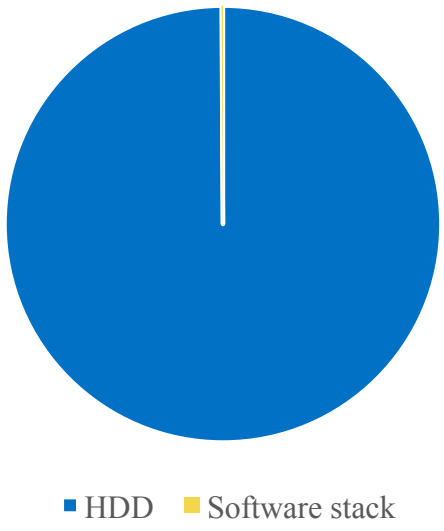
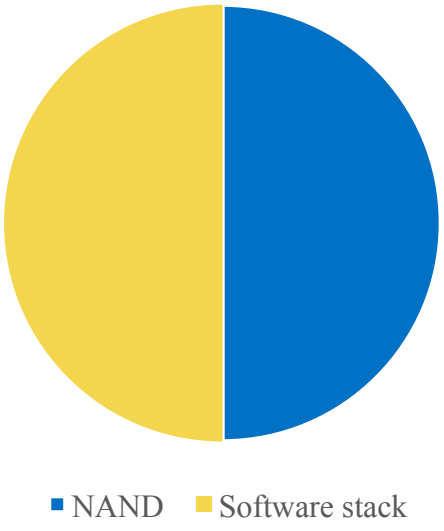
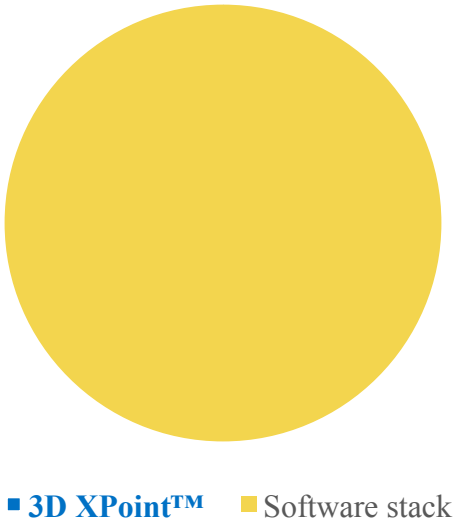
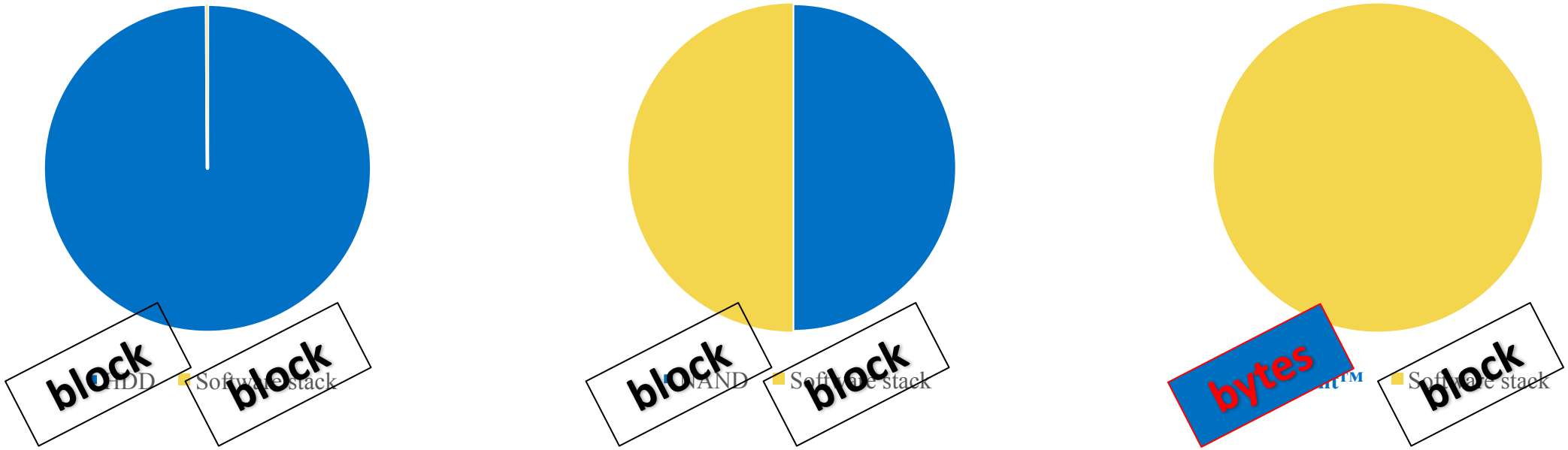






Traditional storage stack entirely masks low latency of 3D XPoint™ !

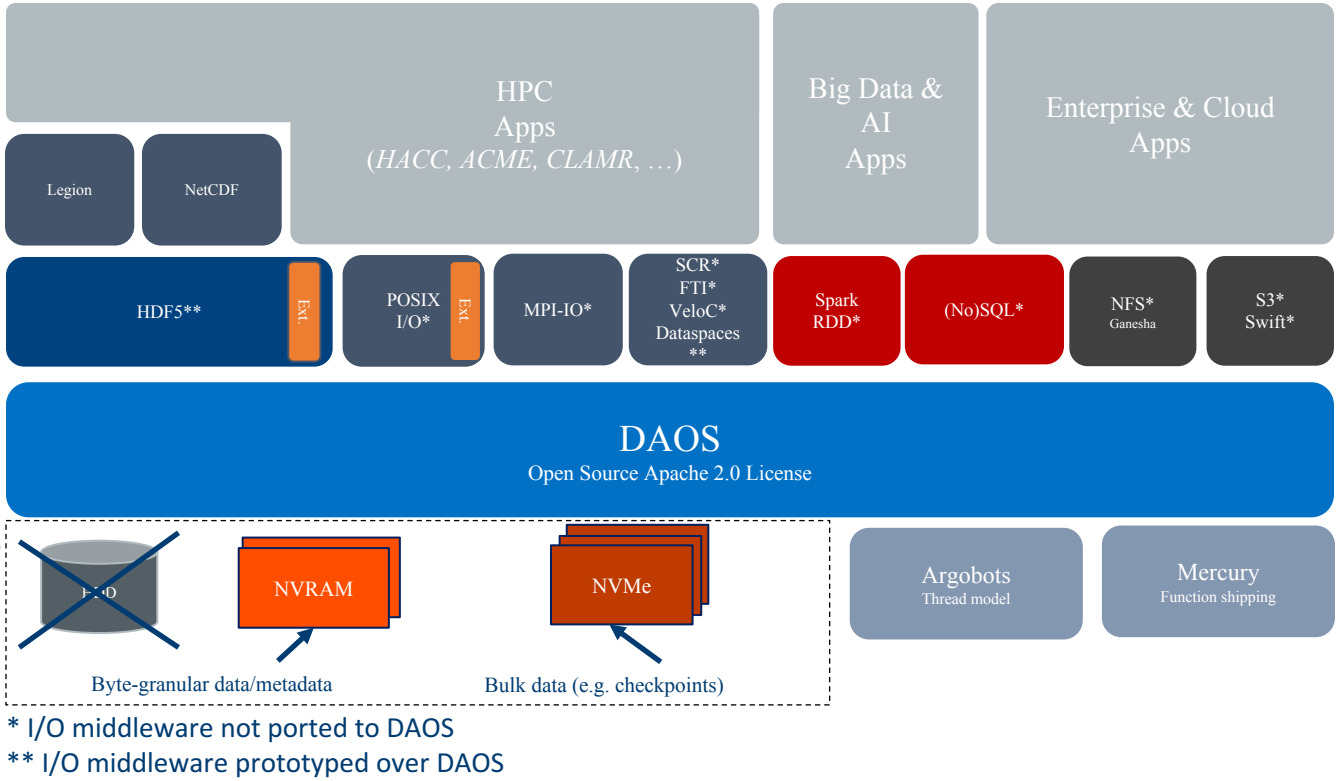
Challenge: Access Granularity



Traditional storage stack entirely **masks**
low latency & capabilities of **3D XPoint™** !

Distributed Asynchronous Object Storage

- **Scale-out object store** designed from the ground up for nextgen storage & fabric technologies
  - High **throughput/IOPS**
  - Byte addressable
  - **OS bypass** with **lightweight** client/server
- **Advanced** storage **API**
  - New scalable **storage model** suitable for **both** *structured* & *unstructured* data
  - **Non-blocking** data & metadata operations



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** I/O middleware prototyped over DAOS

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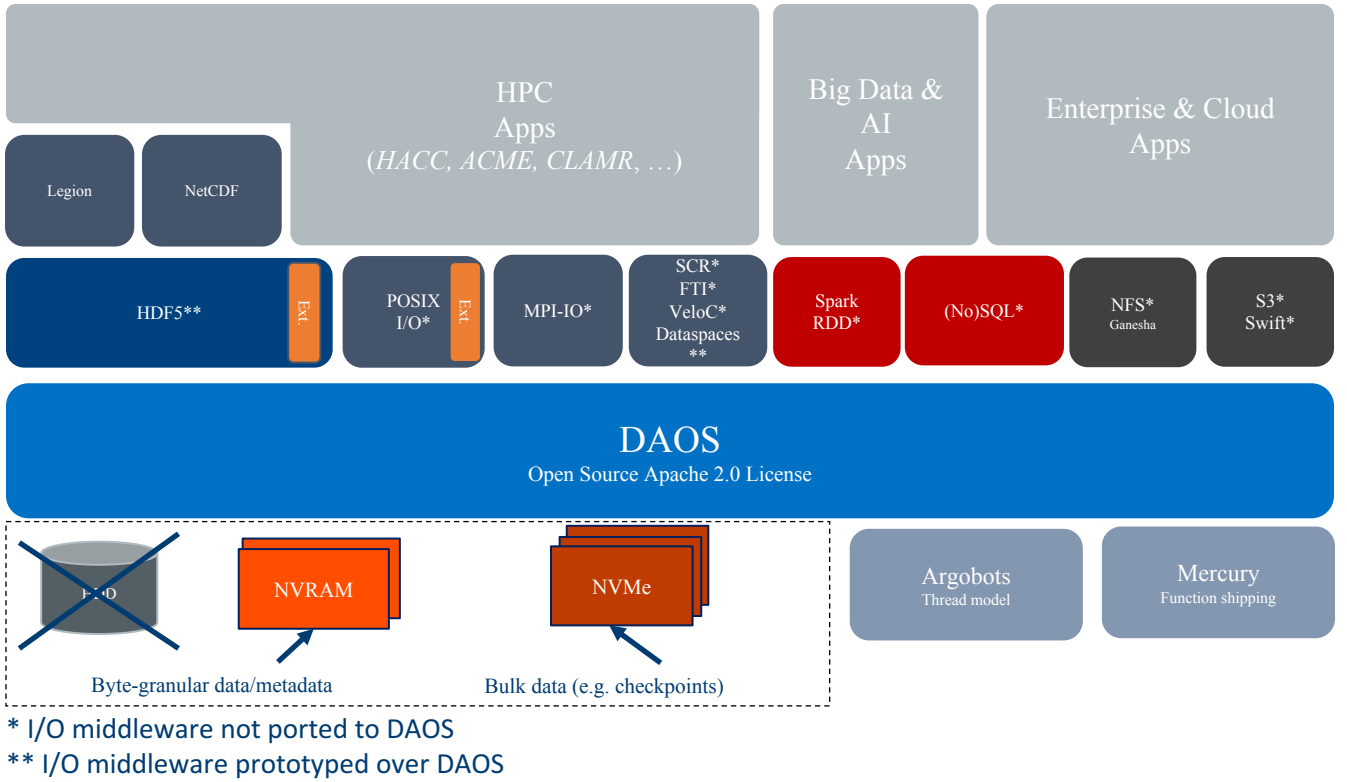
Open source
APACHE 2.0 License
https://github.com/daos-stack



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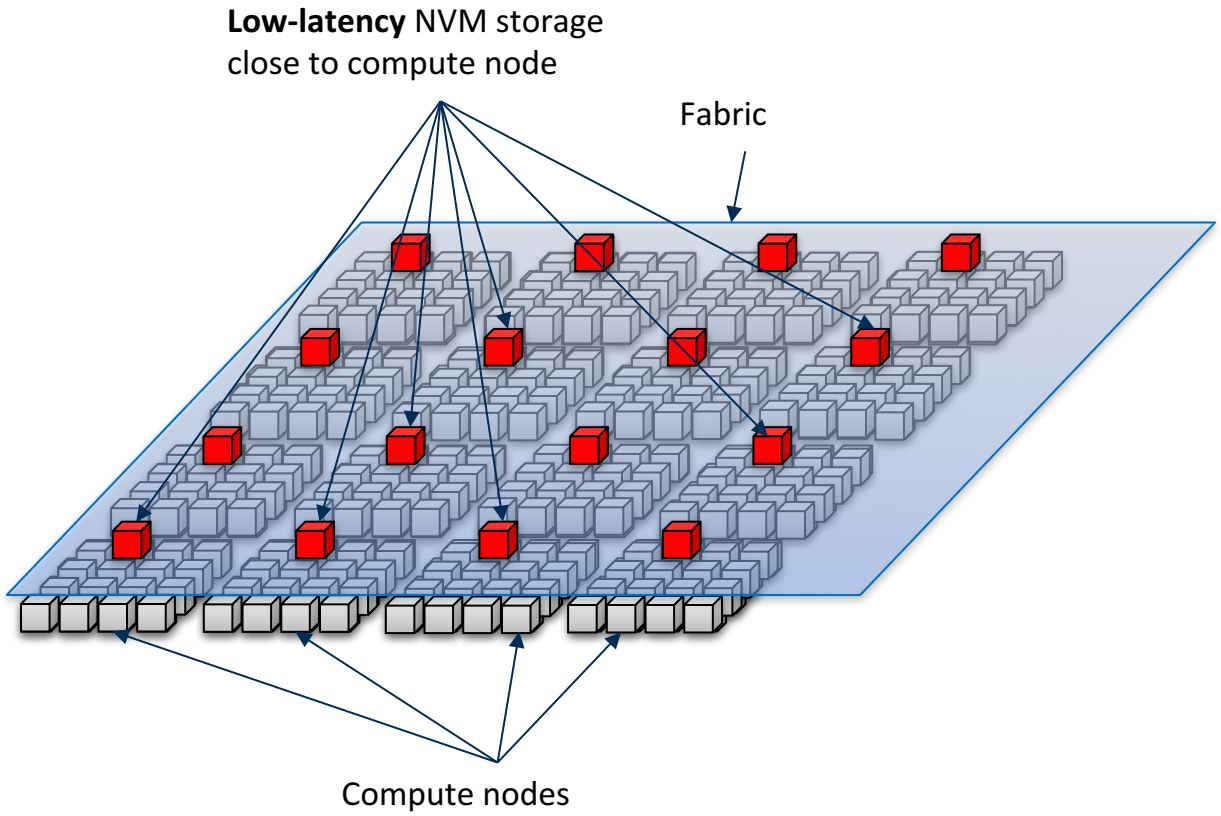
Next Gen HPC Storage Vision

- NVM storage storing datasets



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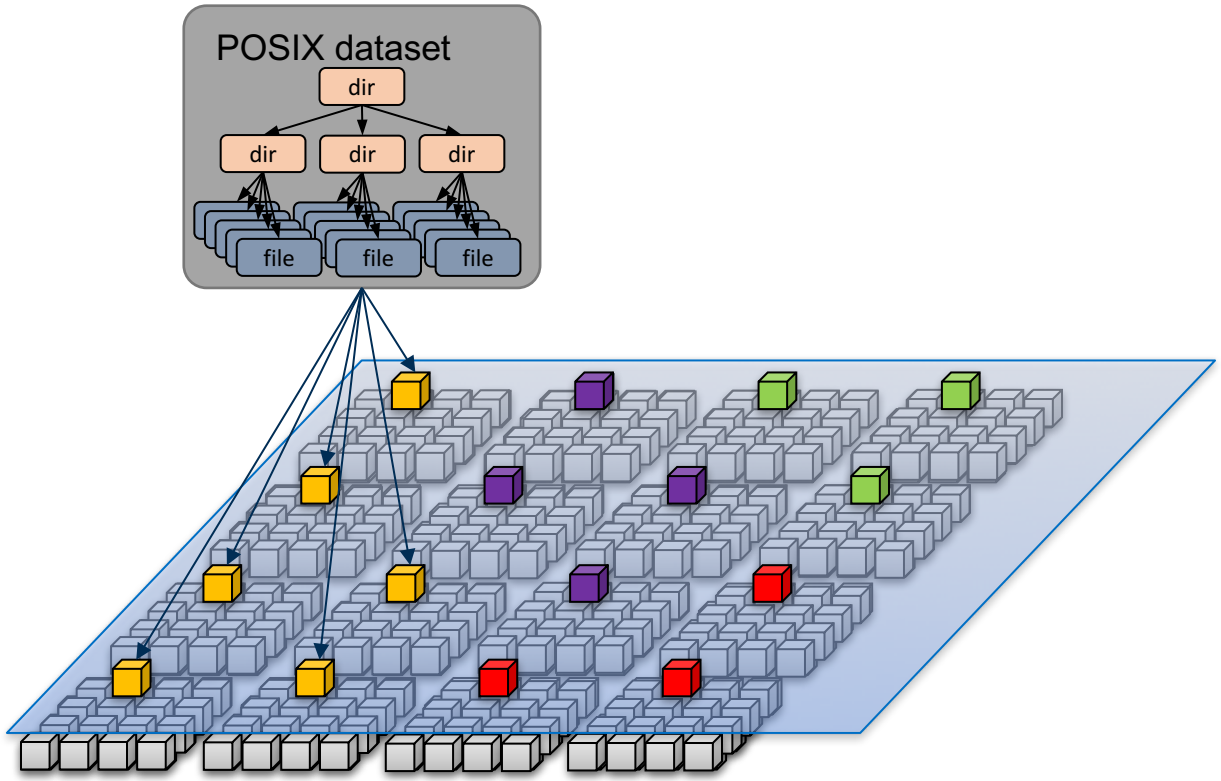

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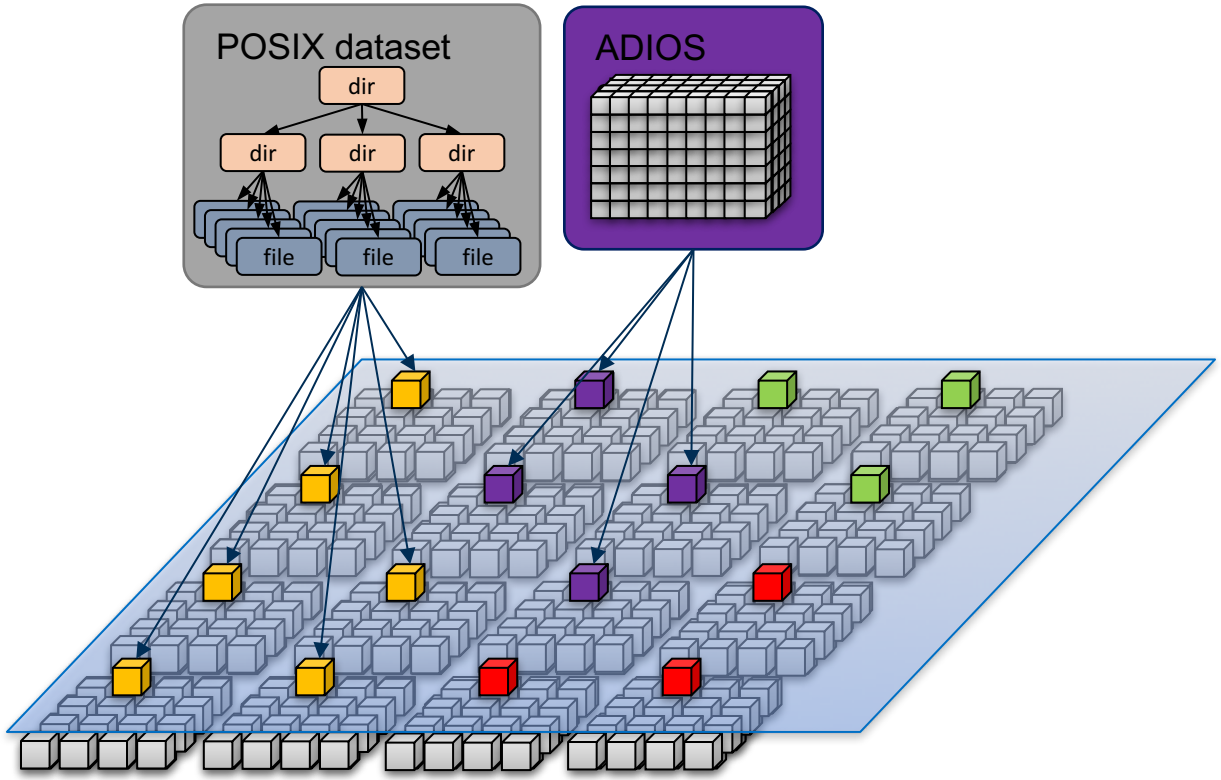

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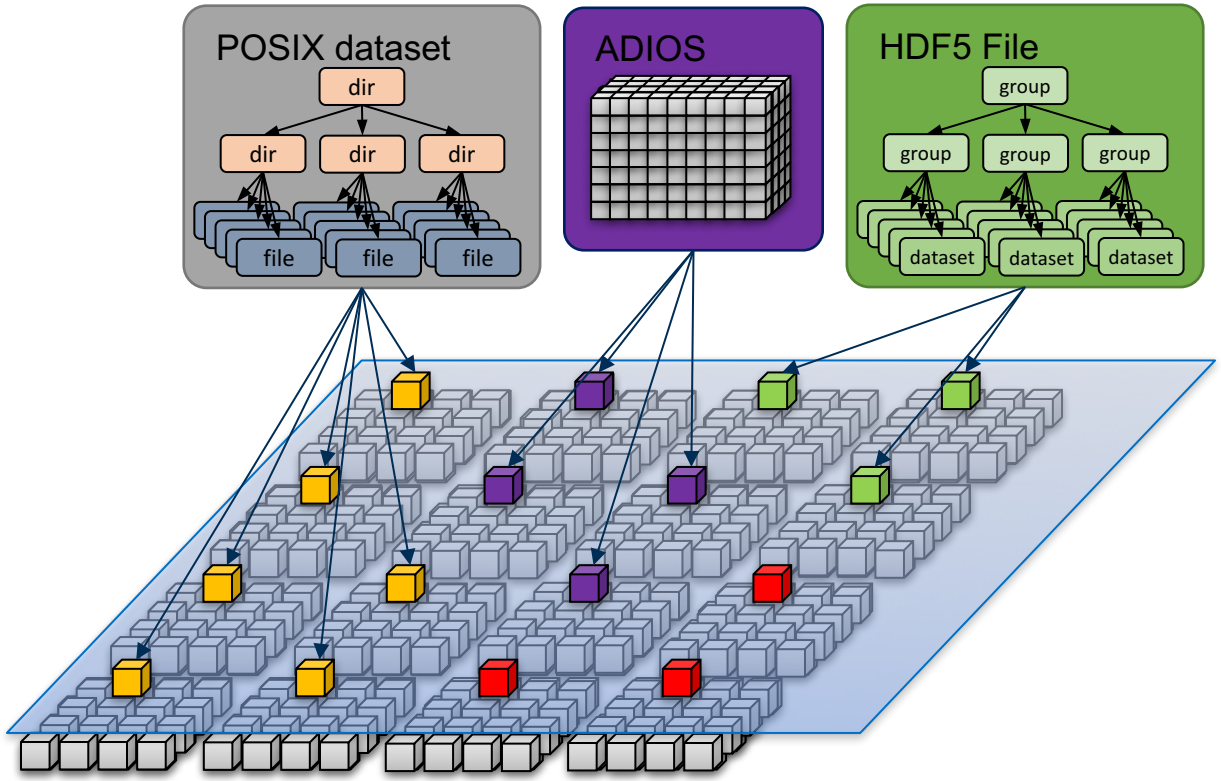

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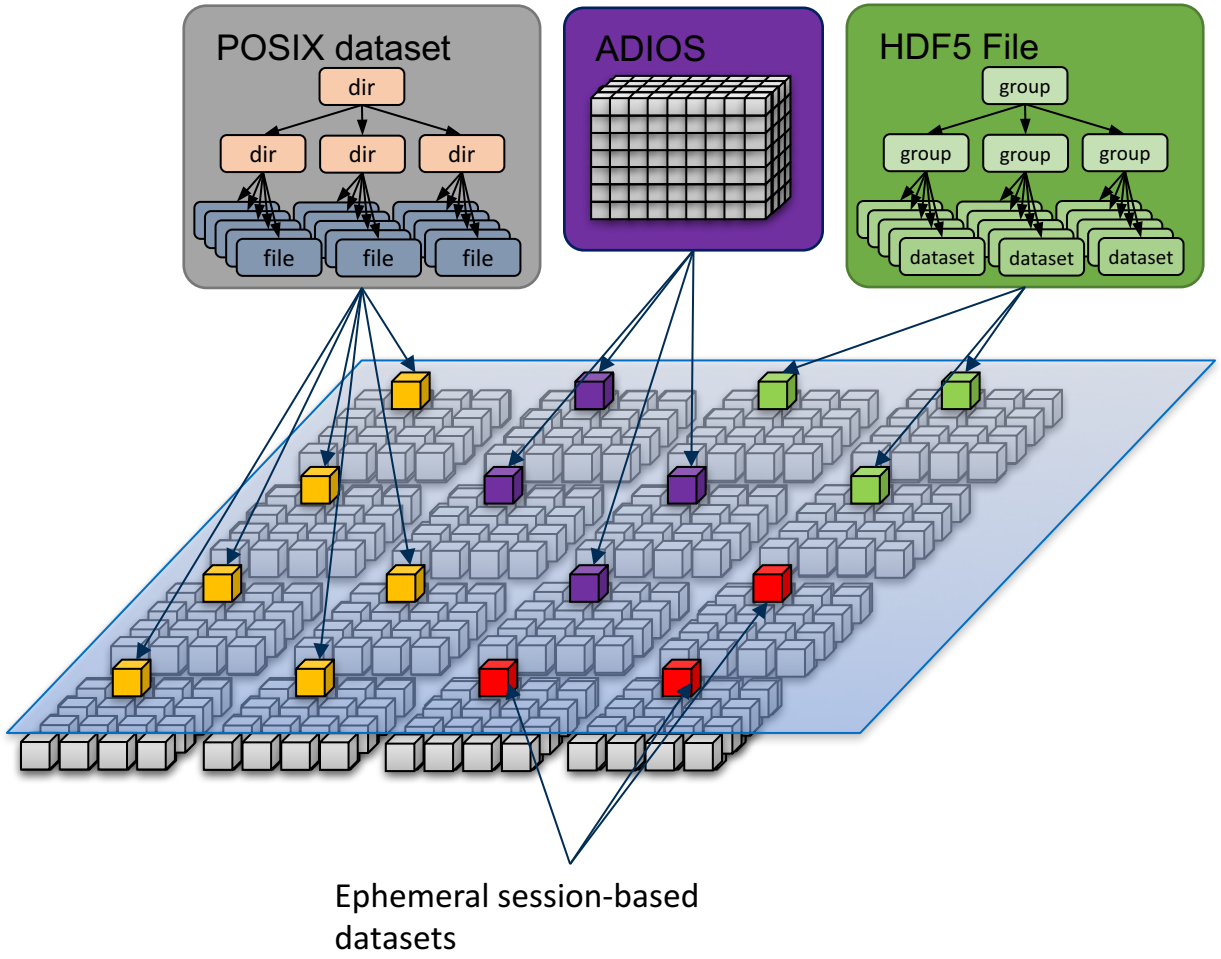
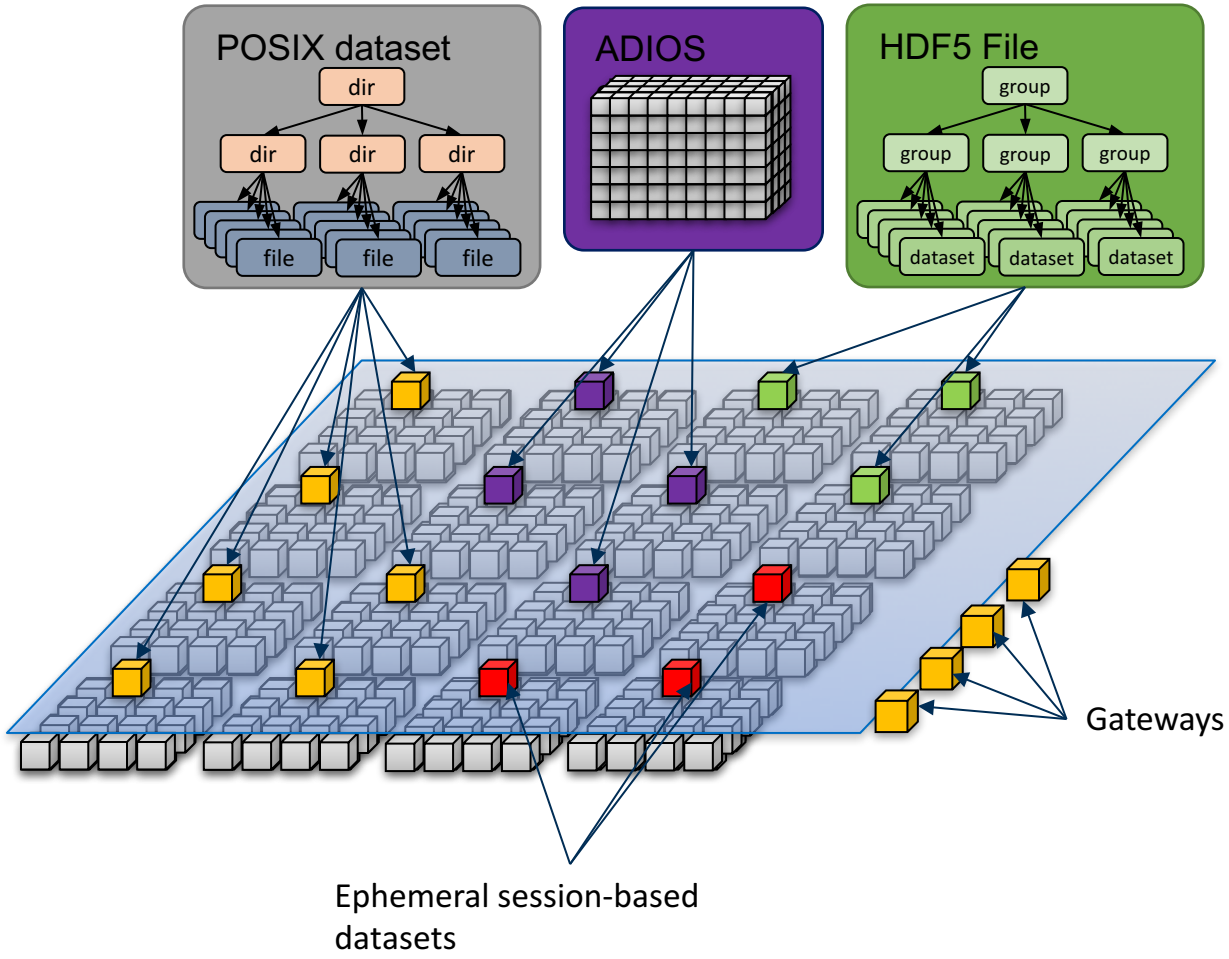


Next Gen HPC Storage Vision

- NVM storage storing datasets
  - **Externally** accessible



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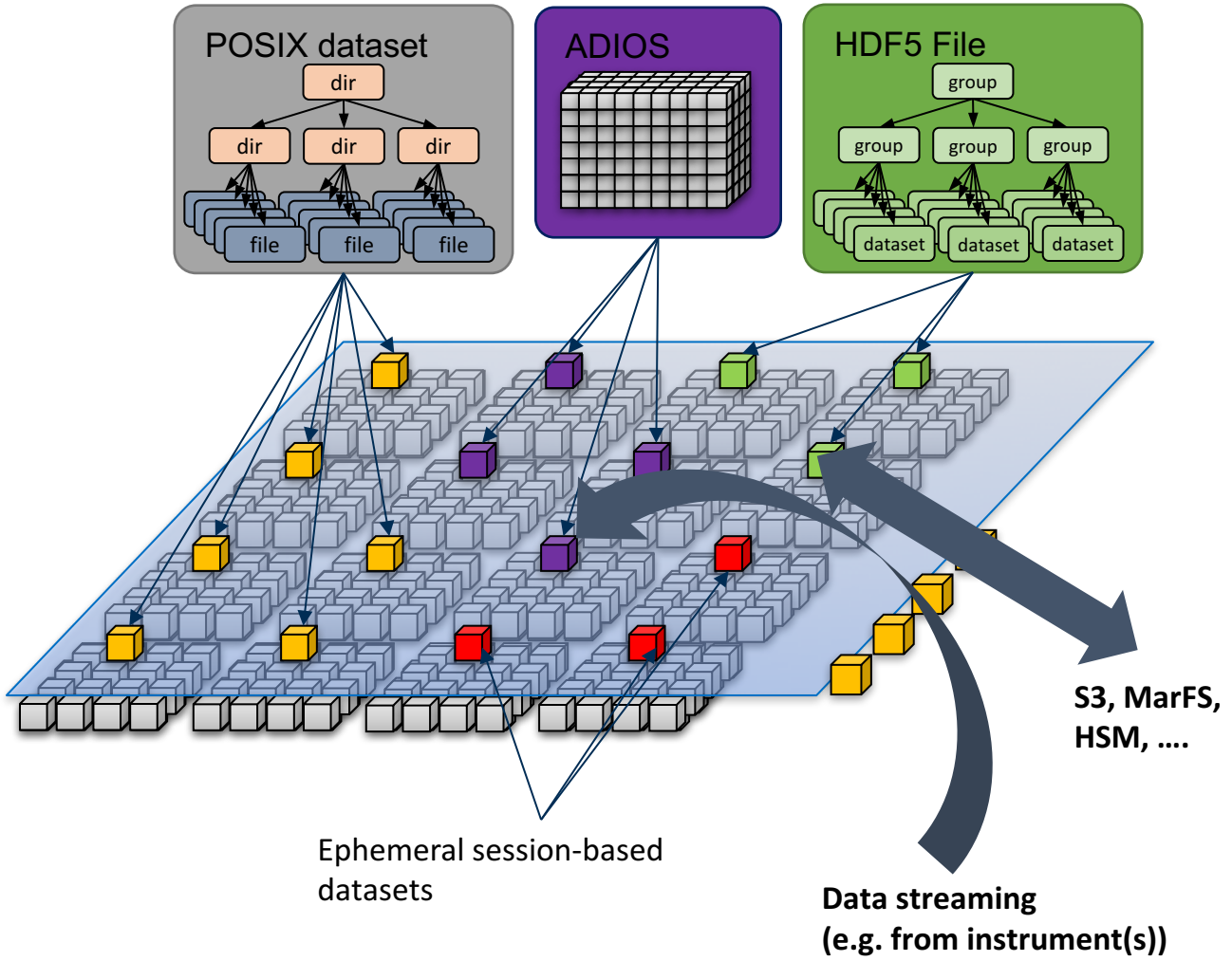
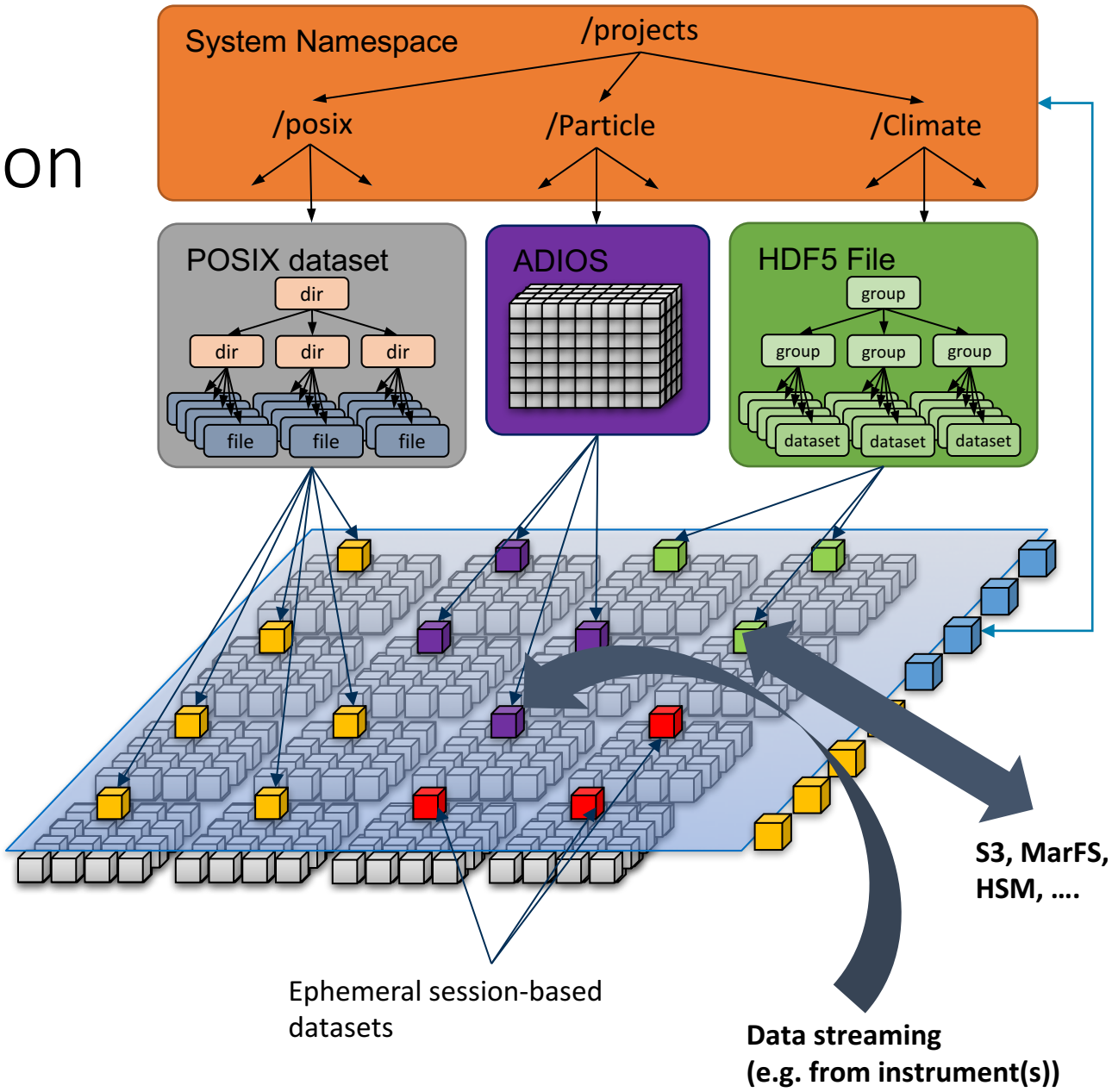
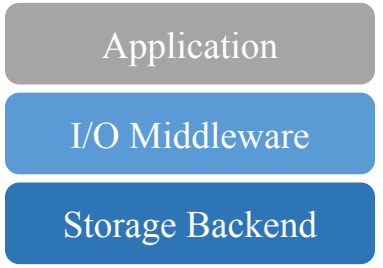


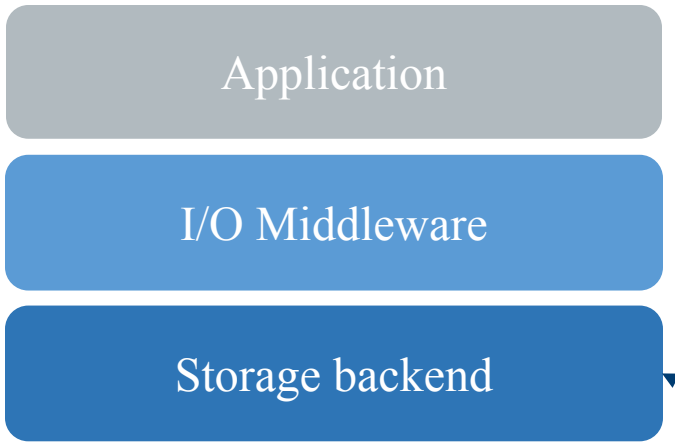
Next Gen HPC Storage Vision

- NVM storage storing datasets
  - **Externally** accessible
- **System namespace**
  - **Global** POSIX namespace
  - **Links** to datasets
  - Binaries, libraries, user files, …



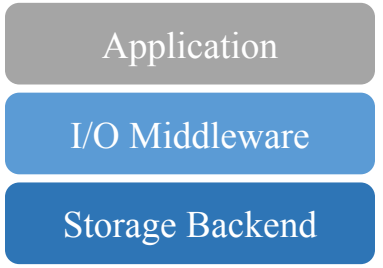
Next Gen Storage Stack

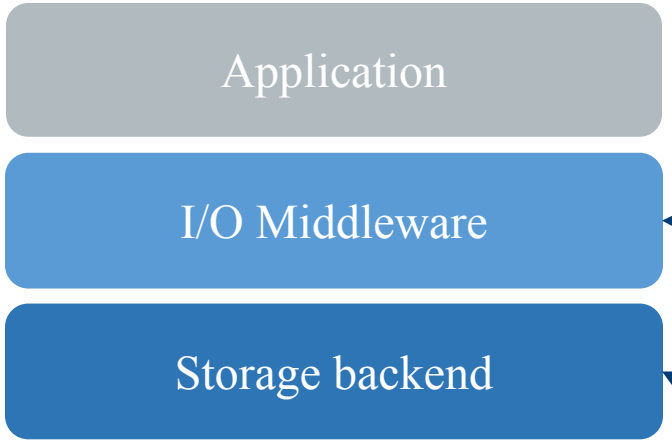




New storage API (*DAOS*) provides extended capabilities and high bandwidth/IOPS to middleware

Next Gen Storage Stack





Port I/O middleware (*HDF5, MPI-I/O, …*) to new storage backend and **augment** API to take advantage of new capabilities

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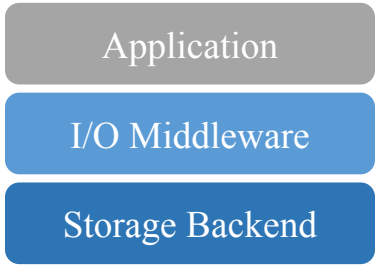
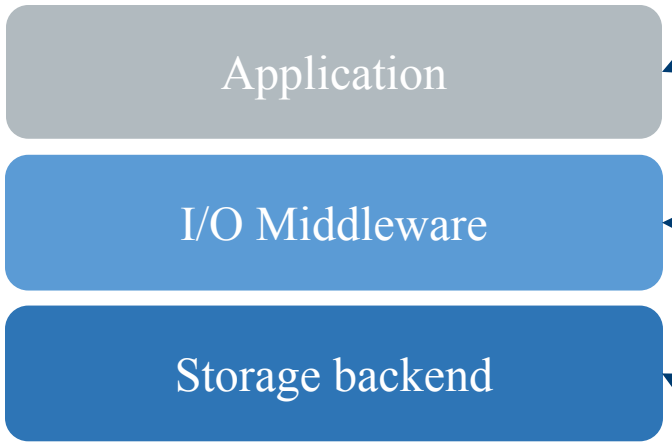
Next Gen Storage Stack





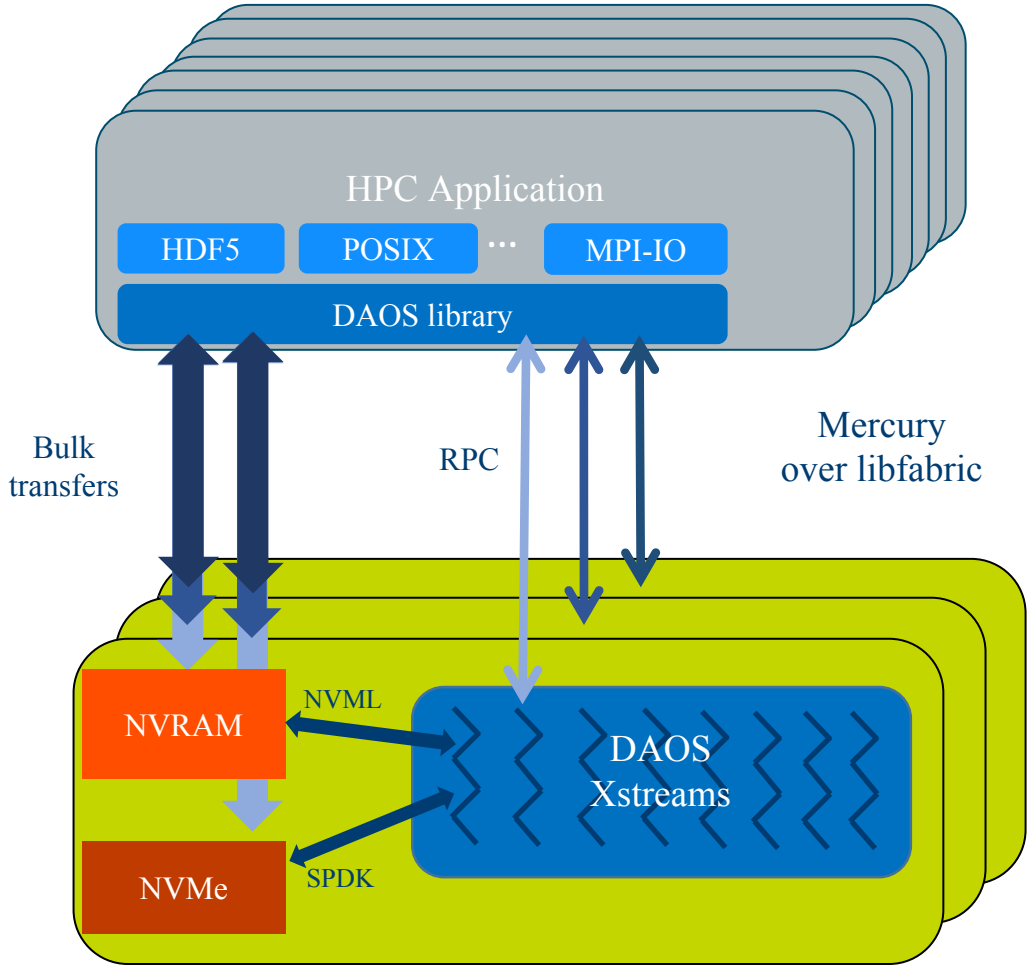
Evaluate applications (*HACC, ACME, CLAMR)* and new programming model (*Legion*) over enhanced I/O middleware

Port I/O middleware (*HDF5, MPI-I/O, …*) to new storage backend and **augment** API to take advantage of new capabilities

New storage API (*DAOS*) provides extended capabilities and high bandwidth/IOPS to middleware

Lightweight Storage Stack

- Mercury user space function shipping
- Applications link directly with DAOS lib
- Userspace DAOS server
  - Mmap non-volatile memory (NVML)
  - NVMe access through SPDK/BlobFS

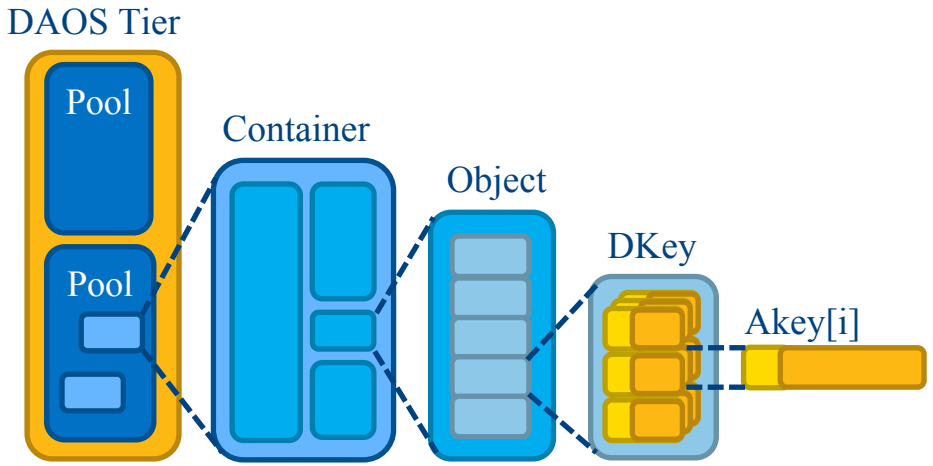


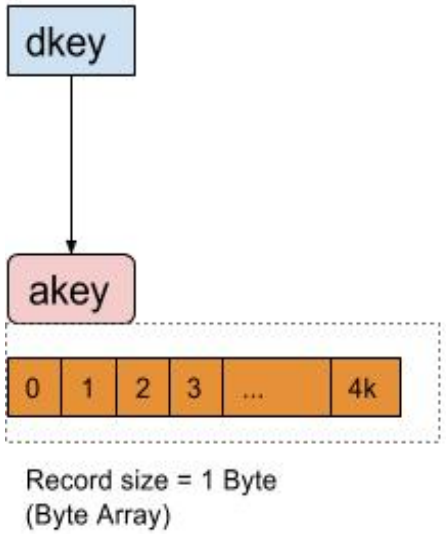
Storage Model

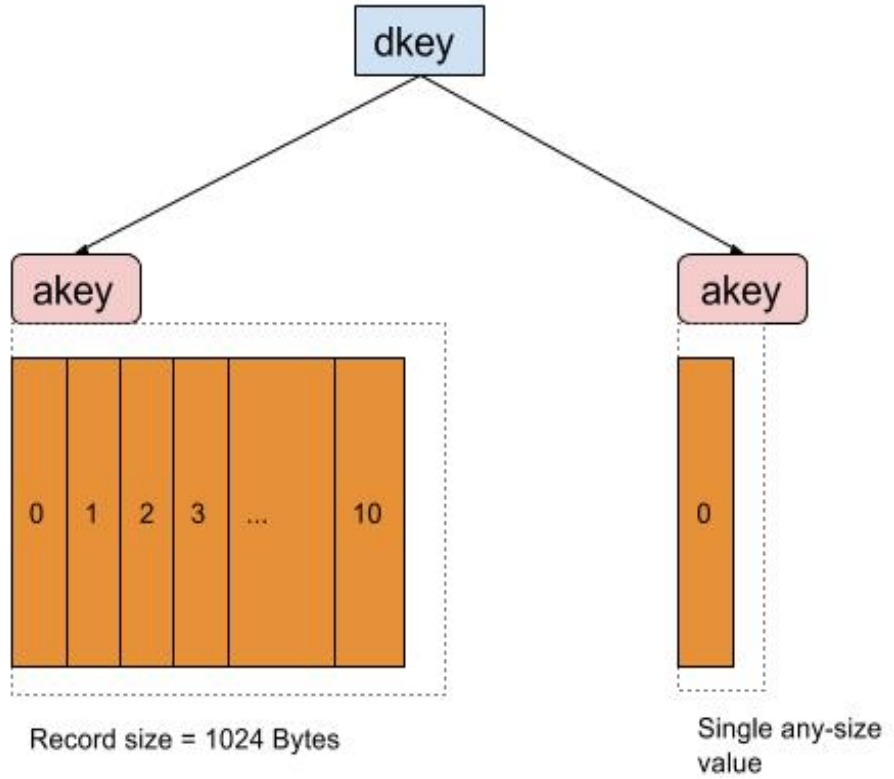
Application

I/O Middleware

Storage Backend

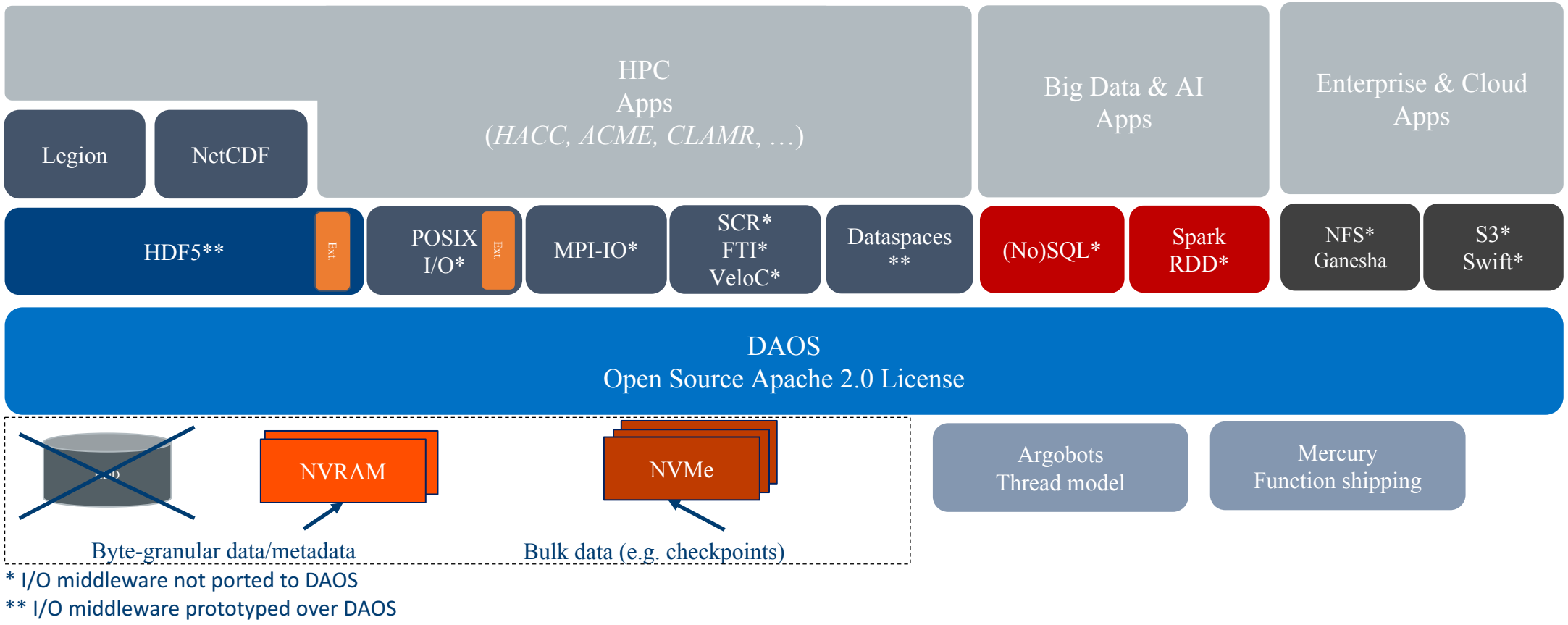






DAOS Ecosystem

Application
I/O Middleware
Storage Backend



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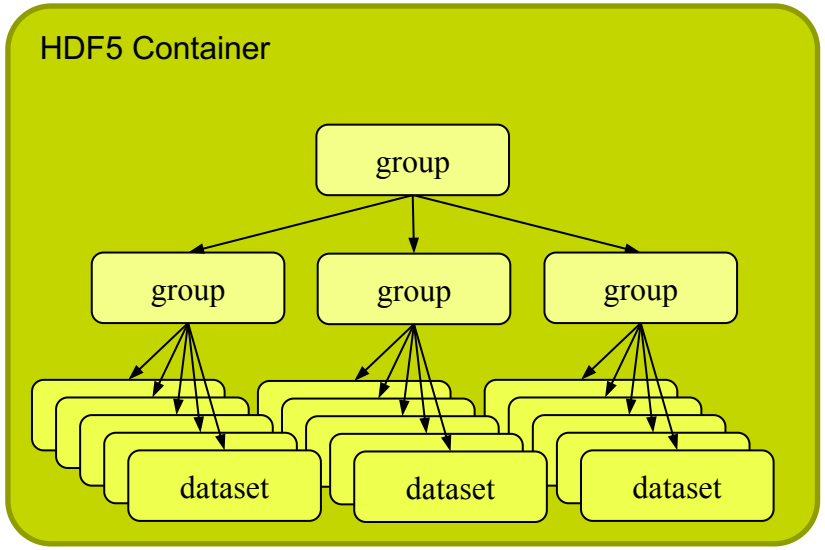
Application

I/O Middleware

Storage Backend

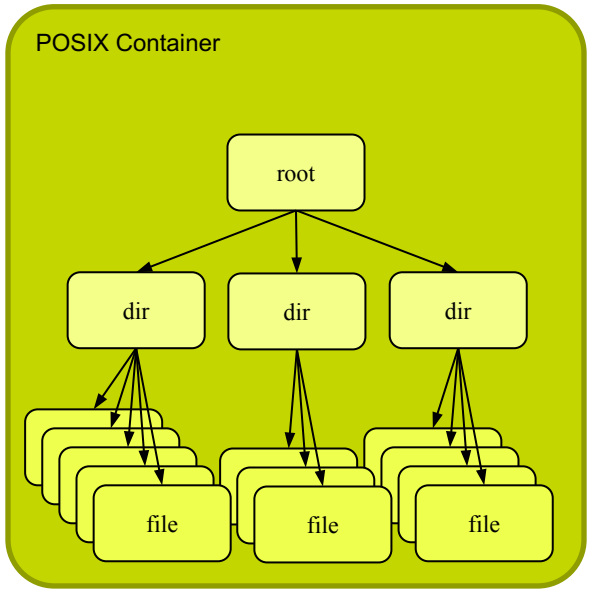
HDF5



- Mapping HDF5 to DAOS:
  - HDF5 file -> DAOS Container
  - HDF5 Objects -> DAOS KV objects

- HDF5 DAOS VOL Plugin
  - Prototyped in ESSIO
  - All applications or middleware I/O libraries (e.g. NetCDF4, PIO, etc.) that use HDF5 would be able to utilize the DAOS tier with minimal changes.
  - Newly developed applications or I/O libraries can utilize new extensions to HDF5 that are not available to date without the DAOS VOL plugin (some might be added to the POSIX HDF5 plugin in the future):
    - Asynchronous I/O for both metadata and raw data operations
    - Query, Indexing, & Analysis shipping
    - Container Snapshots
    - User controlled transactions
    - End to End data integrity

POSIX I/O



- POSIX Encapsulation
  - Each DAOS container encapsulates a namespace.
  - Highly scalable I/O to single shared file or file per process with full OS bypass.
  - Relaxed POSIX compliance
    - OK for most applications
    - Strong compliance comes at the price of complexity and performance.
- POSIX Extensions
  - Asynchronous I/O operations.
  - POSIX namespace snapshots
- Not yet implemented

Application

I/O Middleware

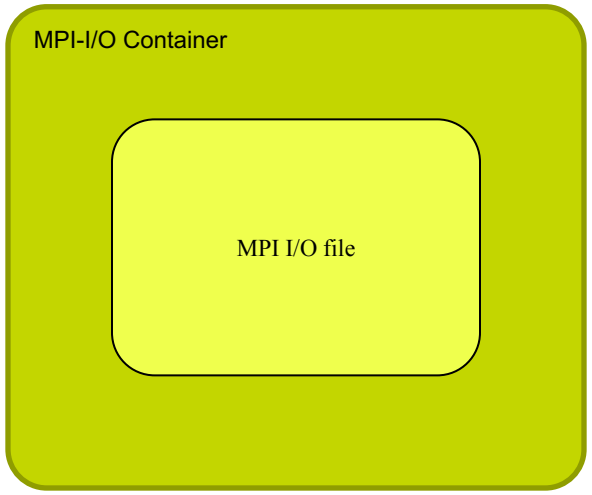
Storage Backend

Application

I/O Middleware

Storage Backend

MPI-I/O



- Mapping MPI-I/O to DAOS:
  - 1 DAOS container to hold 1 MPI-I/O file.
  - File striped across multiple object D-Keys

- MPI-I/O Support
  - Implement an ADIO driver in ROMIO (widely used as the de-facto MPI-I/O implementation in most MPI libraries).
  - Minimal application modification (set a hint to use the DAOS driver) + Supports middleware libraries that use MPI-I/O but have not implemented a DAOS driver as a backend.
  - Scalable mapping of an MPI file to a DAOS object with implicit stripping across multiple Distribution Keys.
  - Consistency and Recoverability features of DAOS epochs can be exposed through *MPI_File_sync()* that advances the container epoch.
- Not yet implemented

Application

I/O Middleware

Storage Backend

Application Evaluation

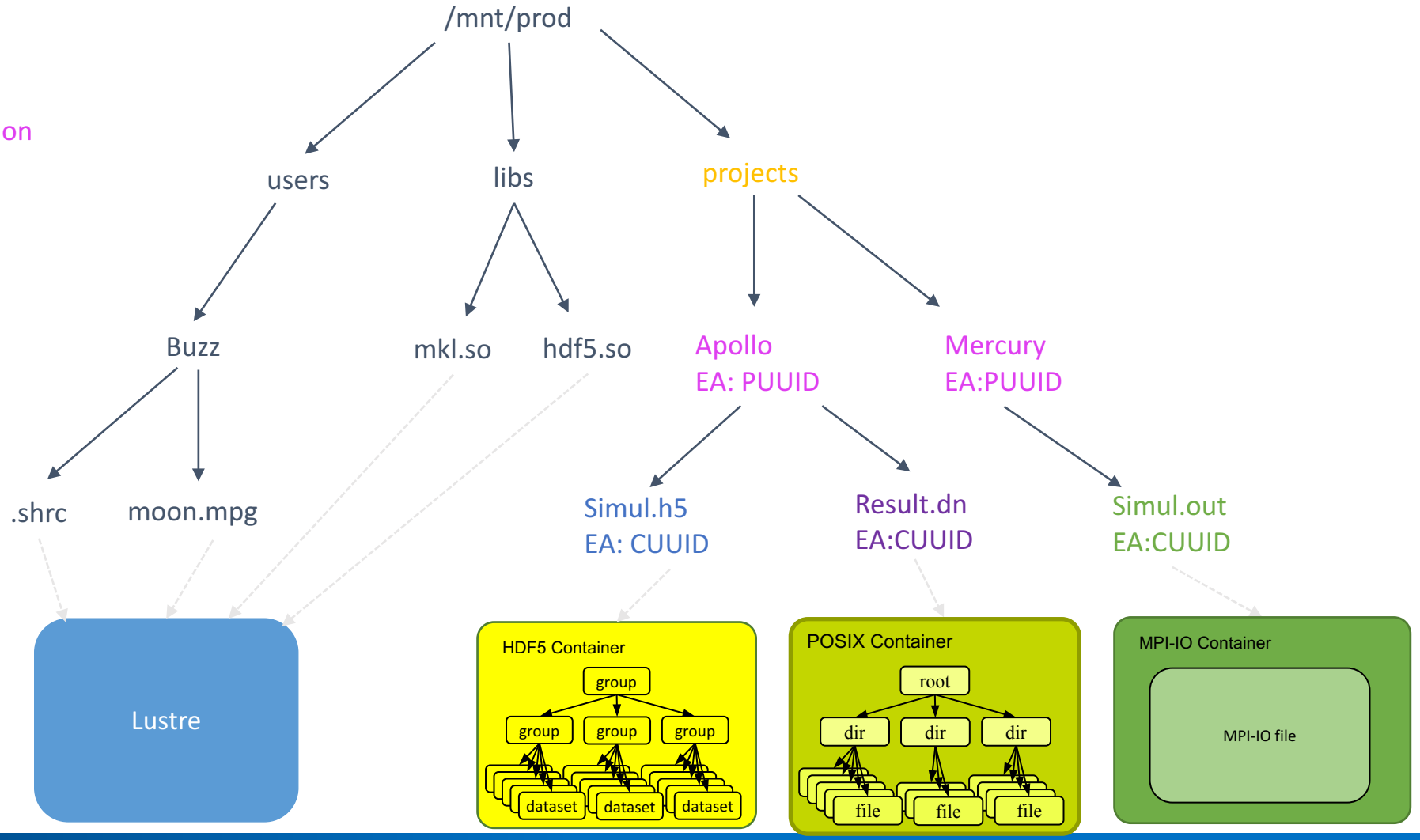
- *Legion*
  - Data Centric programming model
- **H**ardware/Hybrid **A**ccelerated **C**osmology **C**ode
  - Improved fault tolerance by storing transactional checkpoints
- **C**e**l**l-Based **A**daptive **M**esh **R**efinement
  - Use HDF5 instead of POSIX I/O
- **A**ccelerated **C**limate **M**odeling for **E**nergy
  - Ported NetCDF & PIO to HDF5 DAOS VOL plugin

DAOS/Lustre Integration

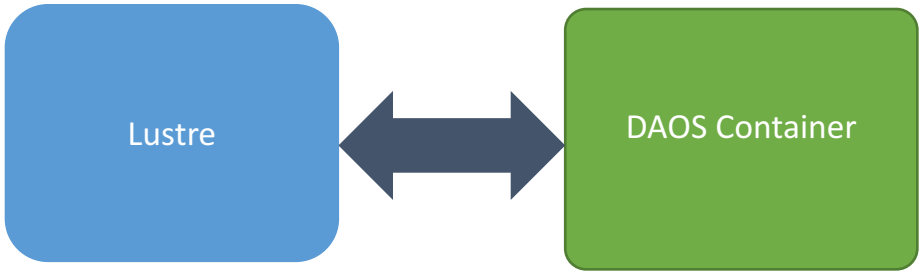
- DAOS Tier
  - **Checkpoint/defensive** I/O
  - Advanced data **analytics**
  - New data intensive **workflow**
  - New data-centric **programming models**
  - Storage media
    - 3D-XPoint **NVDIMMs**
      - byte-granular data & metadata
    - 3D-NAND or 3D-XPoint **SSDs**
      - bulk data, including checkpoint data
- Lustre Tier
  - **Robust** system namespace
    - Mature & scalable POSIX namespace
    - Rich feature sets
  - **Smooth** migration path
    - Lustre directly accessible through Mercury IOF
    - Slowly migrate applications to DAOS
    - APPs with strong POSIX requirements
  - Storage media
    - **Dual**-ported **JBOD**
    - **Dual**-ported **JBOF**

Single Namespace

Lustre directories & files
DAOS storage area
DAOS storage persistent reservation
HDF5 Container
DAOS POSIX Container
DAOS MPI-IO File



Lustre/DAOS Data Mover



- DAOS container parking
  - Serialize/deserialize DAOS container to/from Lustre
    - DAOS specific format
  - Middleware agnostic
  - Retain history, snapshot and DAOS metadata
- Data transformation
  - Convert container from DAOS format to POSIX format and vice versa
  - Middleware dependent
    - MPI-IO & POSIX share same layout
    - hdf5dump
  - Specific snapshot or HCE
    - History lost in transformation

DAOS Development

- Extreme Scale Storage & I/O
  - DAOS prototype
    - N-way replication with online rebuild
    - Metadata replication with Raft
  - HDF5 VOL plugin + extensions
  - *End in Q2'17*
- Follow-on project
  - NVMe support
  - Automatic service discovery, configuration & monitoring
- Future Work
  - DAOS & HDF5 productization
  - MPI-IO support
  - Erasure code & Progressive layout
  - System integration
  - Management tools
  - Security model
  - Application evaluation in co-design

Questions?

Contact:

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Resources:

- https://github.com/daos-stack/daos