IO-SEA introduction, concepts, and challenges

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Introduction

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Working at ATOS HPC SW R&D since 20 years, leading the « Data Management » group with 15 engineers and PhD students

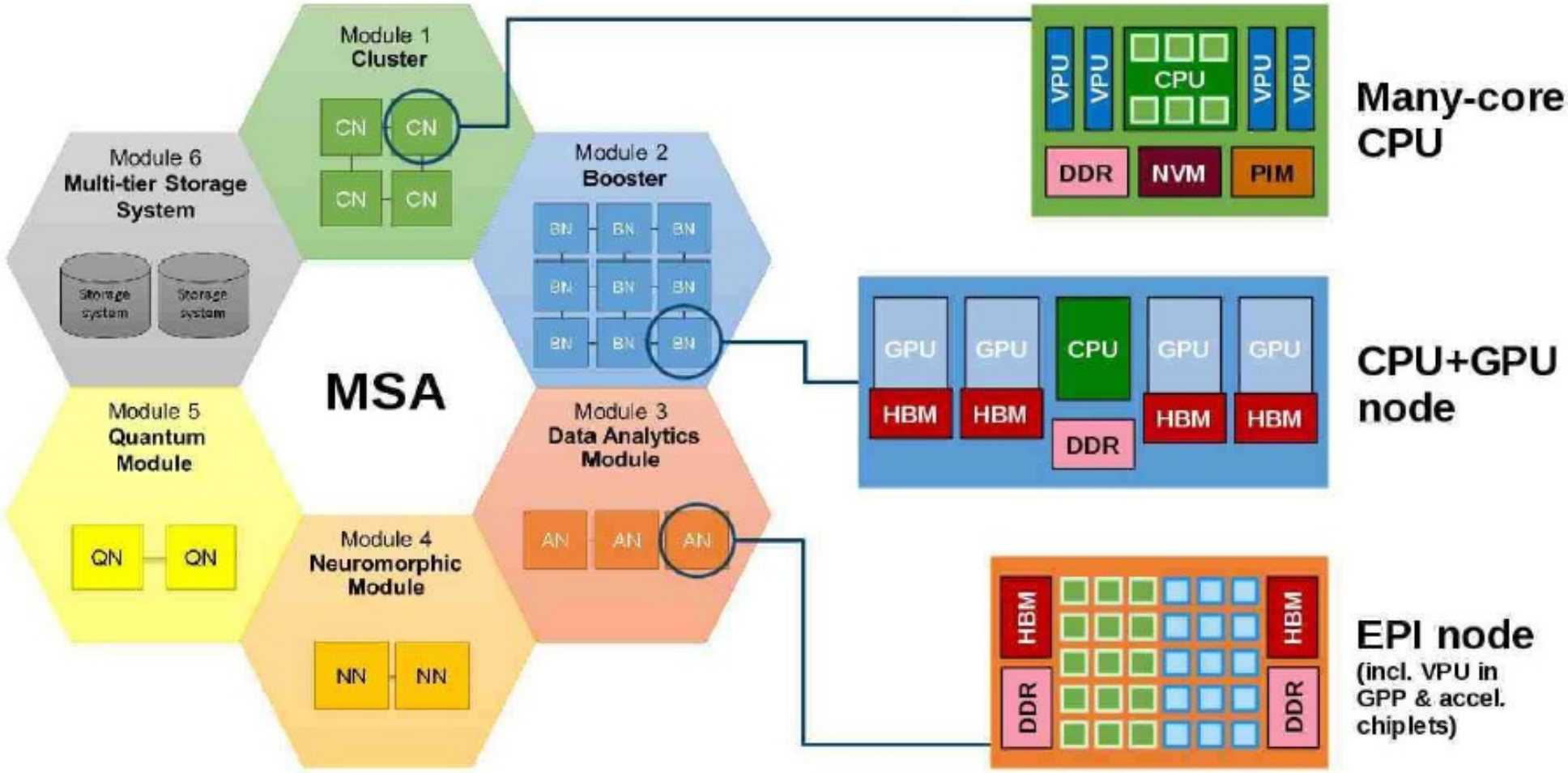
IO-SEA Work Package 2 Leader : https://iosea-project.eu/

IO-SEA

Context

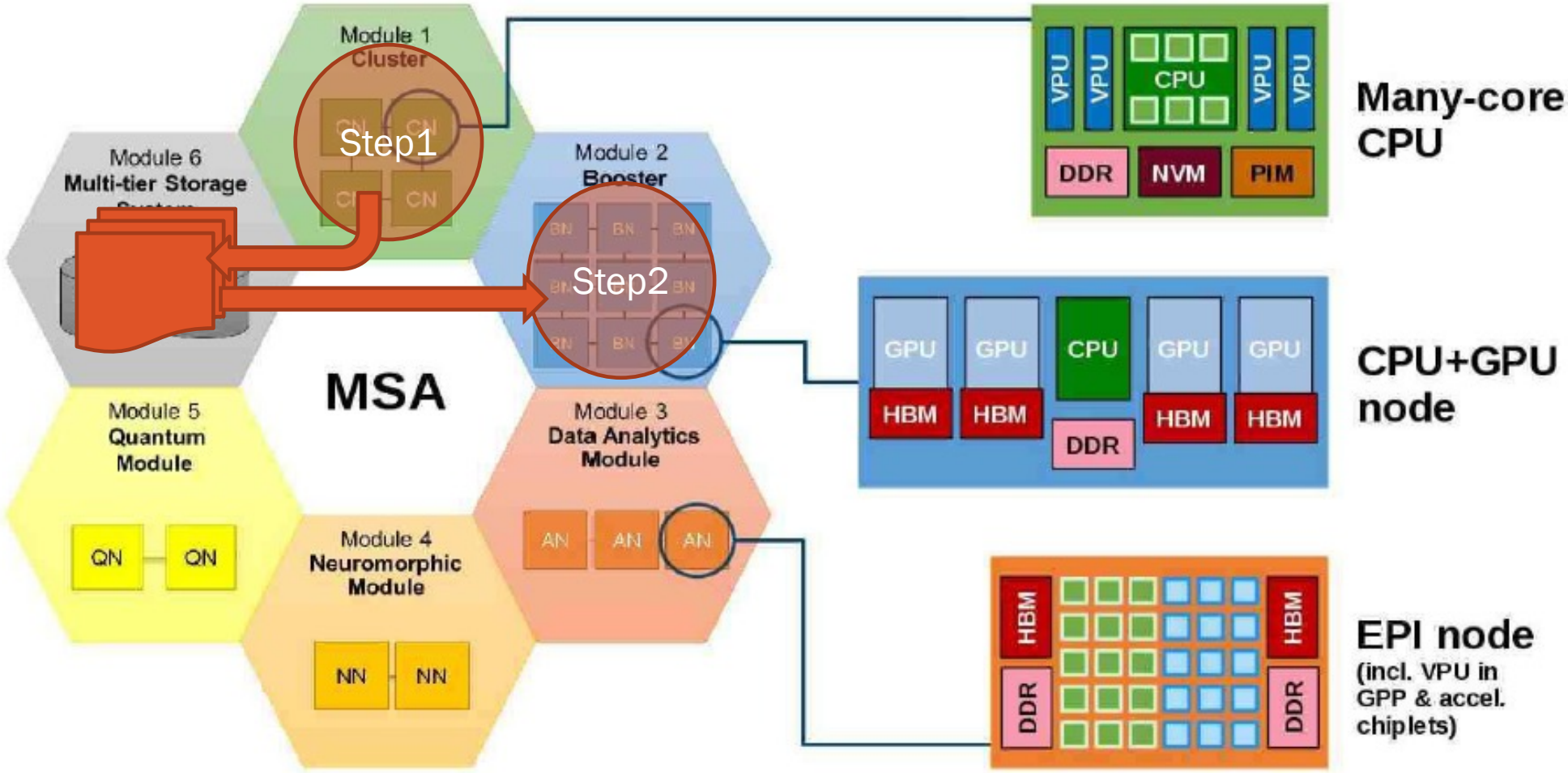
Modular SuperComputer Architecture

- Heterogeneous Compute modules
- « Long Term » Storage module with multiple technologies
- No cluster-wide interconnect
  - High speed Ethernet to connect modules



Modular SuperComputer Architecture

- Complex workflows running simultaneously and/or sequentially on multiple modules
  - Exchanging data through files

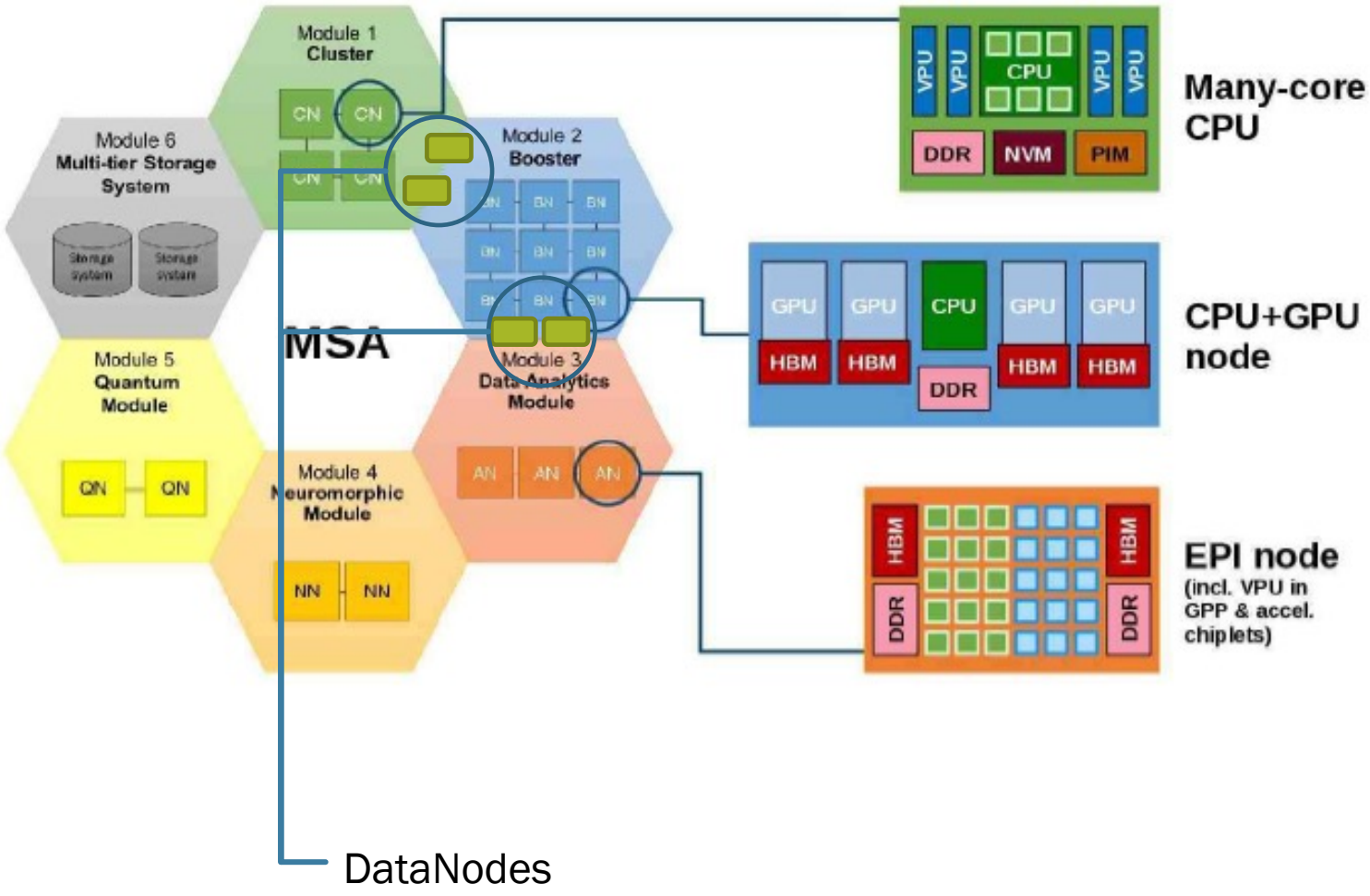


The IO-SEA Solution

IO-SEA Main Concepts 1: Data Nodes

Add **Data Nodes** between compute nodes and Long Term Storage Module

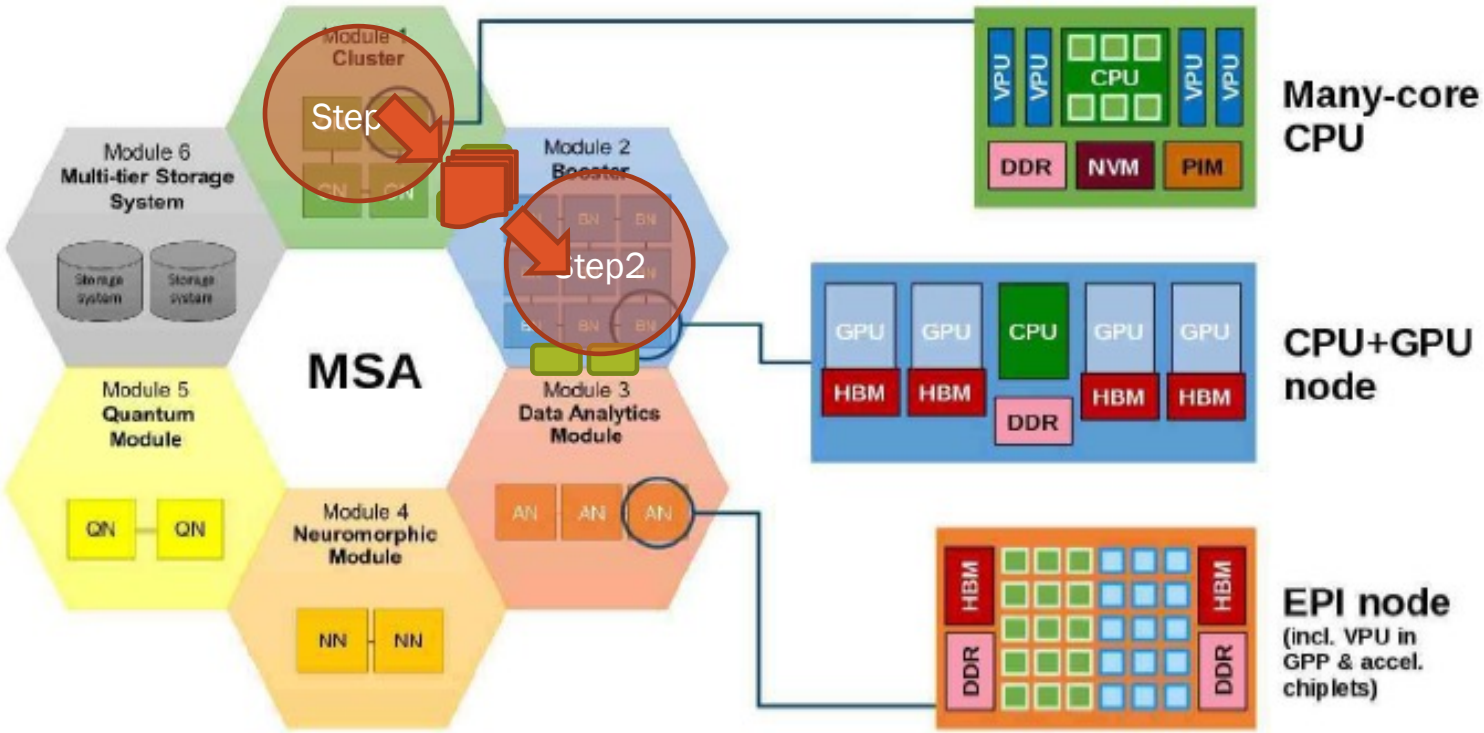
- connected to Compute Modules on their High Speed interconnects, and to the Long Term Storage Module
- Equipped with high speed storage devices
  - NVMe disks
  - NVRAM



IO-SEA Main Concepts 2: Workflows Scheduling

Consider **Workflows** rather than individual applications for scheduling

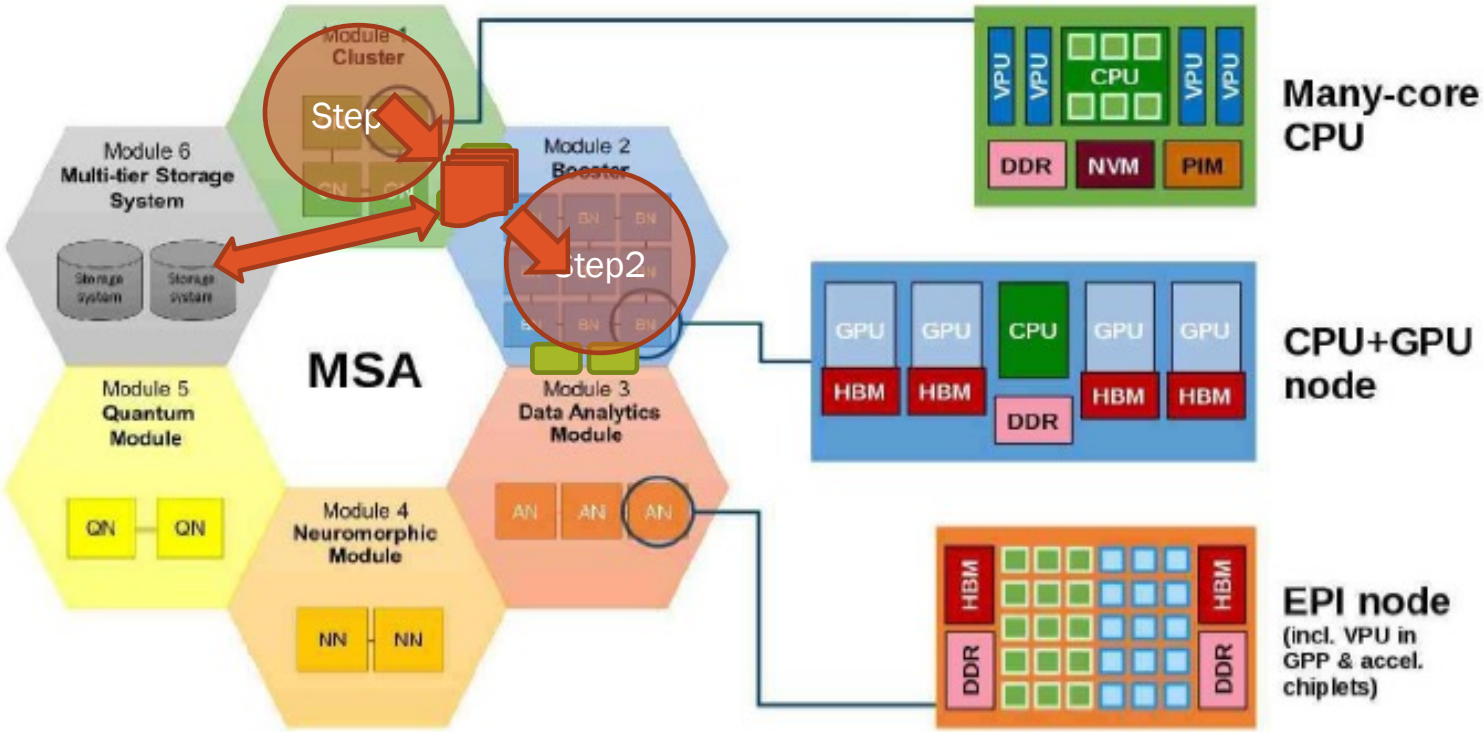
- Workflows composed of many applications (steps) running on different Modules
- Allocate data nodes resources in addition to Compute nodes



IO-SEA Main Concepts 3: Datasets & Ephemeral Services

Store Workflow data in **Datasets**

- Datasets are « data containers » stored in the **long term storage as « objects »,** exposed to compute nodes by **Ephemeral Services** running on Data Nodes



IO-SEA Stack

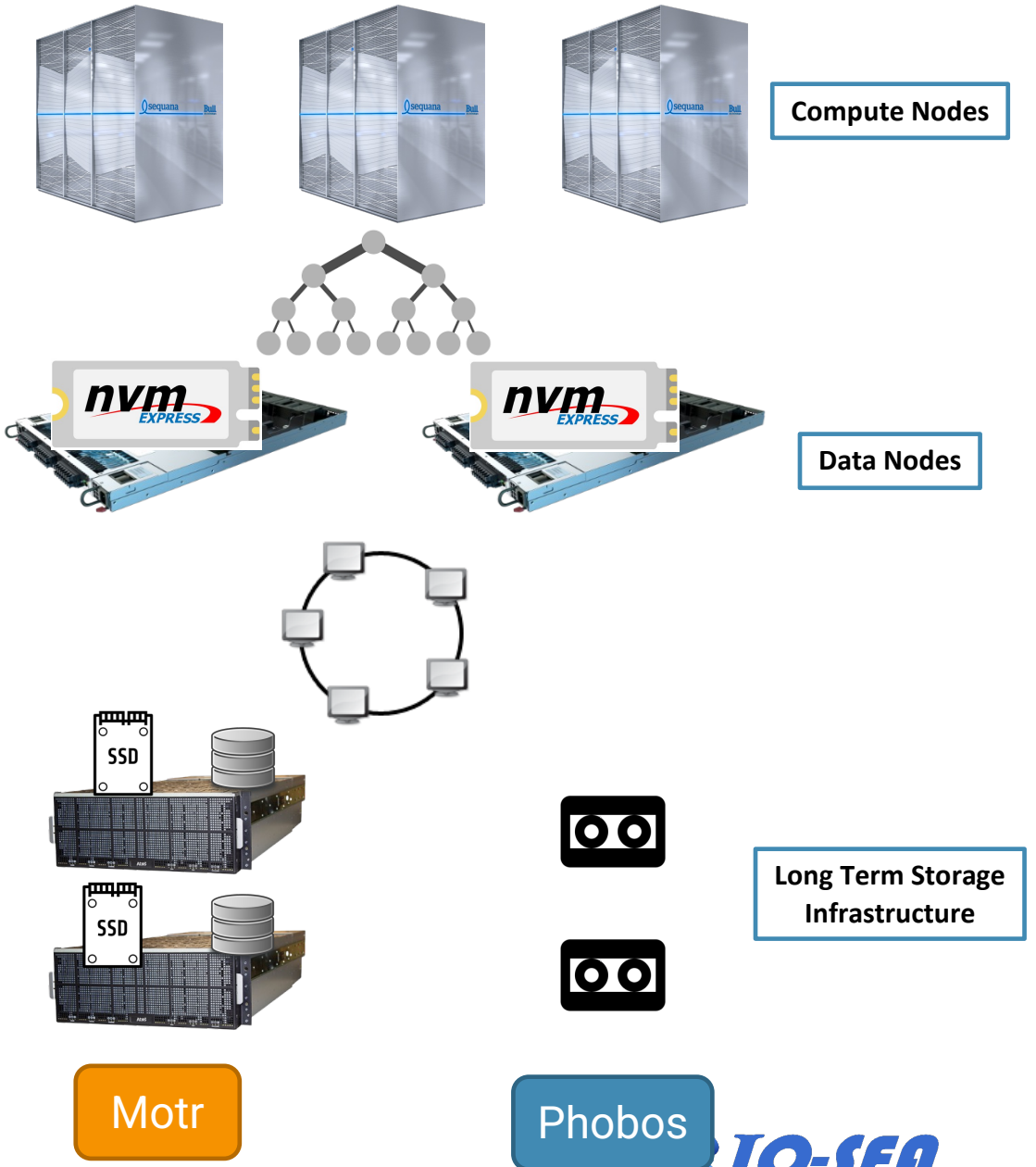
2 HW layers

- Data nodes equipped with high-speed storage devices (NVMe, NVRAM)

Ephemeral

- Long Term Storage composed of different tiers unified by an HSM software solution

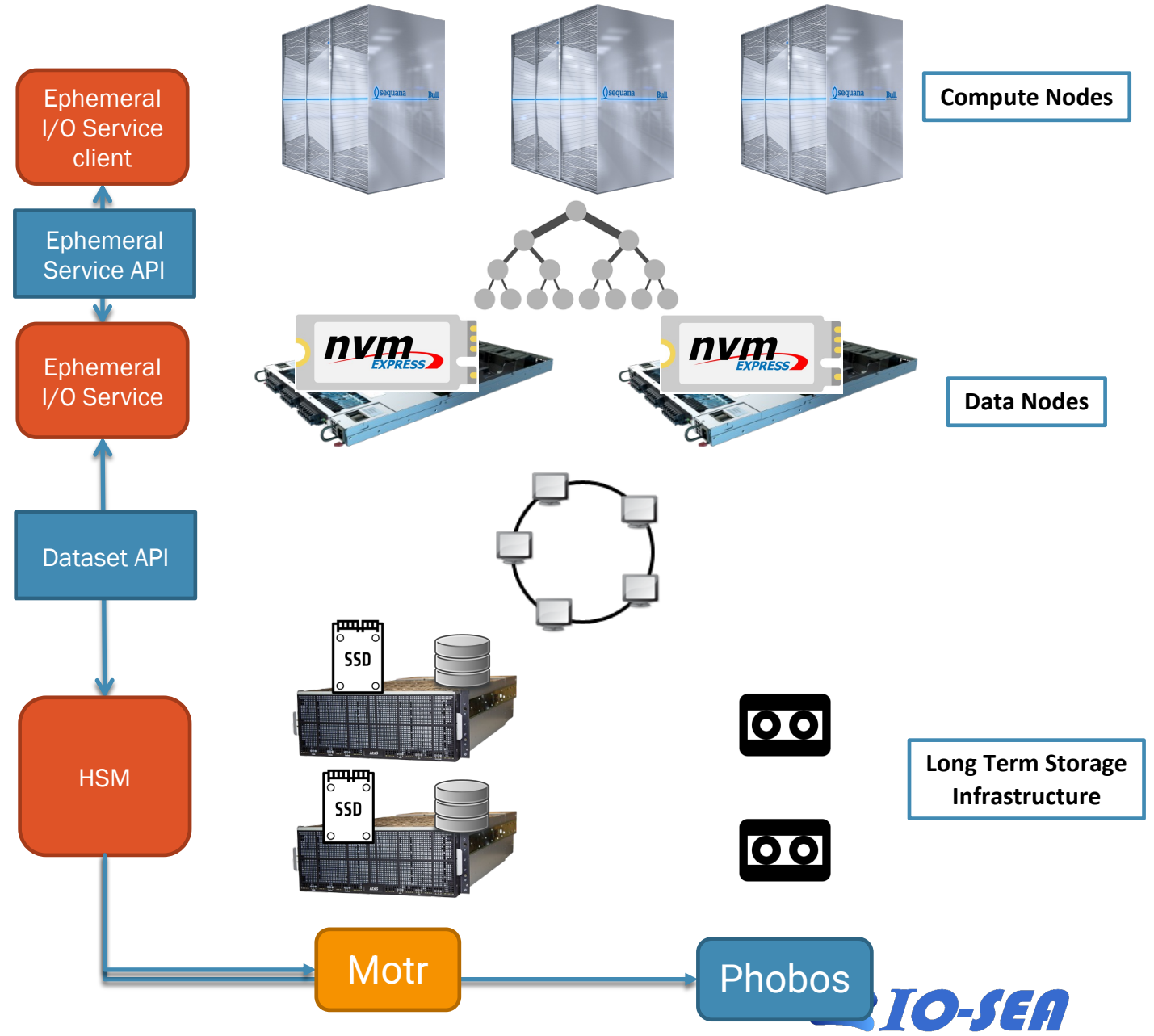
Long Term



IO-SEA Stack

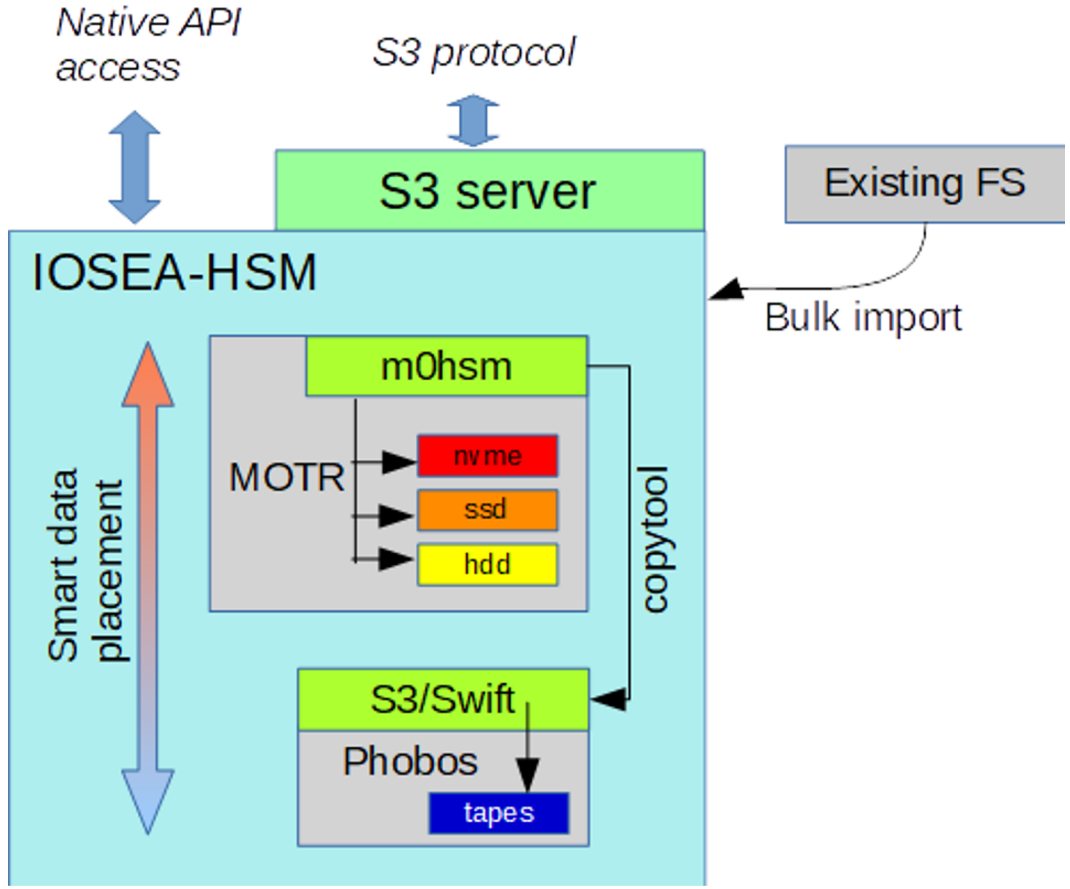
- Datanodes resources (cores, RAM, NVMe) are allocated for a **workflow** to run Ephemeral I/O services to give access to Datasets from compute nodes
  - POSIX, S3, DASI protocols

- Long Term Storage composed of different tiers unified by an HSM software solution
  - **Object Storage based**, no POSIX limitations



IO-SEA Long Term Storage : Hierarchical Storage

- Leverage a wide variety of **storage technologies** in a single system
  - from NVMe to tapes
- Implement **transparent** data migration between many storage tiers
- Smart **data placement** / **movements**:
  - ➢ Place data according to application needs
  - ➢ Gather needs from all running applications and develop a global data placement strategy
  - ➢ Prevent tiers from being fullfilled
  - ➢ Arbitrate conflicting requests / resource usage



DataSets & Namespaces

- Datasets are **data containers** hosting objects
  - Could be seen as private file systems or object stores
  - No data organization, just collections of objects…
- Objects in Datasets are organized with Namespaces
  - Different Namespaces can be created for each Dataset
  - Namespaces can expose the same dataset through different protocols
    - POSIX, S3

Datasets/Namespaces

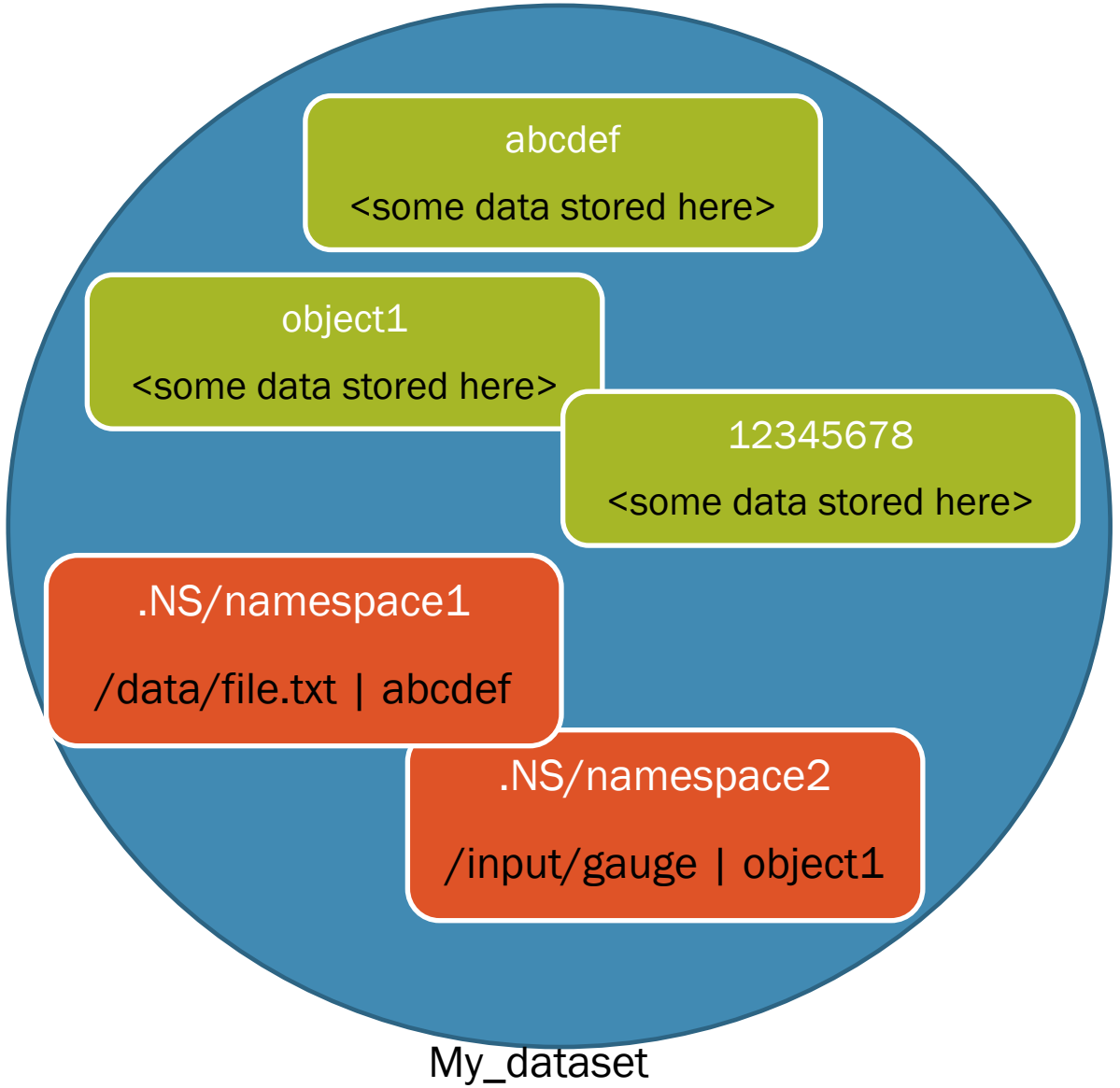
A Dataset is stored as 1 S3 Bucket

Files stored as S3 object

All namespaces stored in « metadata » objects

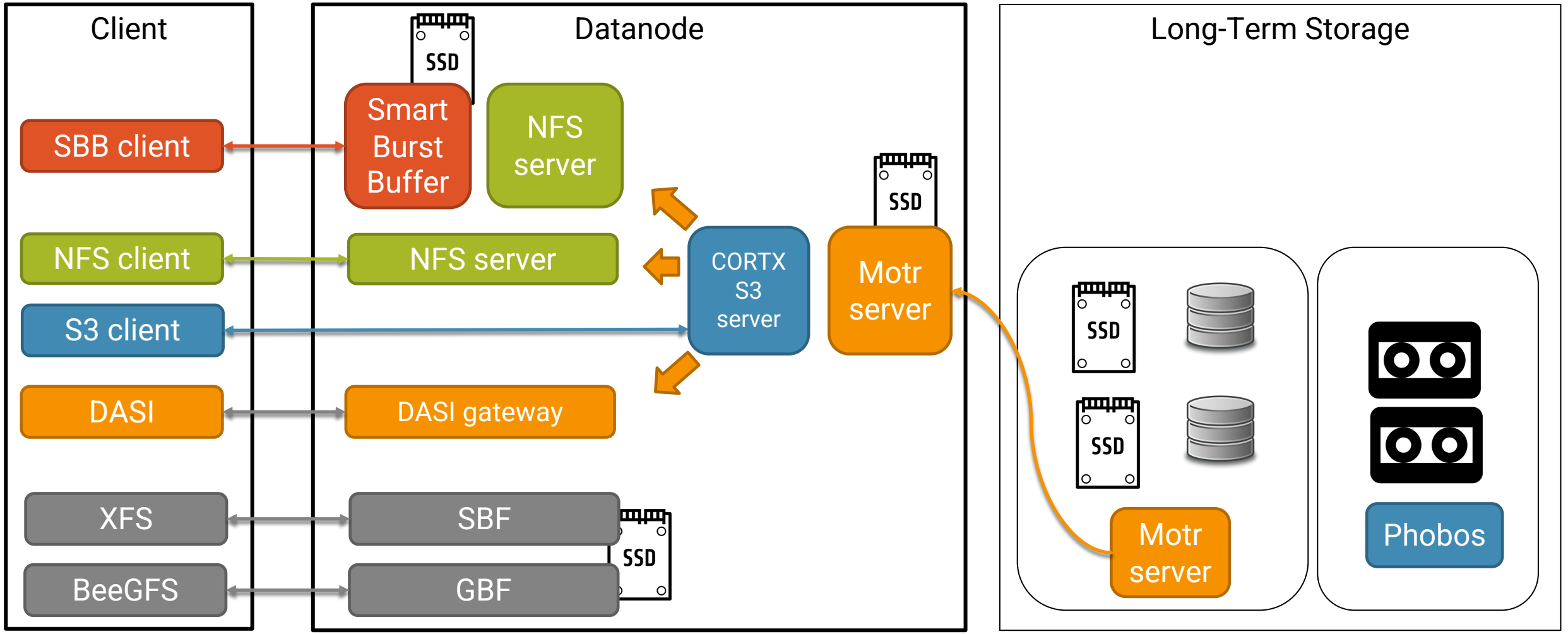
Think of it as a set of directories and symbolic links to objects in dataset

- .NS/namespace1
- .NS/namespace2



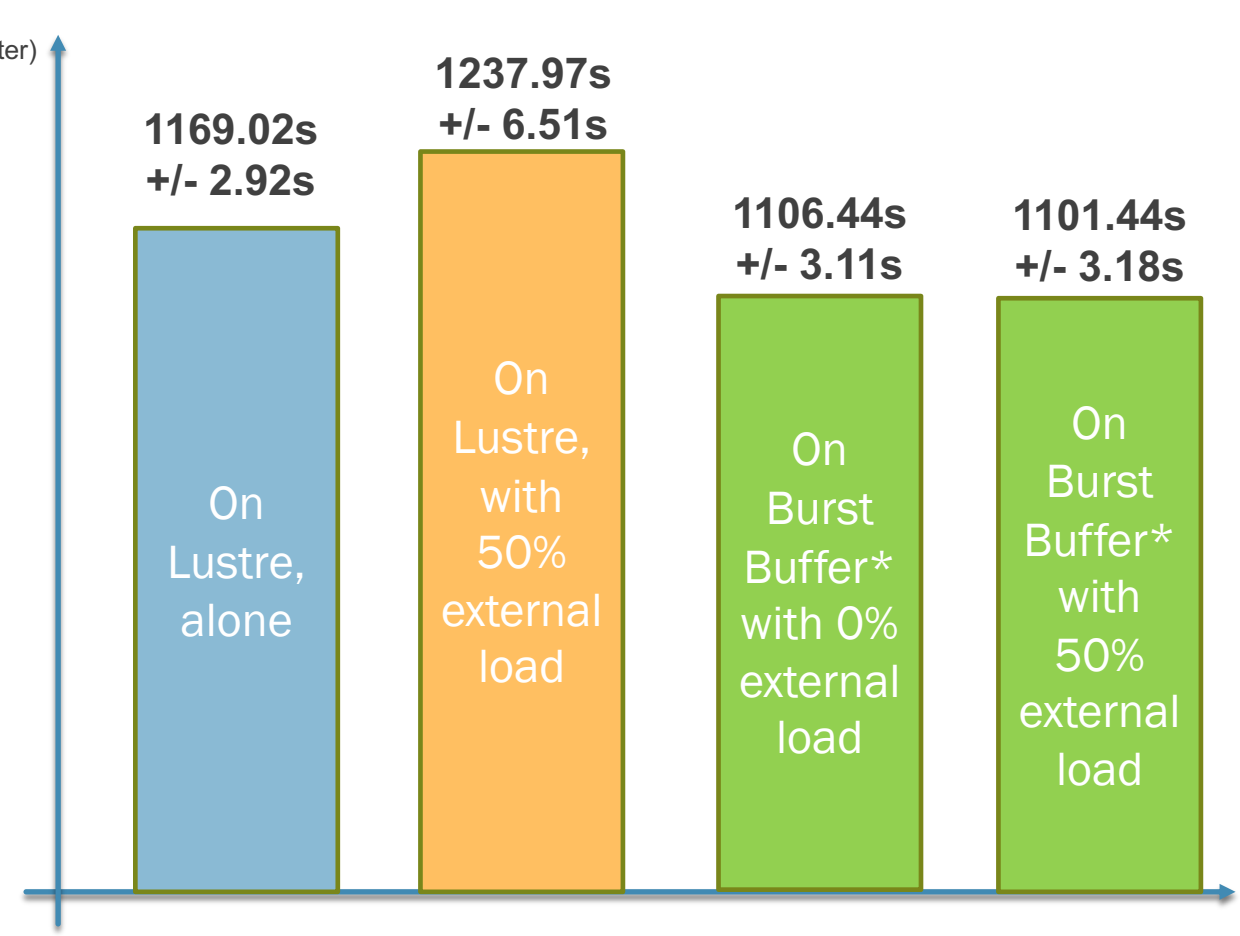
6 Ephemeral I/O Services

- **NFS, BB-NFS, S3, DASI, SBF, GBF**



Example : NAMD

- Filesystem: Lustre, max measured bandwidth ~ 2GBps
- 2 Datanodes, each 50GB RAM, 1.5T Flash
  200Gbps network, 16 allocated CPU cores
- NAMD:
  12 computes nodes (2x 16c/32t@3GHz)
  200Gbps network interconnect
  MPI mpich 3.4.2
  1 checkpoint each ~ 3 min (checkpoint size ~ 12GB)
  input: STMV_210M, size ~ 17GB uncompressed,
  source https://repository.prace-ri.eu/ueabs/NAMD/2.2/NAMD_TestCaseC.tar.gz

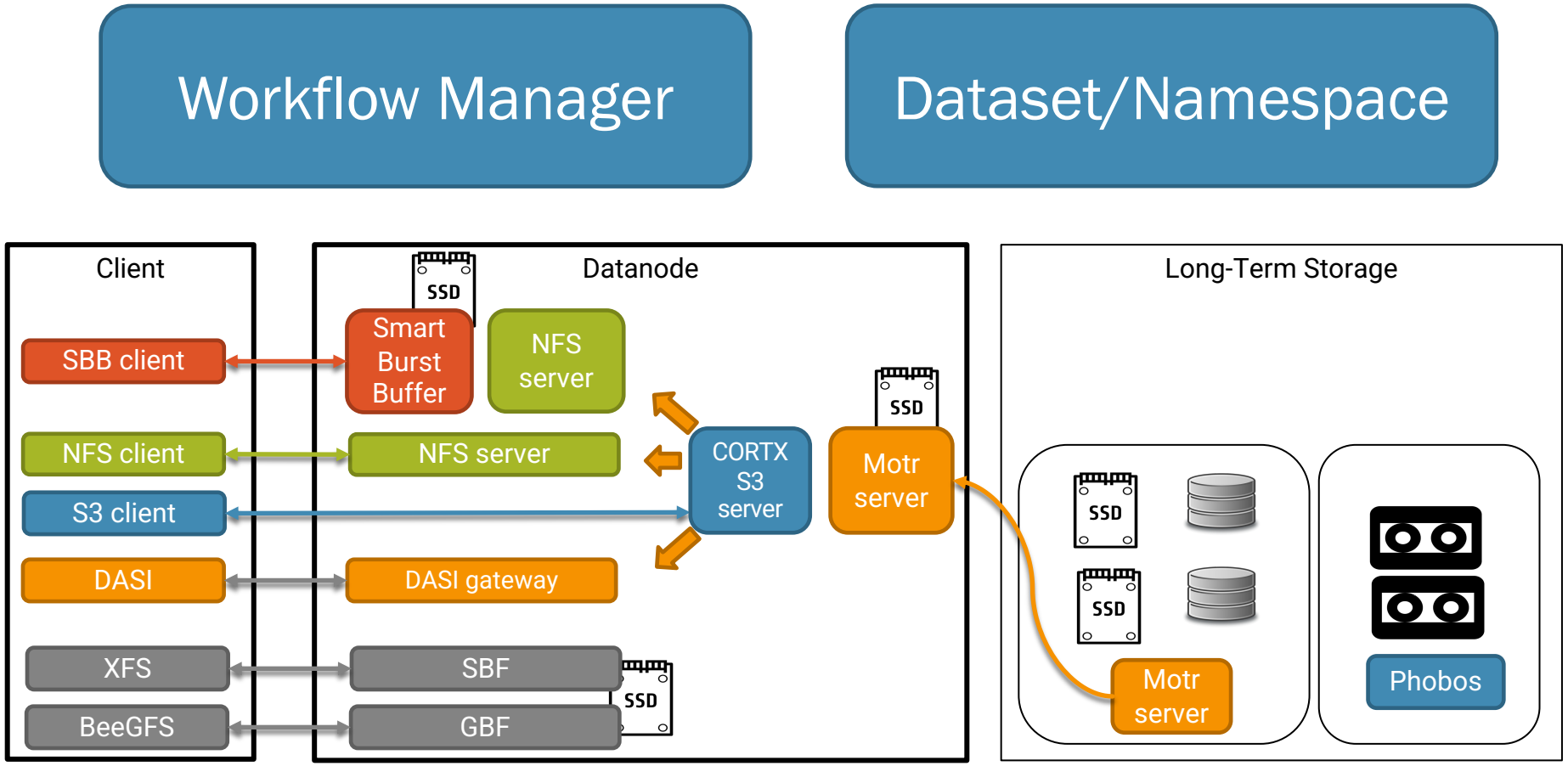


* : prefetch of input data into SBB not included in application runtime measurement

End User Interfaces & APIs

User Interfaces

- **Workflows are described in a « Workflow Description File » . yaml, and managed through command line tools**
- **Datasets/Namespaces are created with command line tools**



Workflow Sessions

- The steps processing the same data are run within a « **session** »
  - **Access tokens** protect against dataset access by multiple sessions in parallel
- Sessions have a user provided name
  - (UID, Session_Name) as identifier

```
# start a session for my workflow described in the WDF.yaml file
iosea-wf start WORKFLOW=WDF.yaml SESSION=My_Session

#run the workflow steps
iosea-wf run SESSION=My_Session STEP=step1
iosea-wf run SESSION=My_Session STEP=step2
iosea-wf run SESSION=My_Session STEP=step3

#stop the session and release the datanode
iosea-wf stop SESSION=My_Session
```

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Workflow Session Management

- **status** & **list** commands to report information
- **access** command to launch an interactive access environment
  - Slurm salloc to launch a shell in which Ephemeral Services clients will be configured
  - Will be « shareable » with team members

```
# display info about jobs & ephemeral services
iosea-wf status SESSION=My_Session

# list all active sessions of the user (report the session-names)
iosea-wf list

# Start an interactive access environment for all or limited to [<service>]
iosea-wf access SESSION=My_Session [NS=service]
```

Workflow Description File (WDF)

- **services** describe the ephemeral services needed to run the workflow

- **steps** describe how to configure the run time environment to run the steps

```
workflow:
  name:      My_Workflow

services:
  - name: ephemeral_service_1
    type: NFS
    attributes:
      namespace: dataset.My_namespace
      mountpoint: /mnt/USER/My_Workflow
      flavor: medium

steps:
  - name: step_A
    location:
      - gpu_module
    command: "srun My_Step_A"
    services:
      - name: ephemeral_service_1
```

Parametric Workflow Description File (WDF)

- To run multiple sessions in parallel, or to make the WDF more generic, variables can be used for most fields
- Variables must be defined « before use »

```
services:
  - name: ephemeral_service_1
    type: NFS
    attributes:
      namespace: {{ NS1 }}
      mountpoint: /mnt/USER/{{ SESSION }} My_Workflow
      flavor: medium
```

```
# start a session for my workflow
iosea-wf start WORKFLOW=WDF.yaml SESSION=My_Session NS1=My_namespace

#run the workflow steps
iosea-wf run SESSION=My_Session STEP=step1 NS1=My_other_namespace
```

Status command

- to monitor steps progress

```
> iosea-wf status SESSION=My_session
Workflow Name       : My_Workflow
Workflow SessionID : My_session_<timestamp>

Pending Steps
Step Name    Slurm ID     Tag      Command
step_B       2767         last     srun My_Step_B
SaveResults ----                   srun My_Copy_Script

Active Steps
Step Name    Slurm ID     Tag      Command
step_B       2763                  srun My_Step_B

Terminated Steps
Step Name    Slurm ID     Tag      Command
step_A       2760         init     srun My_Step_A

Ephemeral Services....
```

Location in the WDF

```
steps:
  - name: step_A
    location:
      - gpu_module
    command: "sbatch My_Step_A"
    services:
      - name: ephemeral_service_1
 - name: step_B
    location:
      - gpu_module
      - cpu_module
    command: "sbatch My_Step_B"
    services:
      - name: ephemeral_service_2
 - name: step_C
    location:
      - datanodes
    command: "sbatch My_Step_C"
    services:
      - name: ephemeral_service_2
```

- Steps indicate the « location » of their compute nodes
- Multiple locations are possible for complex jobs (MSA architecture)
- Location can be also « datanodes » for « on the fly » processing

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Data Movers in the WDF

```
services:
  - name: ephemeral_service_1
    type: NFS
    attributes:
      namespace: {{ NS1 }}
      mountpoint: /mnt/USER/{{ SESSION }}
      flavor: medium
    datamovers:
      - name: datamover1
        trigger: step_start
        target: flash
        operation: copy
        elements:
          - "gauges/*.hdf5"
          - "input/*"
```

- To ensure the elements of a namespace are located in the proper storage tier, a data_mover can be activated before (step_start) and after (step_stop) a step
- Operations are either move or copy
- Data Movers are defined at the service level, but activated per step

```
steps:
  - name: step_A
    location:
      - gpu_module
    command: "sbatch My_Step_A"
    services:
      - name: ephemeral_service_1
        datamovers:
          - datamover1
```

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Hints

"Hints" are optional information given by users about their future use of data, when the workflow is terminated

- **intended_access**: Intended access in the short term (will access, won't change…)
  e.g. intended_access="wont_change"

- **estimated_lifetime**: Estimated time until the object will be deleted (in seconds)
  e.g. estimated_lifetime=2592000 (1 month)

- **estimated_atime**: Estimated time the object will be used (in seconds)

- **access_period**: How often the object will be accessed (in seconds)
  e.g. access_period=60 (every minute)

- **predefined_policy**: Name of a pre-configured policy
  e.g. predefined_policy="temporary_data"

Setting hints

- User Control: CLI
  - `iosea-ns {locate|move|copy|release}`
  - `iosea-ns hints DATASET=My_dataset hint1=value1 hint2=value2 ...`

- User Control: through POSIX Ephemeral Services
  - `Set_attr on files and directories`

Datasets/Namespaces : Command line tools

```
# create namespaces
iosea-ns create my_dataset.my_namespace
iosea-ns create DATASET=my_dataset my_2nd_namespace
# fill my_namespace with a file
io-sea-ns put DATASET=my_dataset NAMESPACE=my_namespace ./gauge.cfg
```

- Enables leveraging standard POSIX tools and scripting

ls, find, …

Challenges

Challenges

- Need an enhanced Batch & Resource Manager
  - Workflow Aware
    - Allocating Datanode resources as part of the workflow
    - Sheduling ***workflows steps*** rather than ***isolated jobs***
      - To minimize data nodes resources allocation time
- Find the balance between compute nodes, data nodes and back end storage resources
  - New « dimensioning rules » to be invented