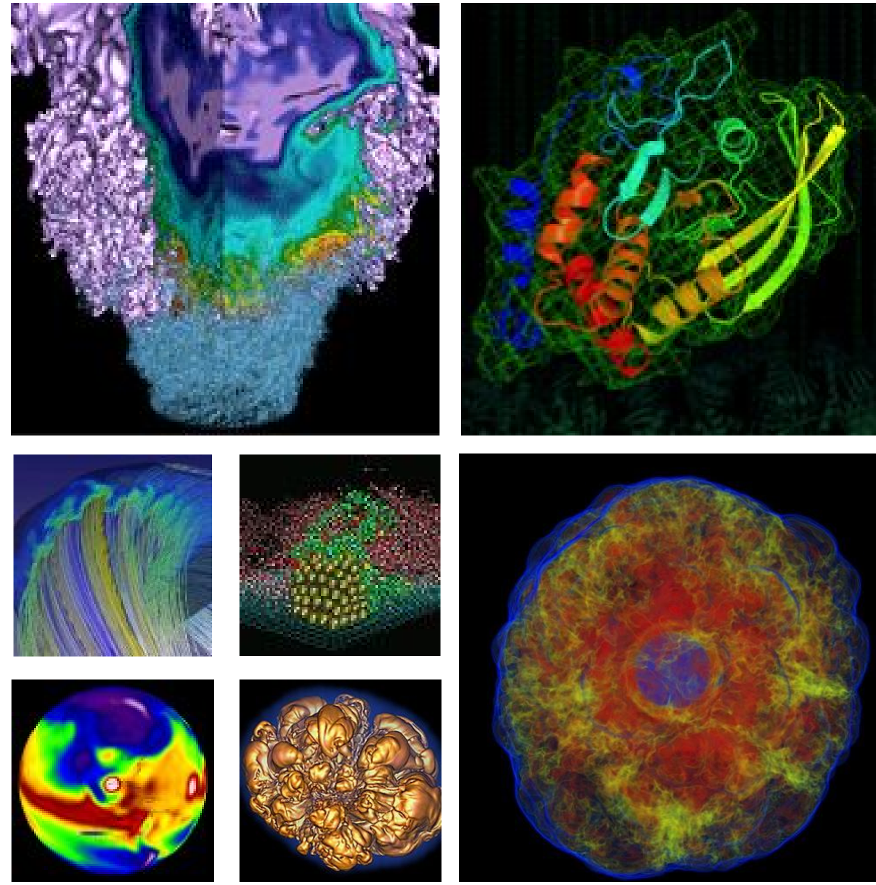
Accelerate your IO with the NERSC Burst Buffer

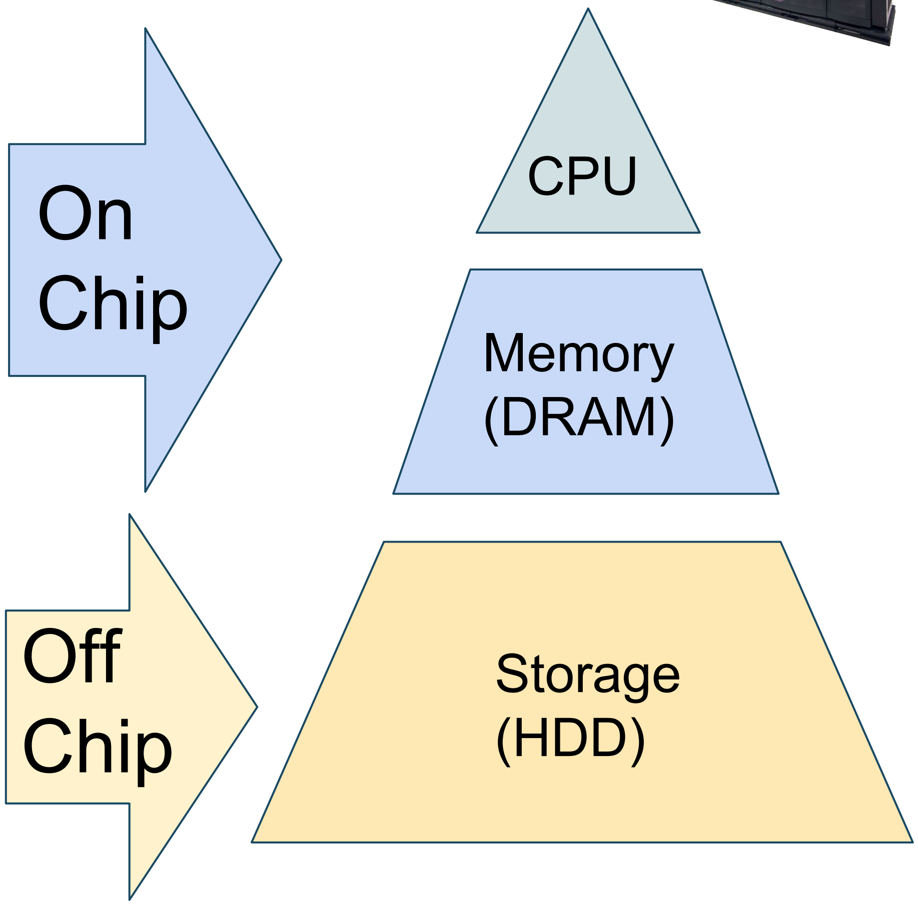


Debbie Bard
Data and Analytics Services
NERSC

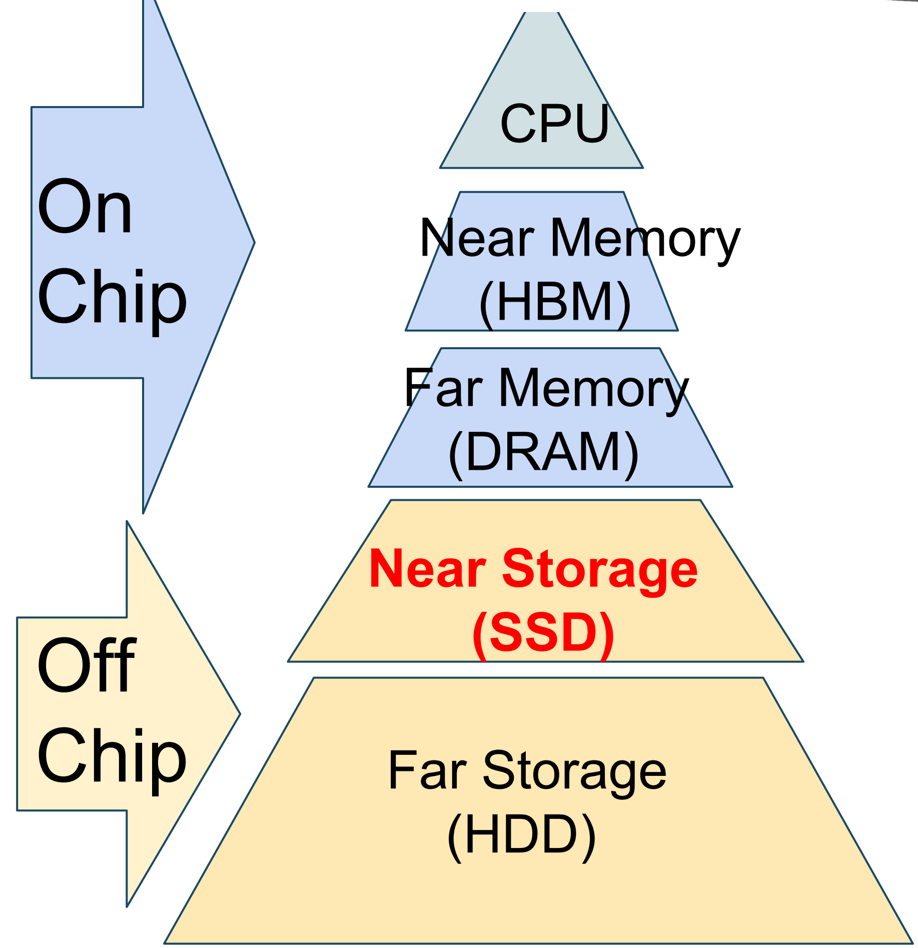
NUG telecon, 26th Jan 2017

HPC memory hierarchy

Past



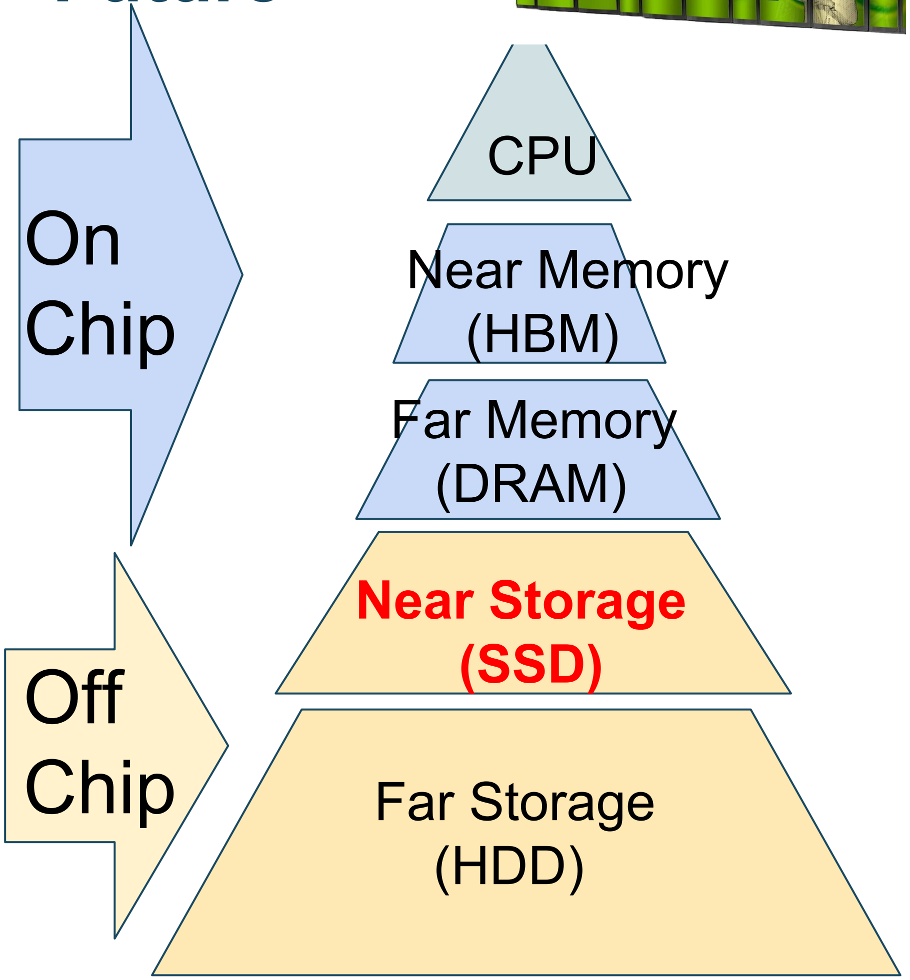
Future



HPC memory hierarchy

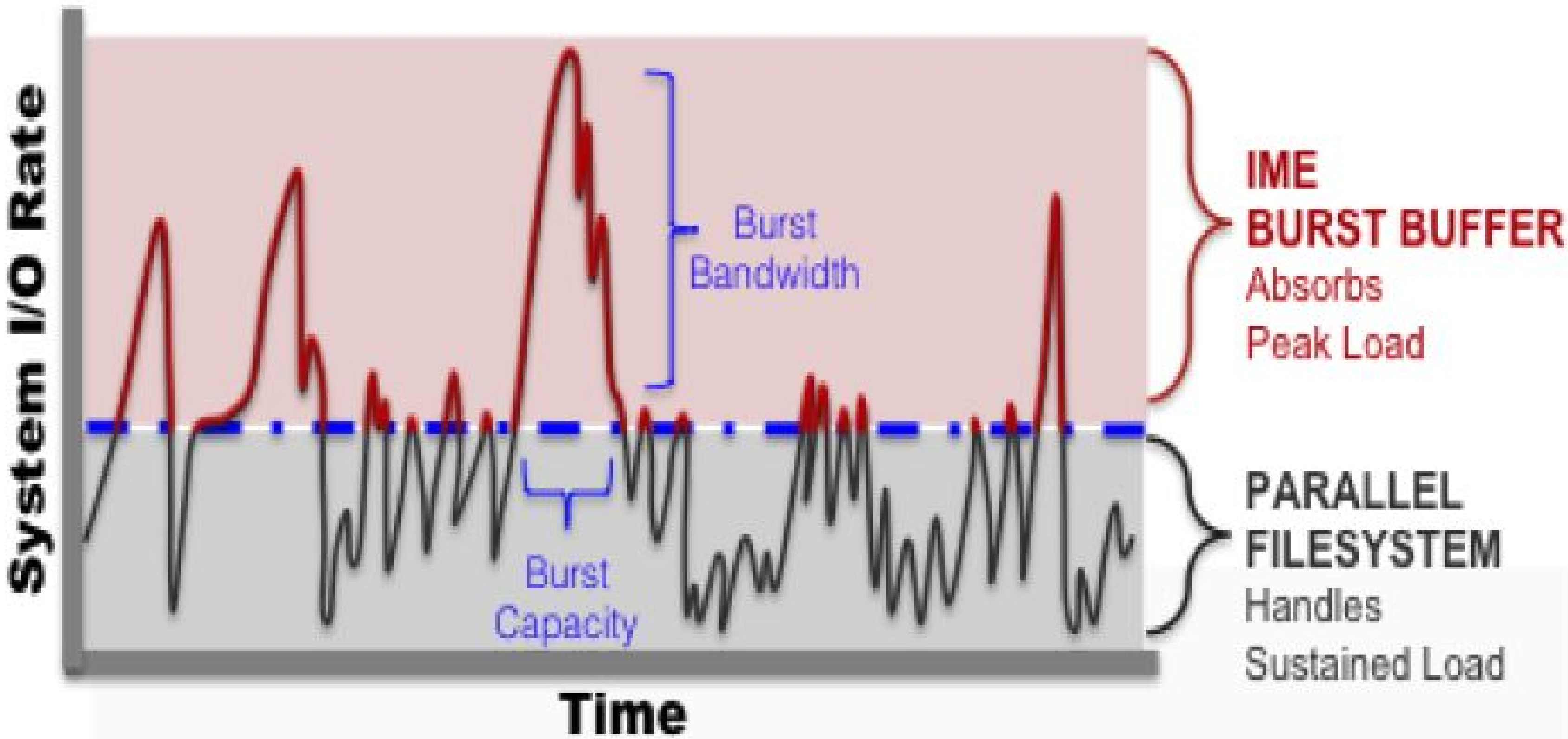
- ***Silicon and system integration***
- **Bring everything – storage, memory, interconnect – closer to the cores**
- **Raise center of gravity of memory pyramid, and make it fatter**
  - *Enable faster and more efficient data movement*
  - *Scientific Big Data: Addressing Volume, Velocity*

Future



Why an SSD Burst Buffer?

- **Motivation: Handle spikes in I/O bandwidth requirements**
  - Reduce overall application run time
  - Compute resources are idle during I/O bursts

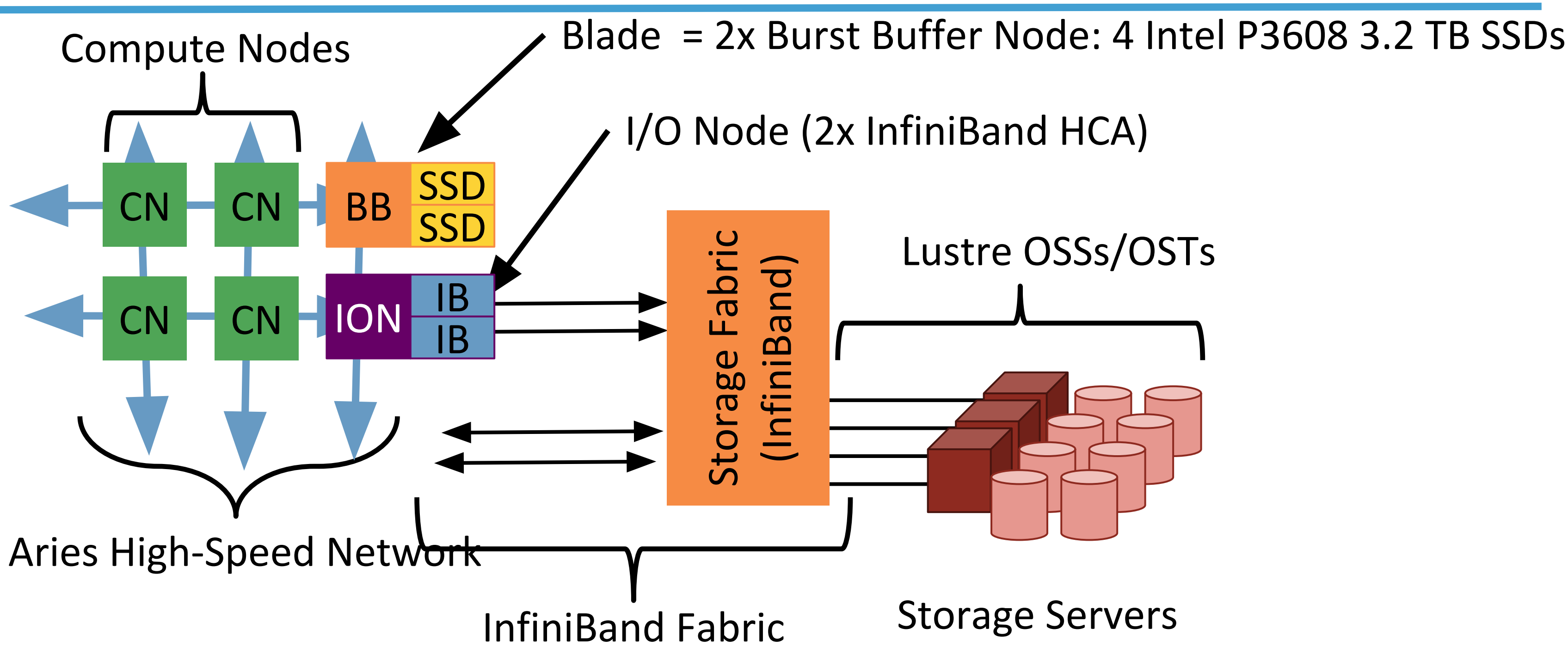


Why an SSD Burst Buffer?

- **Motivation: Handle spikes in I/O bandwidth requirements**
  - Reduce overall application run time
  - Compute resources are idle during I/O bursts
- **Some user applications have challenging I/O patterns**
  - High IOPs, random reads, different concurrency… perfect for SSDs
- **Cost rationale: Disk-based PFS bandwidth is expensive**
  - Disk capacity is relatively cheap
  - SSD *bandwidth* is relatively cheap

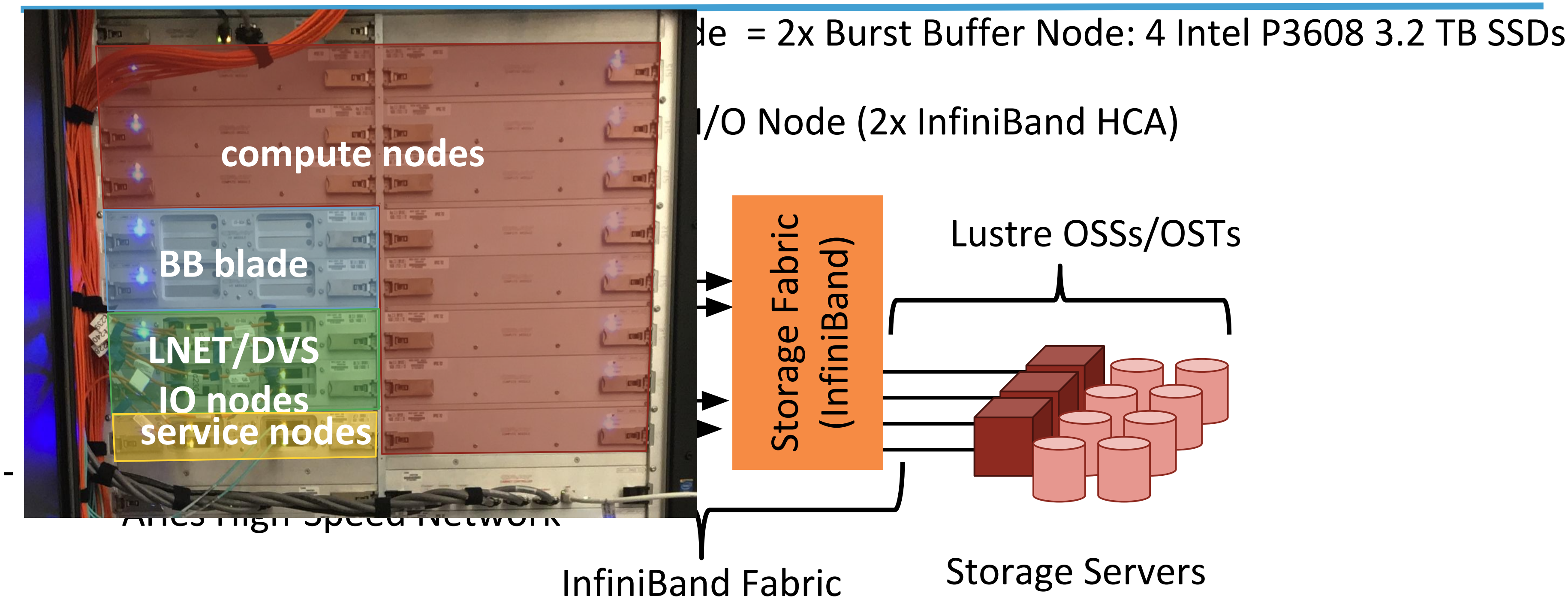
    =>Separate bandwidth and spinning disk
    - Provide high BW without wasting PFS capacity
    - Leverage Cray Aries network speed

NERSC/Cray Architecture



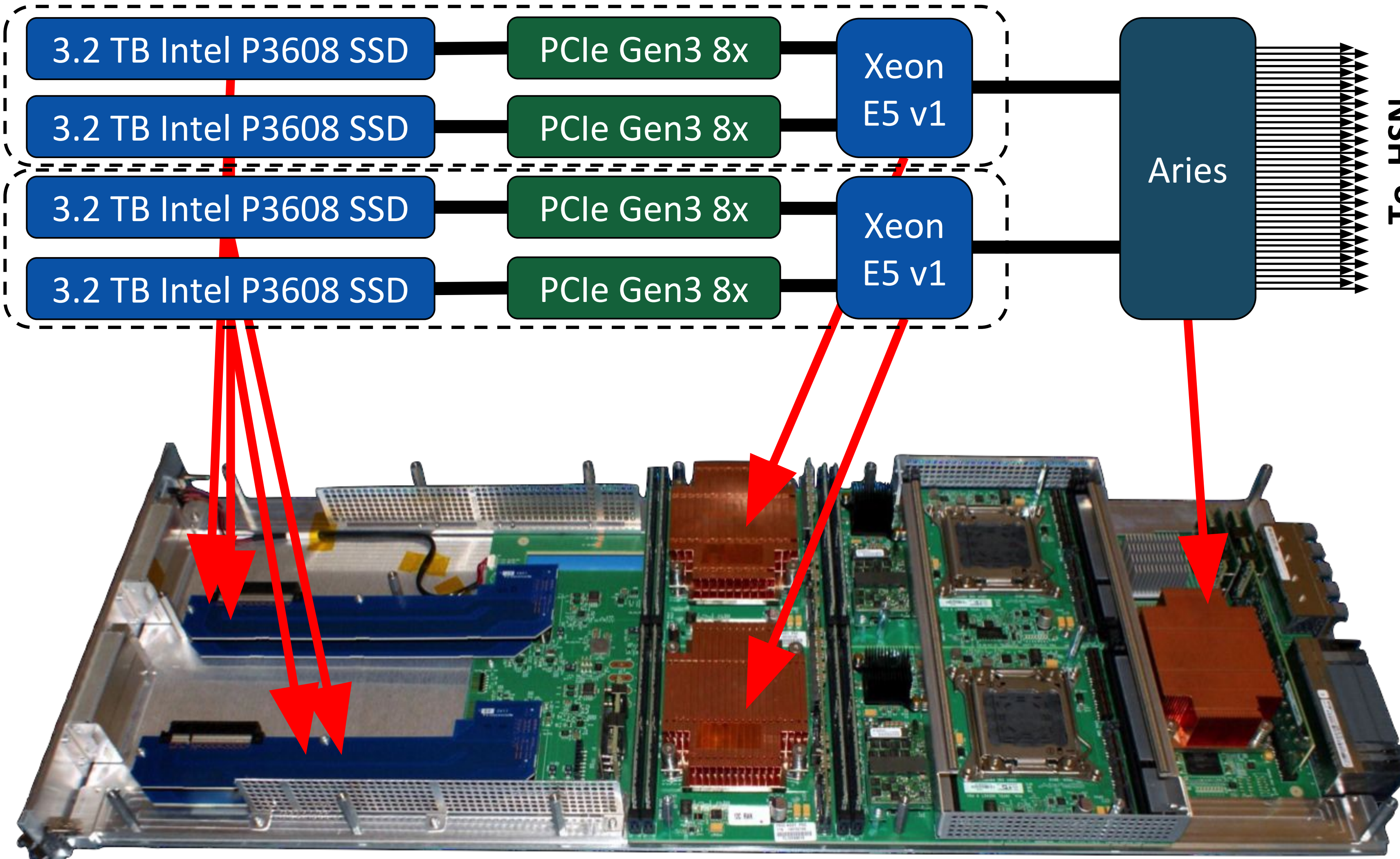
- DataWarp software (integrated with SLURM WLM) allocates portions of available storage to users per-job (or 'persistent').
- Users see a POSIX filesystem
- Filesystem can be striped across multiple BB nodes (depending on allocation size requested)

NERSC/Cray Architecture

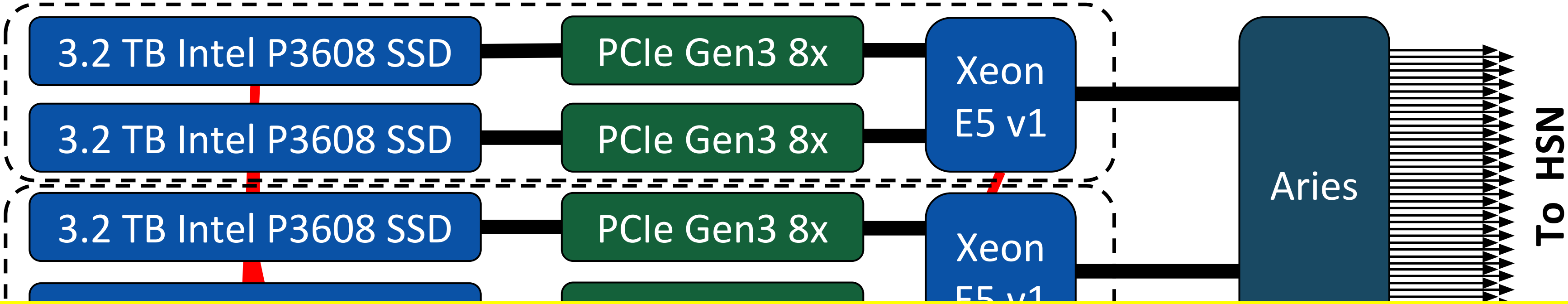


- DataWarp software (integrated with SLURM WLM) allocates portions of available storage to users per-job (or ‘persistent’).
- Users see a POSIX filesystem
- Filesystem can be striped across multiple BB nodes (depending on allocation size requested)

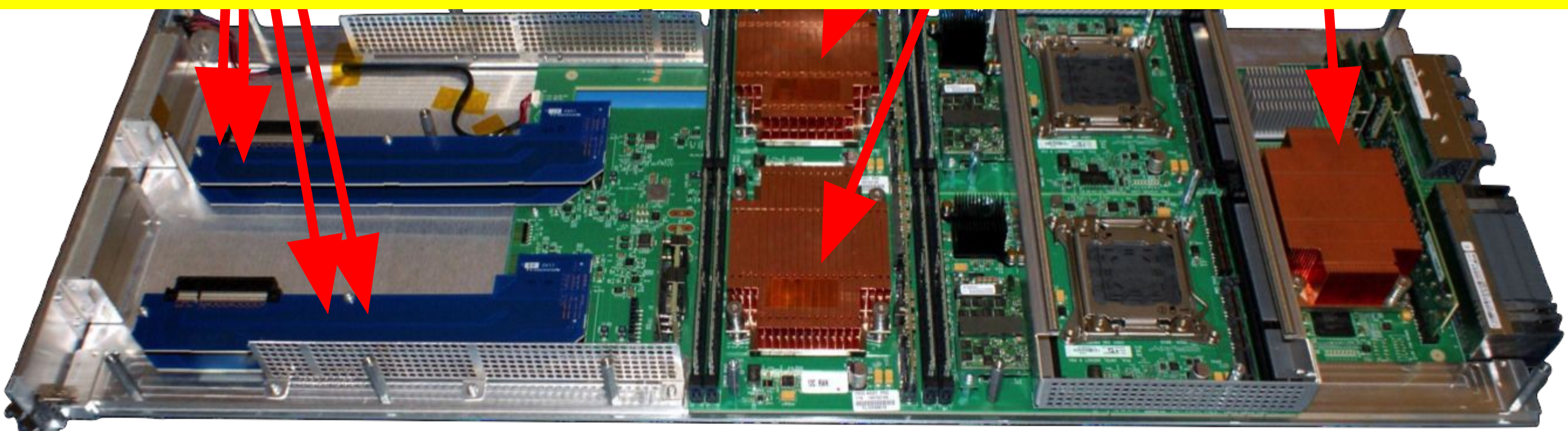
Burst Buffer Blade = 2xNodes



Burst Buffer Blade = 2xNodes



- ~1.8PiB of SSDs over 288 nodes
- Accessible from both HSW and KNL nodes

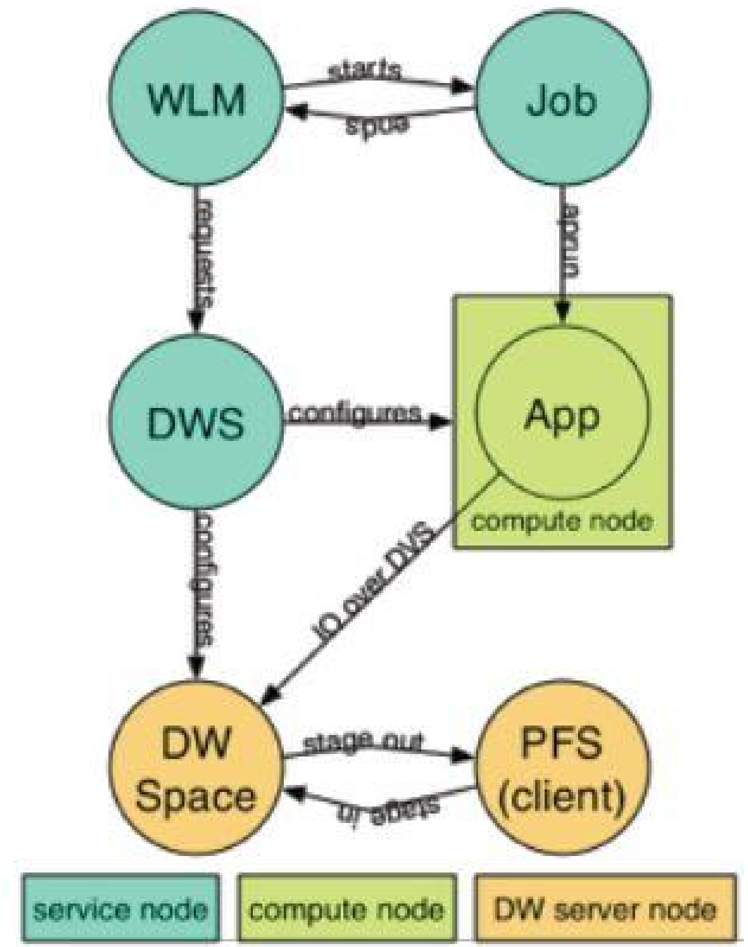


U.S. DEPARTMENT OF ENERGY | Office of Science

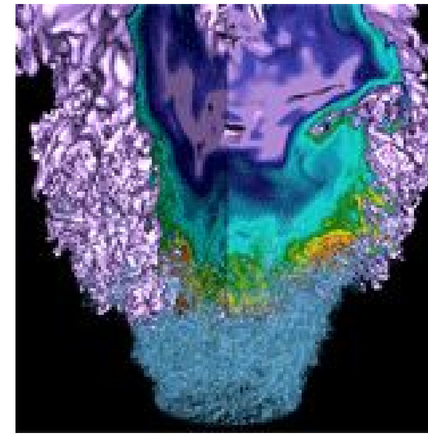
BERKELEY LAB

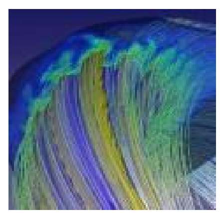
DataWarp: Under the hood

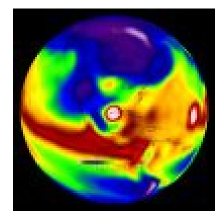
- Workload Manager (Slurm) schedules job in the queue on Cori
- DataWarp Service (DWS) configures DW space and compute node access to DW
- DataWarp Filesystem handles stage interactions with PFS (Parallel File System, i.e. scratch)
- Compute nodes access DW via a mount point

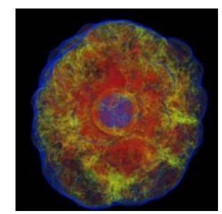


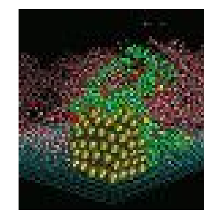
Using Cray DataWarp at NERSC











http://www.nersc.gov/users/computational-systems/cori/burst-buffer/example-batch-scripts/

U.S. DEPARTMENT OF ENERGY | Office of Science

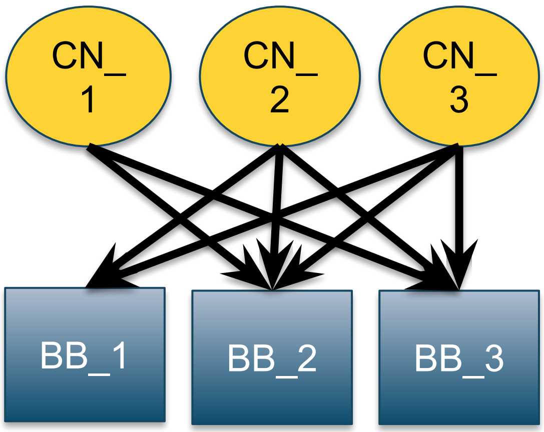
BERKELEY LAB

Two kinds of DataWarp Instances

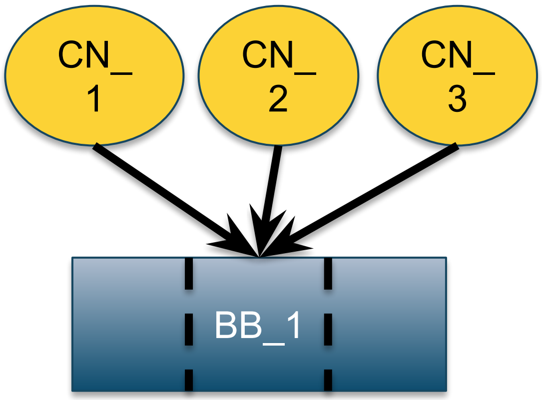
- “Instance”: an allocation on the BB
- Can it be shared? What is its lifetime?
  - Per-Job Instance
    - Can only be used by job that creates it
    - Lifetime is the same as the creating job
    - Use cases: PFS staging, application scratch, checkpoints
  - Persistent Instance
    - Can be used by any job (subject to UNIX file permissions)
    - Lifetime is controlled by creator
    - Use cases: Shared data, PFS staging, Coupled job workflow
    - ***NOT for long-term storage of data!***

Two DataWarp Access Modes

- **Striped ("Shared")**
  - –Files are striped across all DataWarp nodes
  - –Files are visible to all compute nodes
    Aggregates both capacity and BW per file
  - –One DataWarp node elected as the metadata server (MDS)



- **Private**
  - –Files are assigned to *one* DataWarp node
  - –File are visible to *only the compute node that created them*
  - –Each DataWarp node is an MDS for one or more compute nodes



How to use DataWarp

- **Principal user access: SLURM Job script directives: `#DW`**
  - Allocate job or persistent DataWarp space
  - Stage files or directories in from PFS to DW; out DW to PFS
  - Access BB mount point via `$DW_JOB_STRIPED`, `$DW_JOB_PRIVATE`, `$DW_PERSISTENT_STRIPED_name`
- **User library API – `libdatawarp`**
  - Allows direct control of staging files asynchronously
  - C library interface
  - https://www.nersc.gov/users/computational-systems/cori/burst-buffer/example-batch-scripts/#toc-anchor-8
  - https://github.com/NERSC/BB-unit-tests/tree/master/datawarpAPI

Integration with SLURM

```
#!/bin/bash
#SBATCH -p regular -N 10 -t 00:10:00
#DW jobdw capacity=1000GB access_mode=striped type=scratch
#DW stage_in source=/lustre/inputs destination=$DW_JOB_STRIPED/inputs \
type=directory
#DW stage_in source=/lustre/file.dat destination=$DW_JOB_STRIPED/ type=file
#DW stage_out source=$DW_JOB_STRIPED/outputs destination=/lustre/outputs \
type=directory
srun my.x --indir=$DW_JOB_STRIPED/inputs --infile=$DW_JOB_STRIPED/file.dat \
--outdir=$DW_JOB_STRIPED/outputs
```

- **‘type=scratch’ – duration just for compute job (i.e. not ‘persistent’)**
- **‘access_mode=striped’ – visible to all compute nodes (i.e. not ‘private’) and striped across multiple BB nodes**
  - Actual distribution across BB Nodes is in units of (configurable) granularity (currently 200 GB at NERSC in wlm_pool, so 1000 GB would normally be placed on 5 BB nodes)
- **Data ‘stage_in’ before job start and ‘stage_out’ after**

Integration with SLURM

```
#!/bin/bash
#SBATCH -p regular -N 10 -t 00:10:00
#DW jobdw capacity=1000GB access_mode=striped type=scratch
#DW stage_in source=/lustre/inputs destination=$DW_JOB_STRIPED/inputs \
type=directory
#DW stage_in source=/lustre/file.dat destination=$DW_JOB_STRIPED/ type=file
#DW stage_out source=$DW_JOB_STRIPED/outputs destination=/lustre/outputs \
type=directory
srun my.x --indir=$DW_JOB_STRIPED/inputs --infile=$DW_JOB_STRIPED/file.dat \
--outdir=$DW_JOB_STRIPED/outputs
```

- **'type=scratch' – duration just for compute job (i.e. not 'persistent')**
- **'access_mode=striped' – visible to all compute nodes (i.e. not 'private') and striped across multiple BB nodes**
  - Actual distribution across BB Nodes is in units of (configurable) granularity (currently 200 GB at NERSC in wlm_pool, so 1000 GB would normally be placed on 5 BB nodes)
- **Data 'stage_in' before job start and 'stage_out' after**

Integration with SLURM

```
#!/bin/bash
#SBATCH -p regular -N 10 -t 00:10:00
#DW jobdw capacity=1000GB access_mode=striped type=scratch
#DW stage_in source=/lustre/inputs destination=$DW_JOB_STRIPED/inputs \
type=directory
#DW stage_in source=/lustre/file.dat destination=$DW_JOB_STRIPED/ type=file
#DW stage_out source=$DW_JOB_STRIPED/outputs destination=/lustre/outputs \
type=directory
srun my.x --indir=$DW_JOB_STRIPED/inputs --infile=$DW_JOB_STRIPED/file.dat \
--outdir=$DW_JOB_STRIPED/outputs
```

- **'type=scratch' – duration just for compute job (i.e. not 'persistent')**
- **'access_mode=striped' – visible to all compute nodes (i.e. not 'private') and striped across multiple BB nodes**
  - –Actual distribution across BB Nodes is in units of (configurable) granularity (currently 200 GB at NERSC in wlm_pool, so 1000 GB would normally be placed on 5 BB nodes)
- **Data 'stage_in' before job start and 'stage_out' after**

Integration with SLURM

```
#!/bin/bash
#SBATCH -p regular -N 10 -t 00:10:00
#DW jobdw capacity=1000GB access_mode=striped type=scratch
#DW stage_in source=/lustre/inputs destination=$DW_JOB_STRIPED/inputs \
type=directory
#DW stage_in source=/lustre/file.dat destination=$DW_JOB_STRIPED/ type=file
#DW stage_out source=$DW_JOB_STRIPED/outputs destination=/lustre/outputs \
type=directory
srun my.x --indir=$DW_JOB_STRIPED/inputs --infile=$DW_JOB_STRIPED/file.dat \
--outdir=$DW_JOB_STRIPED/outputs
```

- **'type=scratch' – duration just for compute job (i.e. not 'persistent')**
- **'access_mode=striped' – visible to all compute nodes (i.e. not 'private') and striped across multiple BB nodes**
  - Actual distribution across BB Nodes is in units of (configurable) granularity (currently 200 GB at NERSC in wlm_pool, so 1000 GB would normally be placed on 5 BB nodes)
- **Data 'stage_in' before job start and 'stage_out' after**

Integration with SLURM

- Using a *persistent* DataWarp instance
  - Lifetime different from the batch job
  - Usable by any batch job (posix permissions permitting)
  - `name=xyz`: Name of persistent instance to use

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB create_persistent name=myBBname capacity=10GB access=striped type=scratch
```

Delete

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB destroy_persistent name=myBBname
```

Use in another job

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#DW persistentdw name=myBBname
mkdir $DW_PERSISTENT_STRIPED_myBBname/test1
srun a.out INSERT_YOUR_CODE_OPTIONS_HERE
```

Integration with SLURM

- **Using a *persistent* DataWarp instance**
  - Lifetime different from the batch job
  - Usable by any batch job
  - `name=xyz`: Name of persistent instance to use

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB create_persistent name=myBBname capacity=10GB access=striped type=scratch
```

Delete

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB destroy_persistent name=myBBname
```

Use in another job

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#DW persistentdw name=myBBname
mkdir $DW_PERSISTENT_STRIPED_myBBname/test1
srun a.out INSERT_YOUR_CODE_OPTIONS_HERE
```

Integration with SLURM

- **Using a *persistent* DataWarp instance**
  - –Lifetime different from the batch job
  - –Usable by any batch job
  - –`name=xyz`: Name of persistent instance to use

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB create_persistent name=myBBname capacity=10GB access=striped type=scratch
```

Delete

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB destroy_persistent name=myBBname
```

Use in another job

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#DW persistentdw name=myBBname
mkdir $DW_PERSISTENT_STRIPED_myBBname/test1
srun a.out INSERT_YOUR_CODE_OPTIONS_HERE
```

Integration with SLURM

- **Using a *persistent* DataWarp instance**
  - –Lifetime different from the batch job
  - –Usable by any batch job
  - –`name=xyz`: Name of persistent instance to use

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB create_persistent name=myBBname capacity=10GB access=striped type=scratch
```

Delete

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#BB destroy_persistent name=myBBname
```

Use in another job

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
#DW persistentdw name=myBBname
mkdir $DW_PERSISTENT_STRIPED_myBBname/test1
srun a.out INSERT_YOUR_CODE_OPTIONS_HERE
```

Resources

- NERSC Burst Buffer Web Pages

http://www.nersc.gov/users/computational-systems/cori/burst-buffer/

- Example batch scripts

http://www.nersc.gov/users/computational-systems/cori/burst-buffer/example-batch-scripts/

- Burst Buffer Early User Program Paper

http://www.nersc.gov/assets/Uploads/Nersc-BB-EUP-CUG.pdf

Benchmark Performance

- **Burst Buffer is doing very well against benchmark performance targets**
  - Out-performs Lustre significantly
  - Fastest IO system in the world!

	IOR Posix FPP		IOR MPIO Shared File		IOPS	
	Read	Write	Read	Write	Read	Write
Best Measured (287 Burst Buffer Nodes : 11120 Compute Nodes; 4 ranks/node)*	1.7 TB/s	1.6 TB/s	1.3 TB/s	1.4 TB/s	28M	13M

**Bandwidth tests: 8 GB block-size 1MB transfers IOPS tests: 1M blocks 4k transfer*

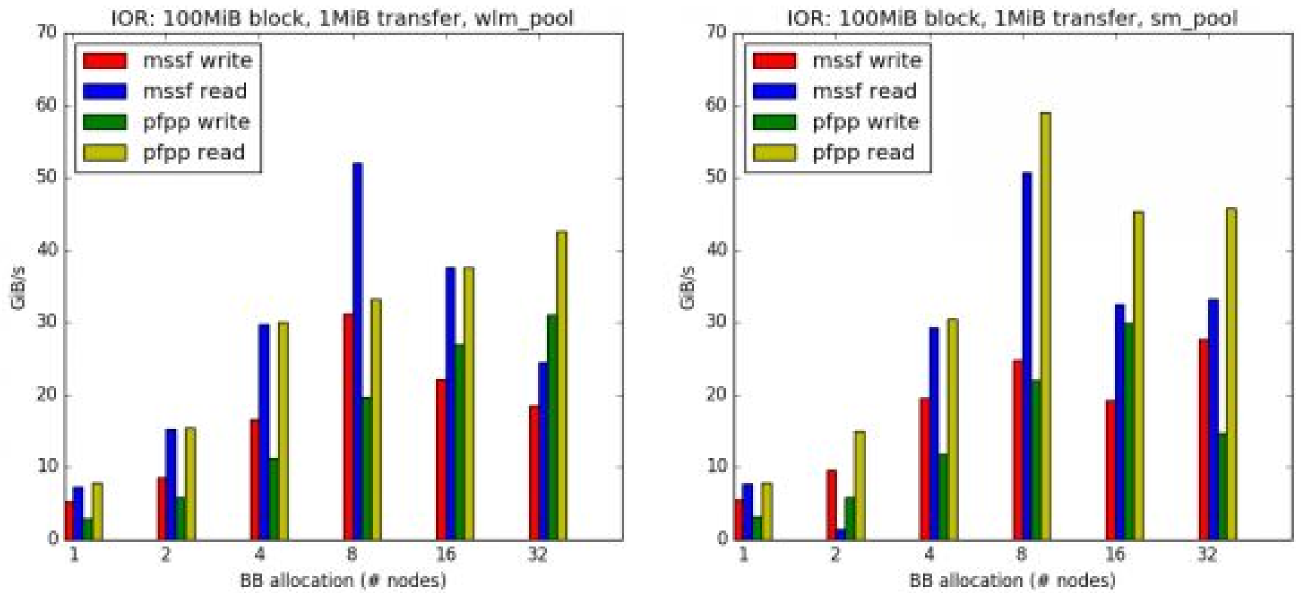
Striping, granularity and pools

- **DataWarp nodes are configured to have "granularity"**
  - Minimum amount of data that will land on one node
- **Two "pools" of DataWarp nodes, with different granularity**
  - wlm_pool (default): 200GiB
    - `#DW jobdw capacity=1000GB access_mode=striped type=scratch pool=wlm_pool`
  - sm_pool: 20.14 GiB
    - `#DW jobdw capacity=1000GB access_mode=striped type=scratch pool=sm_pool`
- **For example, 1.2TiB will be striped over 6 BB nodes in wlm_pool, but over 60 BB nodes in sm_pool**
  - **No guarantee that allocation will be spread evenly ove**

    - may see >1 "grain" on a single node

Performance tips

- **Stripe your files across multiple BB servers**
  – To obtain good scaling, need to drive IO with sufficient compute - scale up # BB nodes with # compute nodes



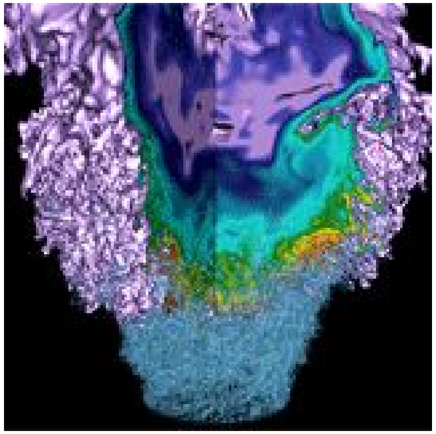
Summary

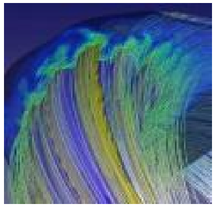
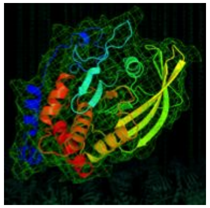
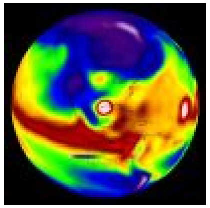
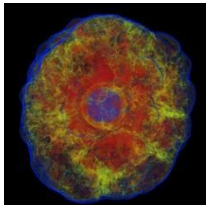
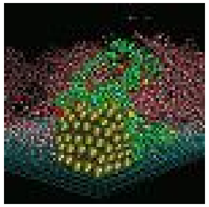
- **NERSC has the first Burst Buffer for open science in the USA**
  - And the first in the world that is being tested for real use cases!
- **Users are able to take advantage of SSD performance**
  - Some tuning may be required to maximise performance
- **Many bugs now worked through**
  - But care is needed when using this new technology!
- **User experience today is generally good**
  - Let us know if you're interested in using the Burst Buffer…

More information…

https://www.nersc.gov/users/computational-systems/cori/burst-buffer/

Extra slides



SSD write protection

- SSDs support a set amount of write activity before they wear out
- Runaway application processes may write an excessive amount of data, and therefore, “destroy” the SSDs
- Three write protection policies
  - Maximum number of bytes written in a period of time
  - Maximum size of a file in a namespace
  - Maximum number of files allowed to be created in a namespace
- Log, error, log and error
  - -EROFS (write window exceeded)
  - -EMFILE (maximum files created exceeded)
  - -EFBIG (maximum file size exceeded)

U.S. DEPARTMENT OF ENERGY | Office of Science

BERKELEY LAB