# Introduction to Lustre

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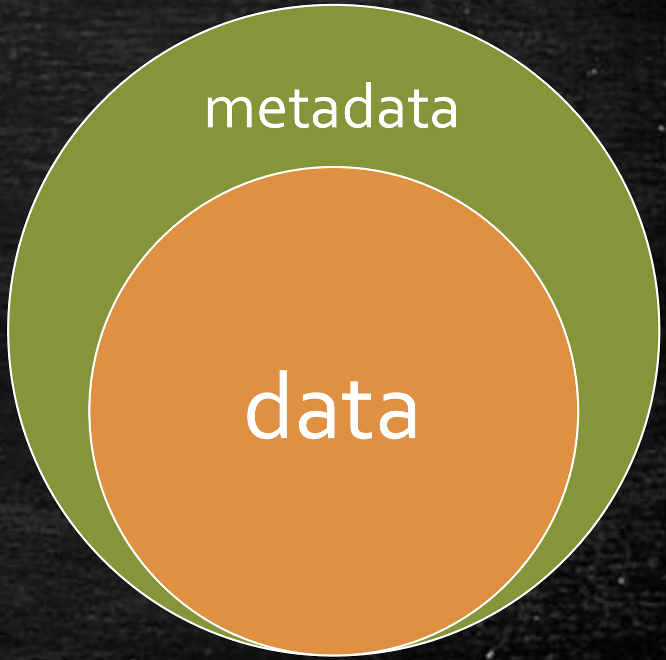
# Parallel filesystem basics

# What is a filesystem?

- A way of organizing data on a storage device
- We *see* data as having two components:
  - Data: raw information
    - numbers, characters, images, etc
  - Metadata: description of the stored data
    - array length
    - type (integer, float, double, etc)
    - address at which data is stored
- I/O operations use both components



# What’s different with parallel filesystems?

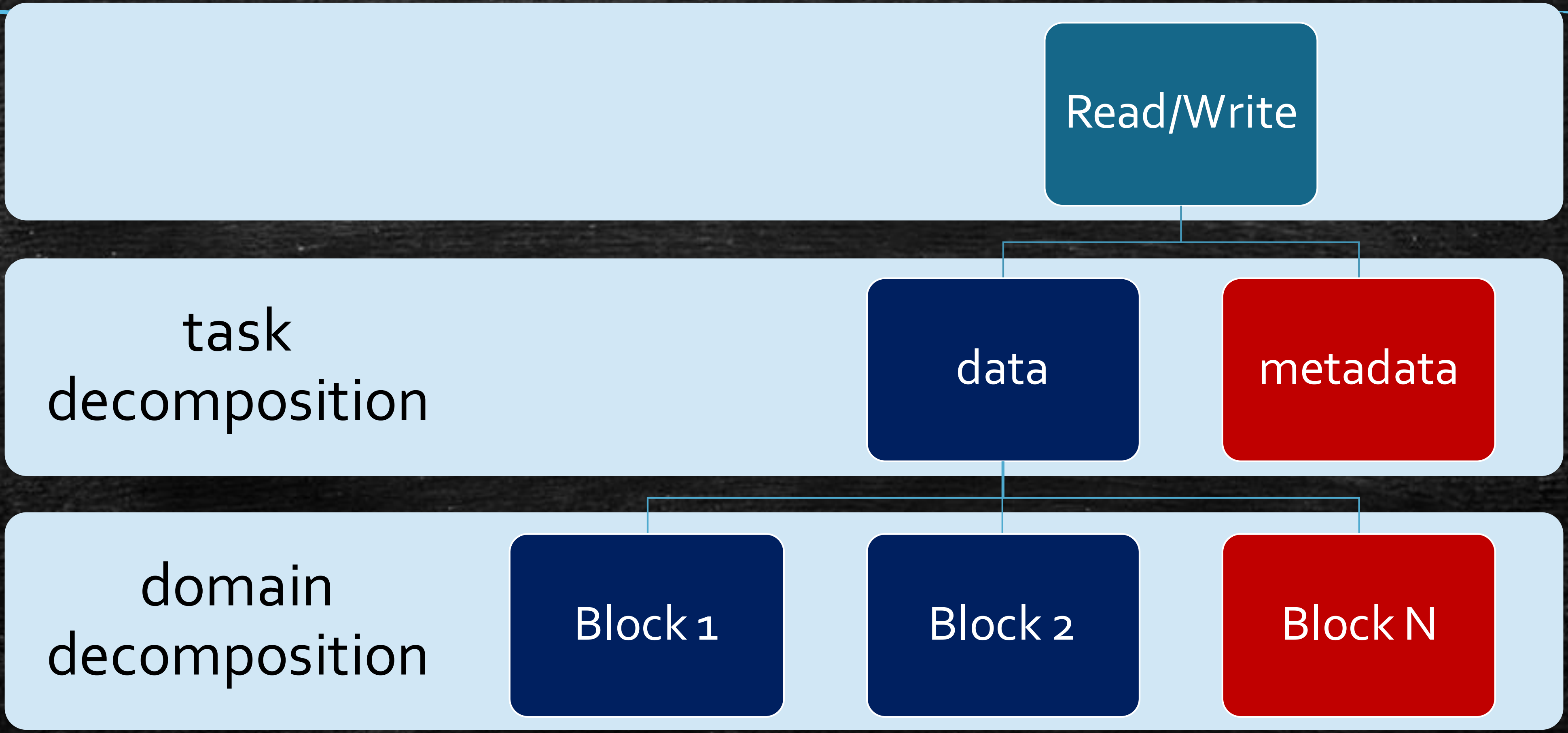
A parallel filesystem employs both task and domain parallelism to increase throughput of I/O operations.

**Task Parallelism**

Separation of metadata and data operations

**Domain Decomposition**

Break data into pieces that are to be handled on different hardware



Read/Write

task decomposition

data

metadata

domain decomposition

Block 1

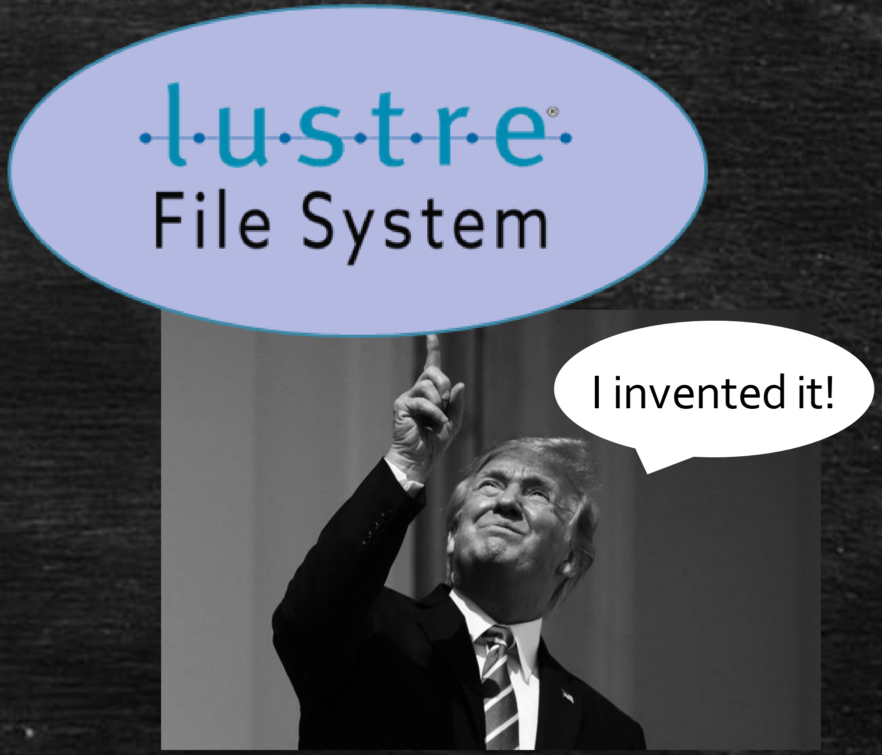
Block 2

Block N

# Common Parallel Filesystems

- General Parallel File System (GPFS) / Lustre
  - Commonly associated with supercomputing
  - Employed at NCI, Pawsey, CSIRO and Swinbourne
  - Can be used on AWS and Azure

- Gluster, BeeGFS
  - Parallel distributed file systems
  - More associated with cloud computing



# What is Lustre?

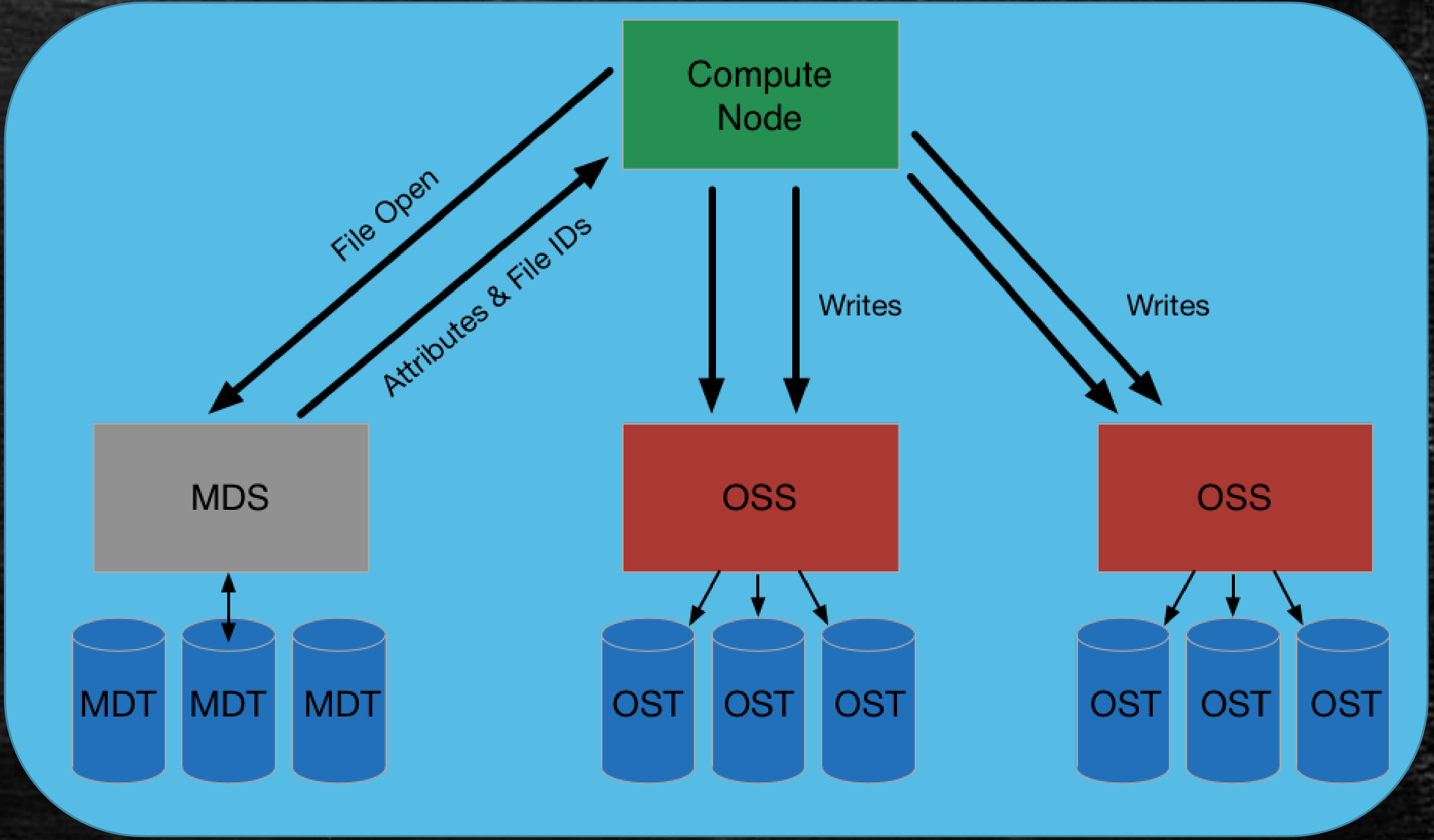
# Points of Interest

- Widely used
  - Most hardware vendors offer support
  - Majority of Top 500 systems use it
- Built for heavy duty performance
  - Used with hundreds of thousands of compute nodes
  - Deployed on filesystems with petabytes of capacity
  - capable of Terabyte/sec throughputs
- Industry & community acceptance
  - Lustre users group
  - Application support in libraries such as HDF5
  - Can get service contracts through vendors

# Overview

Lustre uses both task and domain parallelism

Different hardware is used for metadata and data operations.



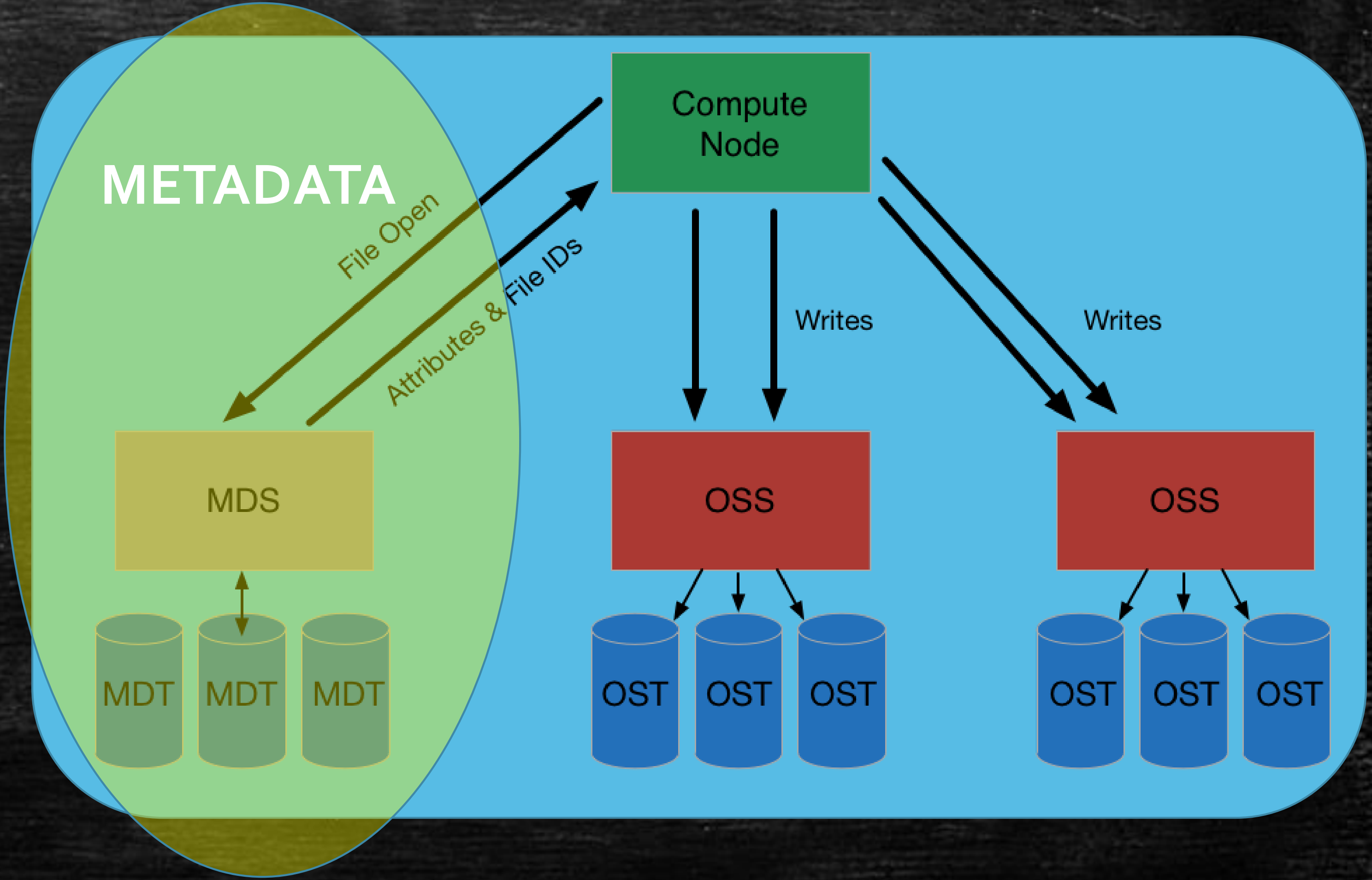
# Overview

## Meta-Data Server (MDS)

- Tracks storage locations of all files
- Directs I/O requests to appropriate OSTs and OSSes

## Meta-Data Target (MDT)

- Stores all metadata
- Filenames, permissions, paths, layout, etc



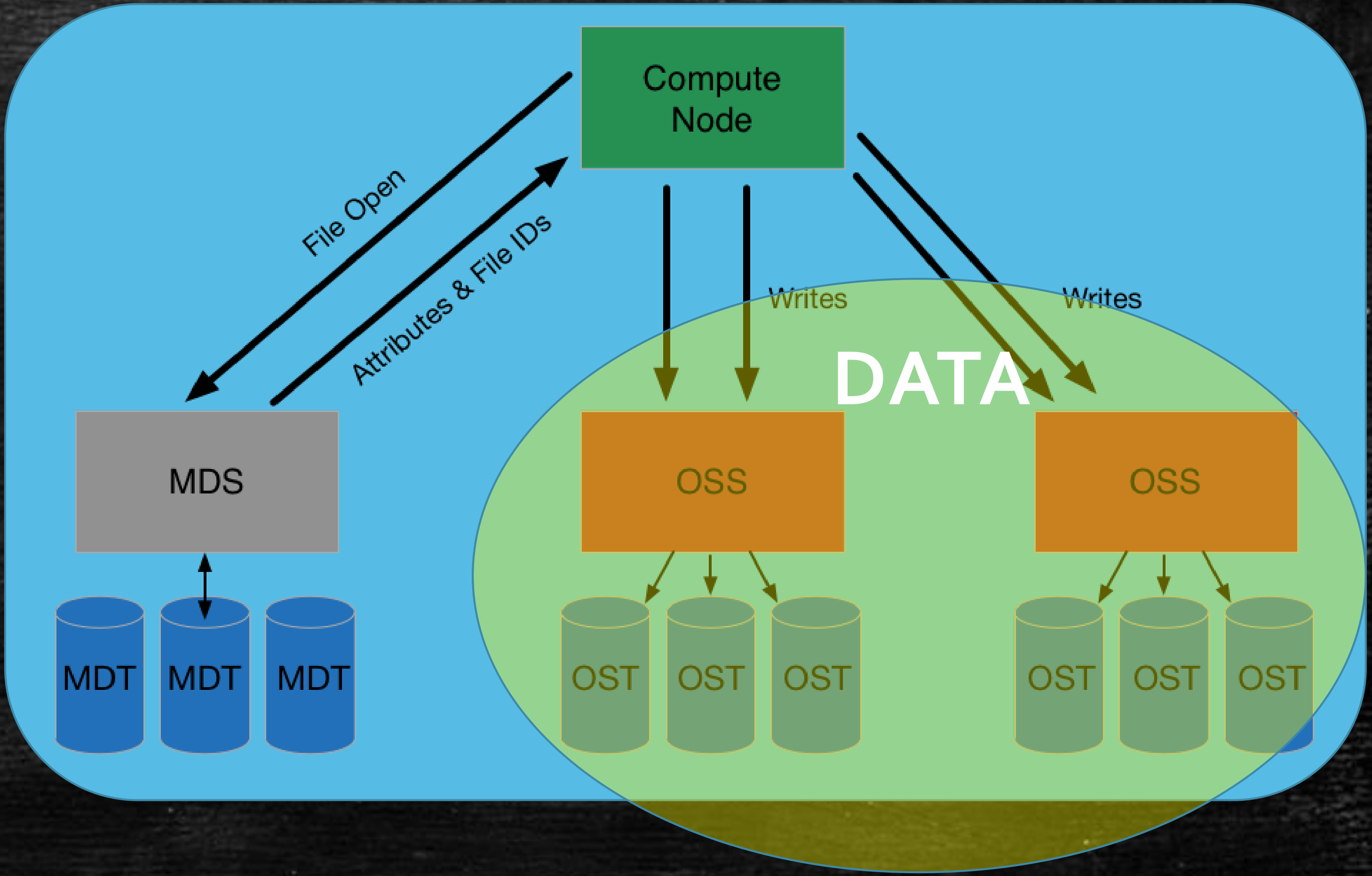
# Overview

Object Storage Server (OSS)

- manages a subset of OSTs
- handles network and I/O requests

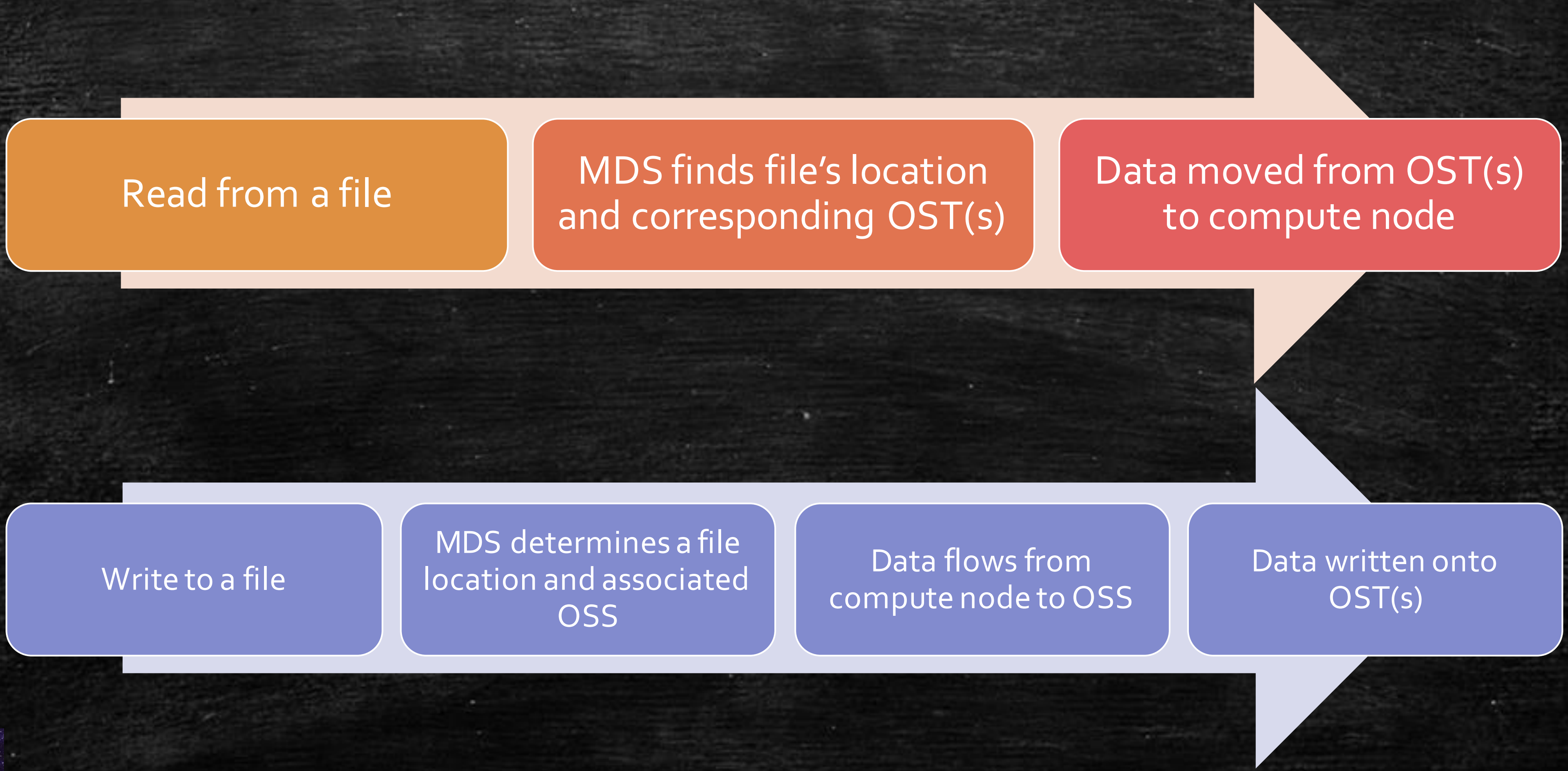
Object Storage Target (OST)

- stores data stripes
- RAID array of hard disks



More hardware dedicated to the DATA side

# What happens during a read/write?



Read from a file

MDS finds file’s location and corresponding OST(s)

Data moved from OST(s) to compute node

Write to a file

MDS determines a file location and associated OSS

Data flows from compute node to OSS

Data written onto OST(s)

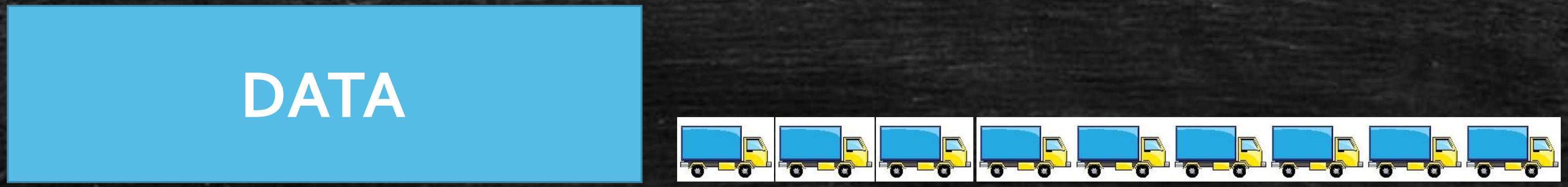
# Tuneable Parameters in Lustre

Will stick to two parameters from that effect IO performance:

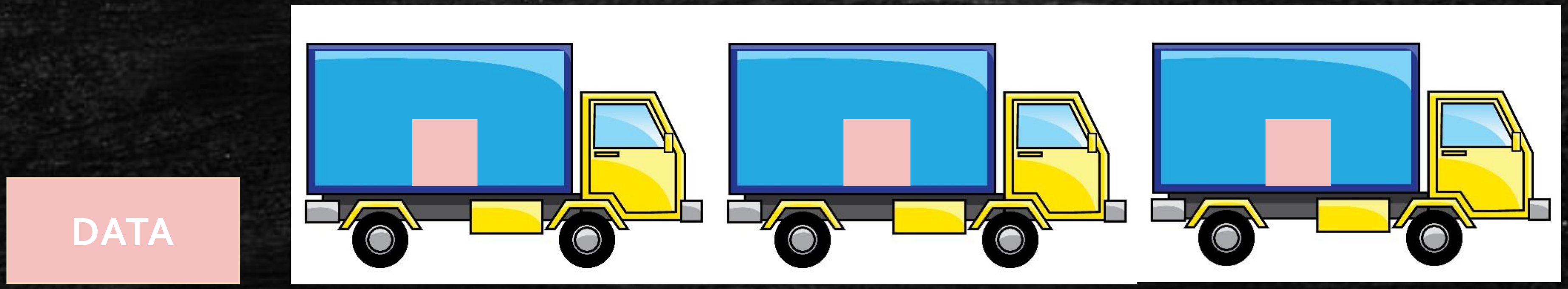
# Block Size

The size of the individual data chunks that are routed to/from OSTs.

**Too small**: there will be too many blocks leading to bandwidth issues


DATA

**Too large**:  partially filled blocks are used leading to latency issues


DATA

# Number of OSTs

A file or directory can have a specified number of OSTs assigned to it. It will have its data blocks spread among these OSTs.

**Too few OSTS**: Bandwidth issues arise as the data blocks are blocked by the lack of "connections" to hard disk.

**Too many OSTS**: Latency can become an issue as data blocks are too spread. Metadata tracking can become prohibitively expensive.

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# Changing Lustre Parameters

- These parameters can be attributed to a single file or a directory of individual files.
- ***Be careful when modifying these parameters.  Know what you are doing!***
- System defaults are generally good. Only change when observed IO performance is bad.
- Remember that filesystems are a shared resource!

# Demo: Striping and IO performance

Two Python demo scripts are available:

lustre_block_size_test.py

lustre_num_stripes_test.py

We will investigate the effect that stripe size and number of OSTs play in write performance on a Lustre filesystem.

Which factor has the greatest effect? Why?

Can you think of situations when the each factor is dominant in determining observed IO performance?

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# Demo: How to Run

1. Click on the terminal in your JupyterHub screen
2. Connect via ssh to the Athena cluster located at Pawsey

   ```
   ssh couXXX@athena.pawsey.org.au
   ```

3. Go into the Lustre demo directory

   ```
   cd HPC-Workshop/lustre
   ```

4. Submit the 2 demo jobscripts to SLURM

   ```
   sbatch jobscript.slurm_block_size
   sbatch jobscript.slurm_num_osts
   ```

5. Look at the output with the vi text editor

   ```
   vi LustreTest_VaryingBlockSize
   vi LustreTest_VaryingNumOSTs
   ```

6. Exit vi by pressing :q and then ENTER

# Getting the most out of Lustre

# The Good and Bad of Lustre

It excels at:

- large contiguous or uniformly positioned reads/writes
- low frequency IO patterns
- using MPI-IO

It struggles with:

- high frequency reads/writes
- discontinuous / non-uniform read or write patterns
- accessing large numbers of files simultaneously
- Metadata heavy operations (ls –la)

# Useful Lustre-specific Commands

| Command | Description |
|---|---|
| **lfs mkdir –c <# ost> -s <stripe size> <dir>** | Create a directory over a given # of OSTs and stripe size |
| **lfs getstripe <file / dir>** | Get the stripe size and # of OSTs assigned to a file or directory |
| **lfs setstripe –c <# ost> -s <stripe size> <file>** | Set the stripe size. # is number of bytes |
| **lfs migrate –c <# ost> -s <stripe size> <file>** | Modify the stripe count and/or size for an existing file or directory |
| **lfs find <dir>** | List the contents of a directory |
| **lfs df** | Check disk space usage |

# Other recommendations

- Avoid doing the following:
  - using auto/tab complete
  - wildcard expressions (especially `tar` and `rm`)
    - Generate an explicit list of files and operate on each individually
  - thousands of files in a single directory
    - use a directory structure
  - Using ls –l unless absolutely necessary
- Open files as `READ_ONLY` if they will only be accessed for reading
- Don’t stripe small files (<1 MB) across multiple OSTs
  - Set stripe count to 1 for a directory and write files in it
  - Be careful not to specify a specific OST!!

# Other recommendations

- Store executables in non-parallel file system
- Don’t edit text/source files in a Lustre file system
  - vi creates temporary “snapshot” files that increase metadata loads
- Remember to appropriately stripe when moving files from a non-parallel filesystem to the Lustre filesystem
- System-level caching can effect expected performance