Asynchronous Object Storage with QoS for Scientific and Commercial Data

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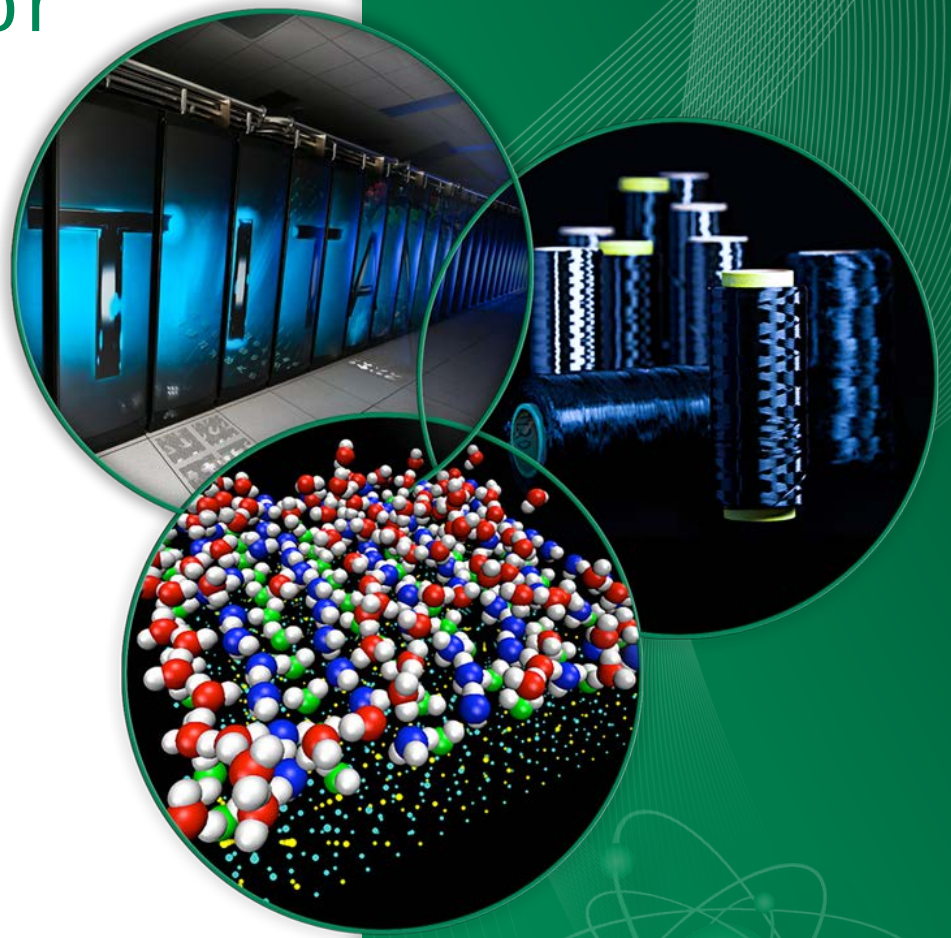

PDSW
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Introduction

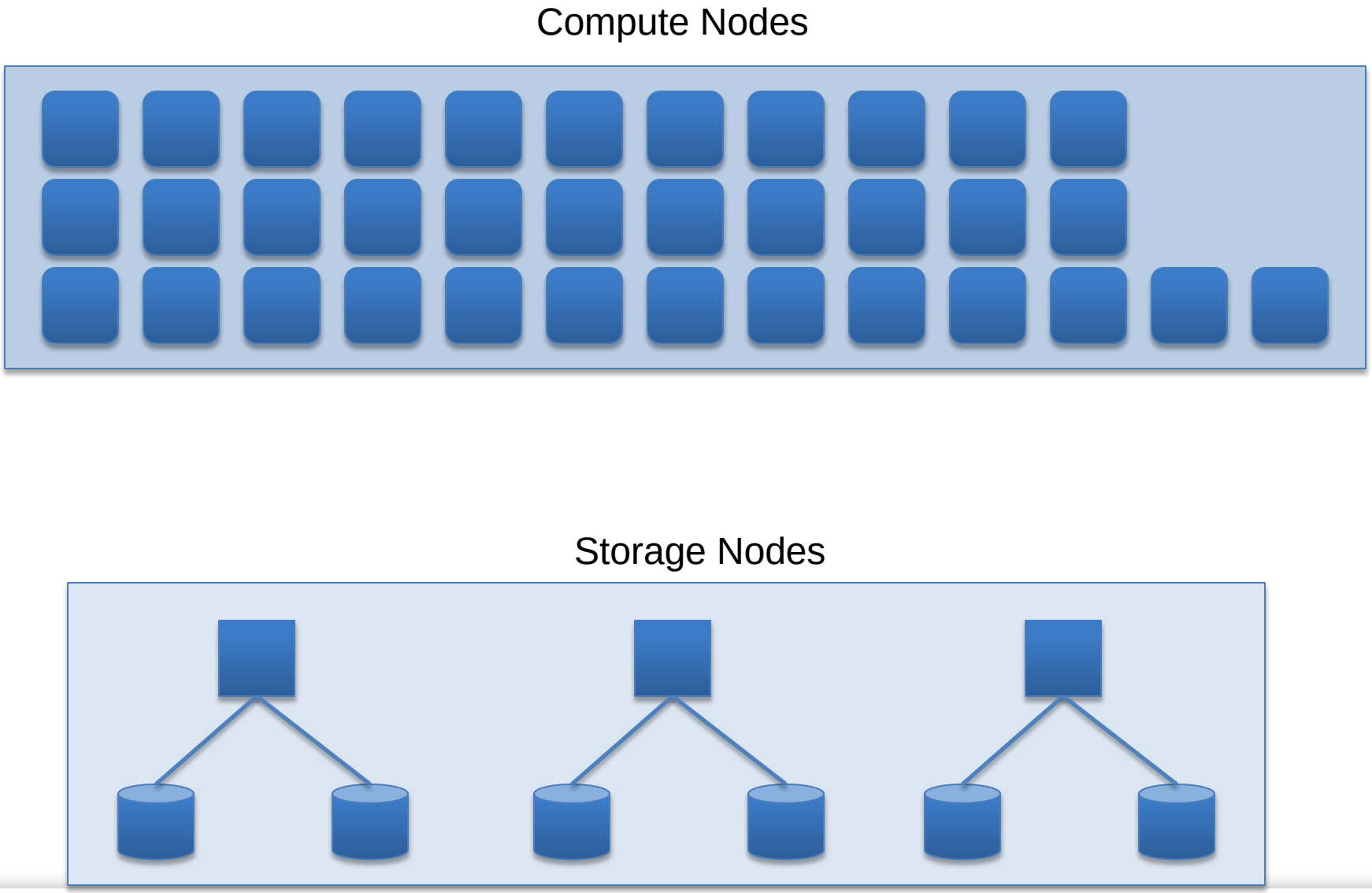
> "Scientific discovery in energy research and a wide range of other fields increasingly depends on effectively managing and searching large datasets for new insights."
>
> - Dr. Steven Chu, Secretary of Energy
> Big Data Research Initiative, March 29, 2012

- What is Big Data
  - Volume, variety, and velocity
  - Good support for statistical inference/induction
    - As opposed to traditional descriptive statistics
  - Exposes some weaknesses in existing HPC storage systems

Big Data HPC Use Cases

1. Scientific Application Checkpointing
   - Codes often time-step based simulation
   - Bursty I/O (write for 5 minutes, once an hour)
   - Almost entirely storage system write limited
   - Large fraction of the memory space of the entire application streaming to storage
2. Big Data Analysis
   - Data mining, parallel data analysis, statistical induction
   - Ideally, Map-Reduce
   - Large block storage system reads
   - Almost continuous storage system load

Interference Scenario



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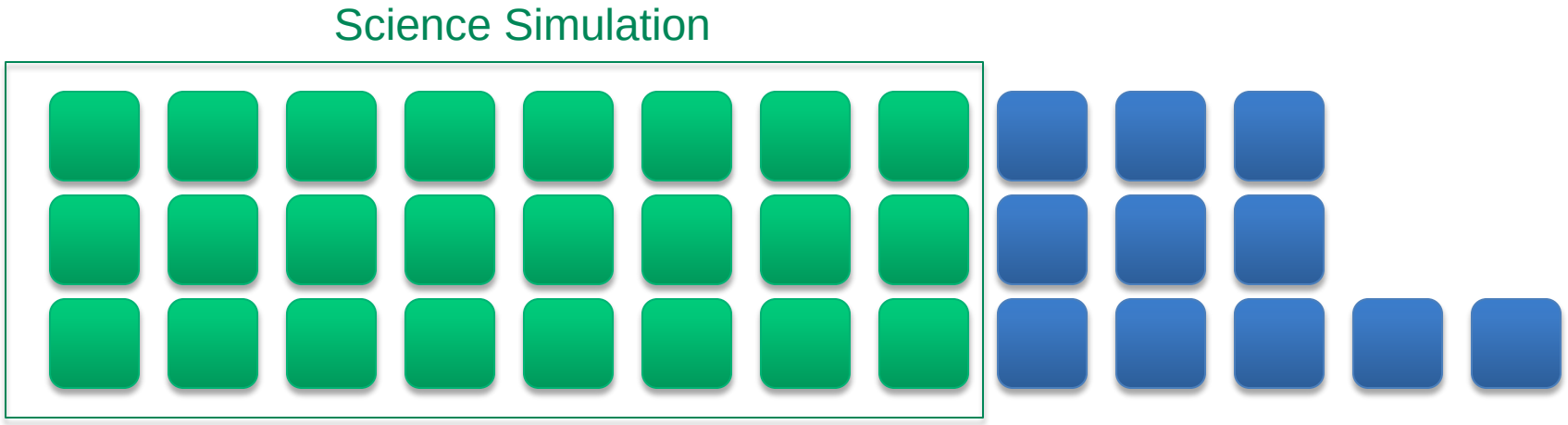

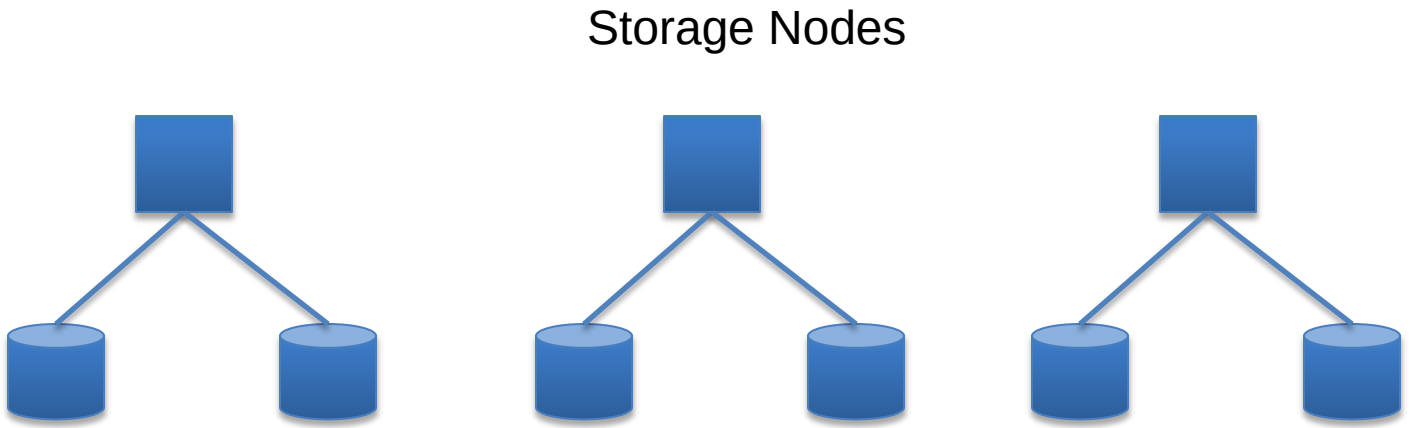

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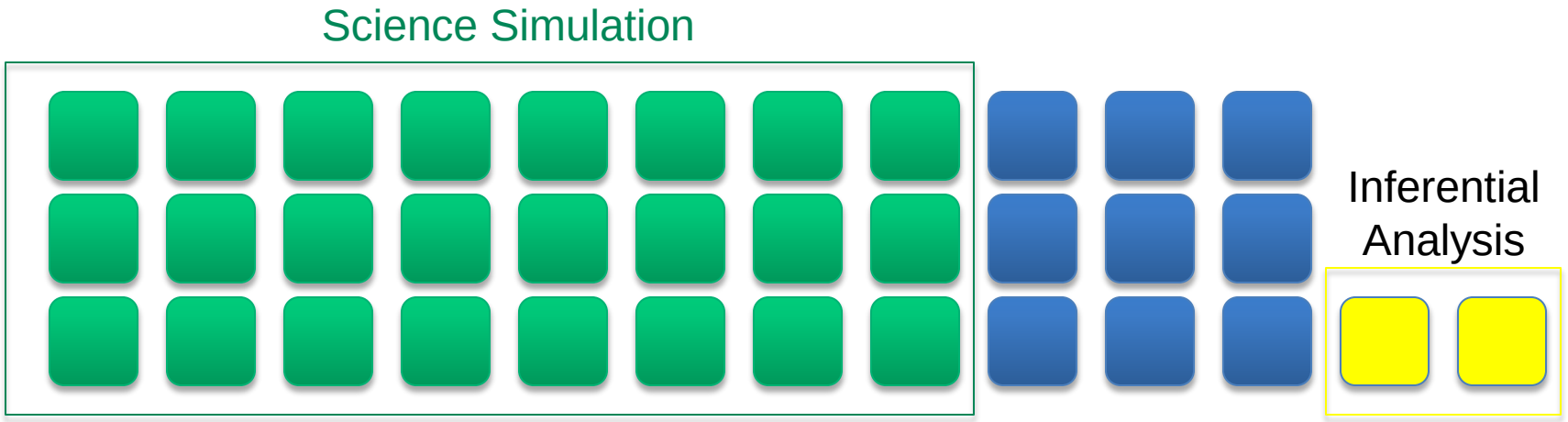

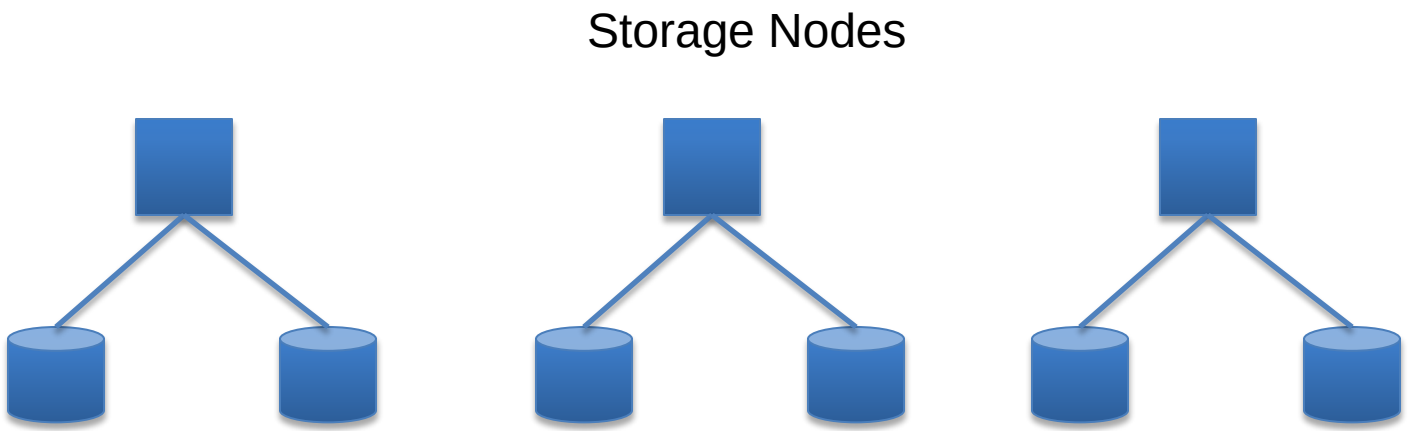

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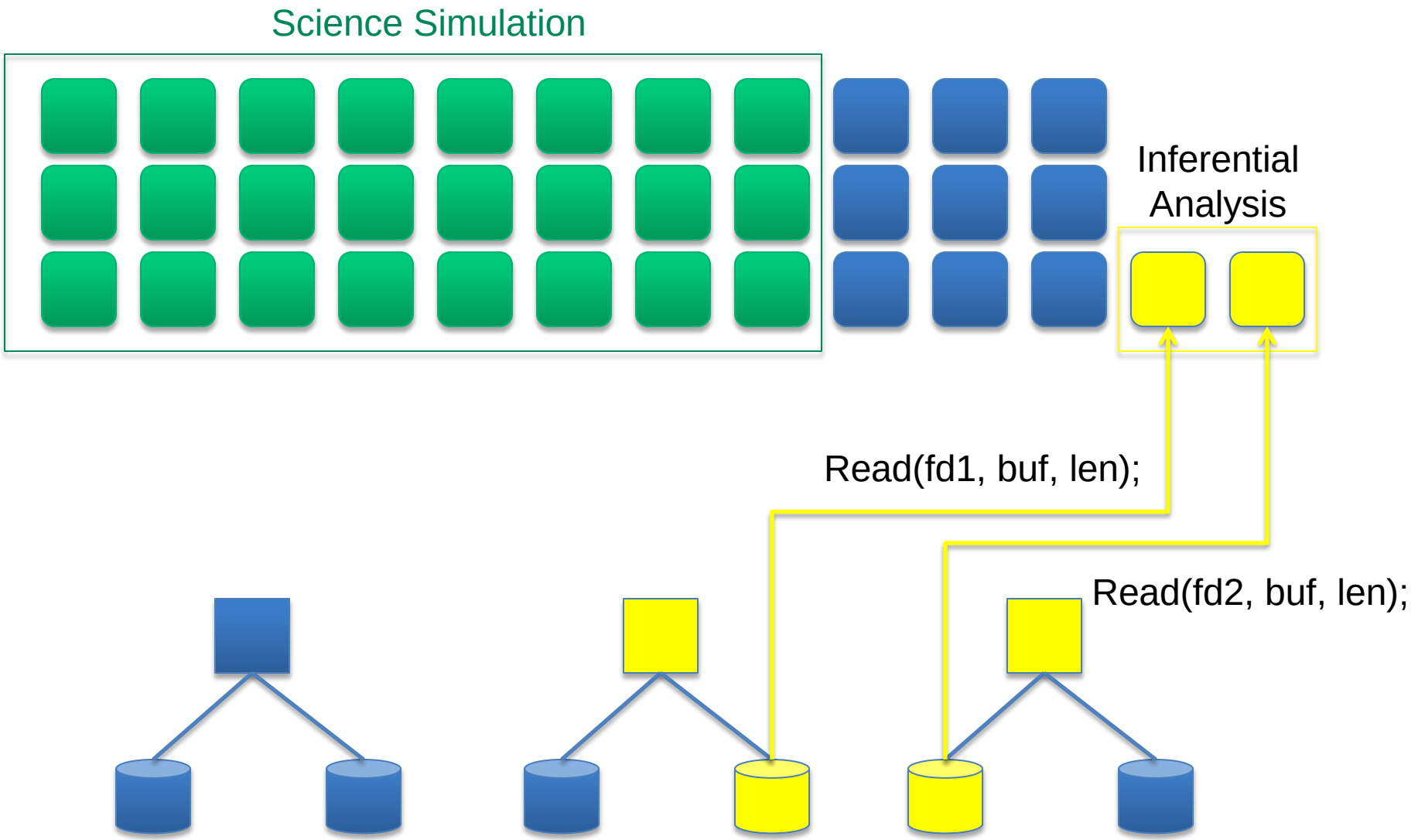

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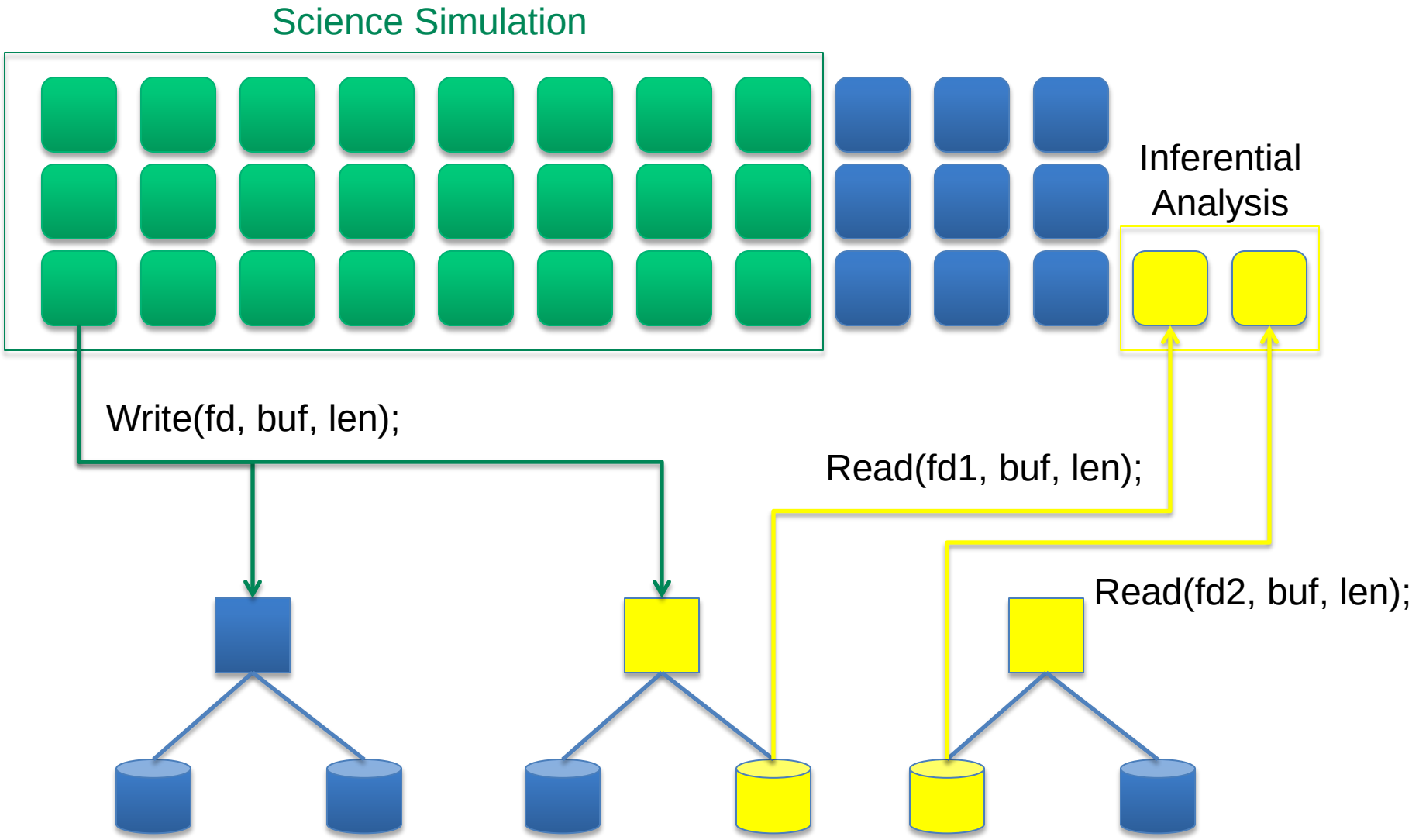

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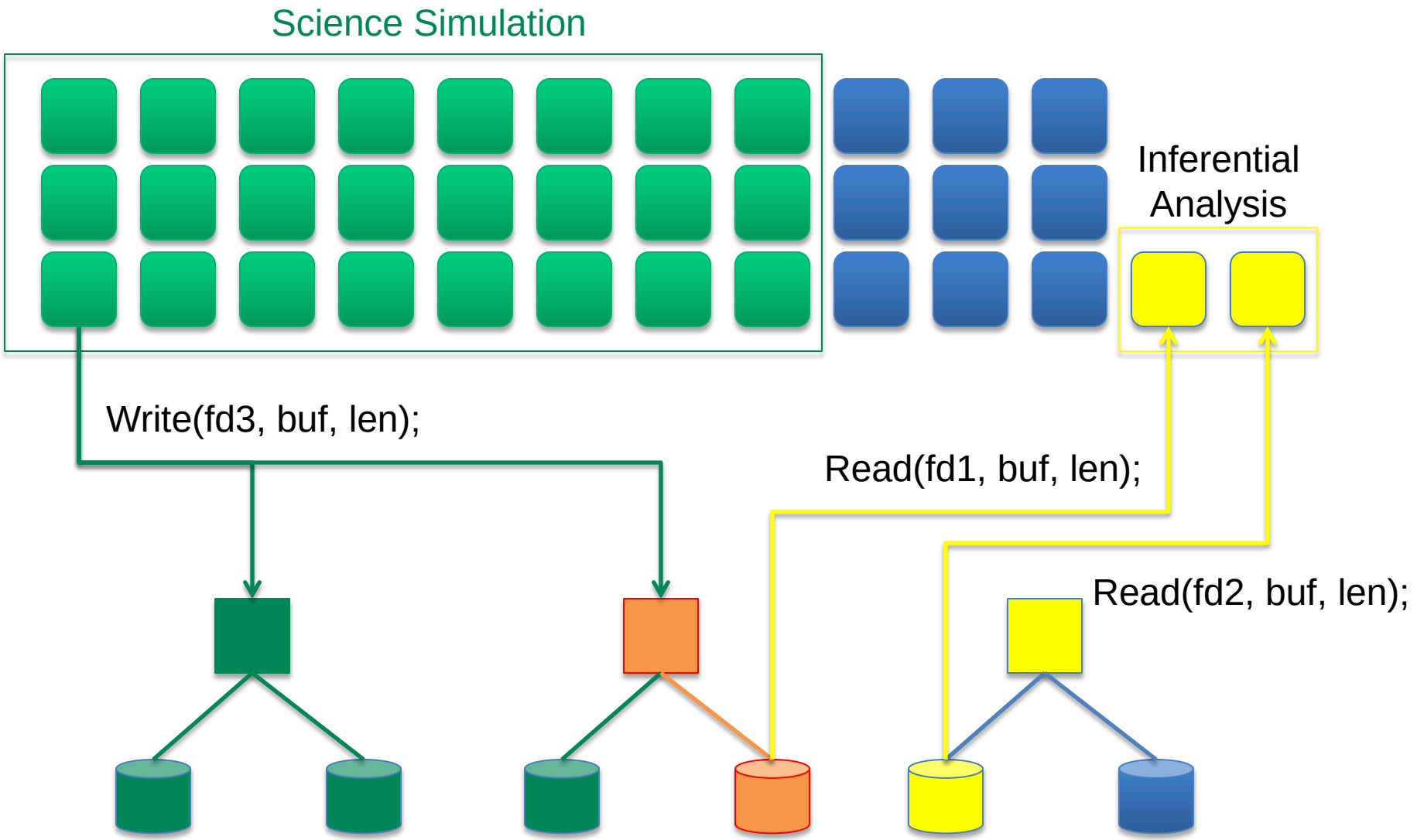

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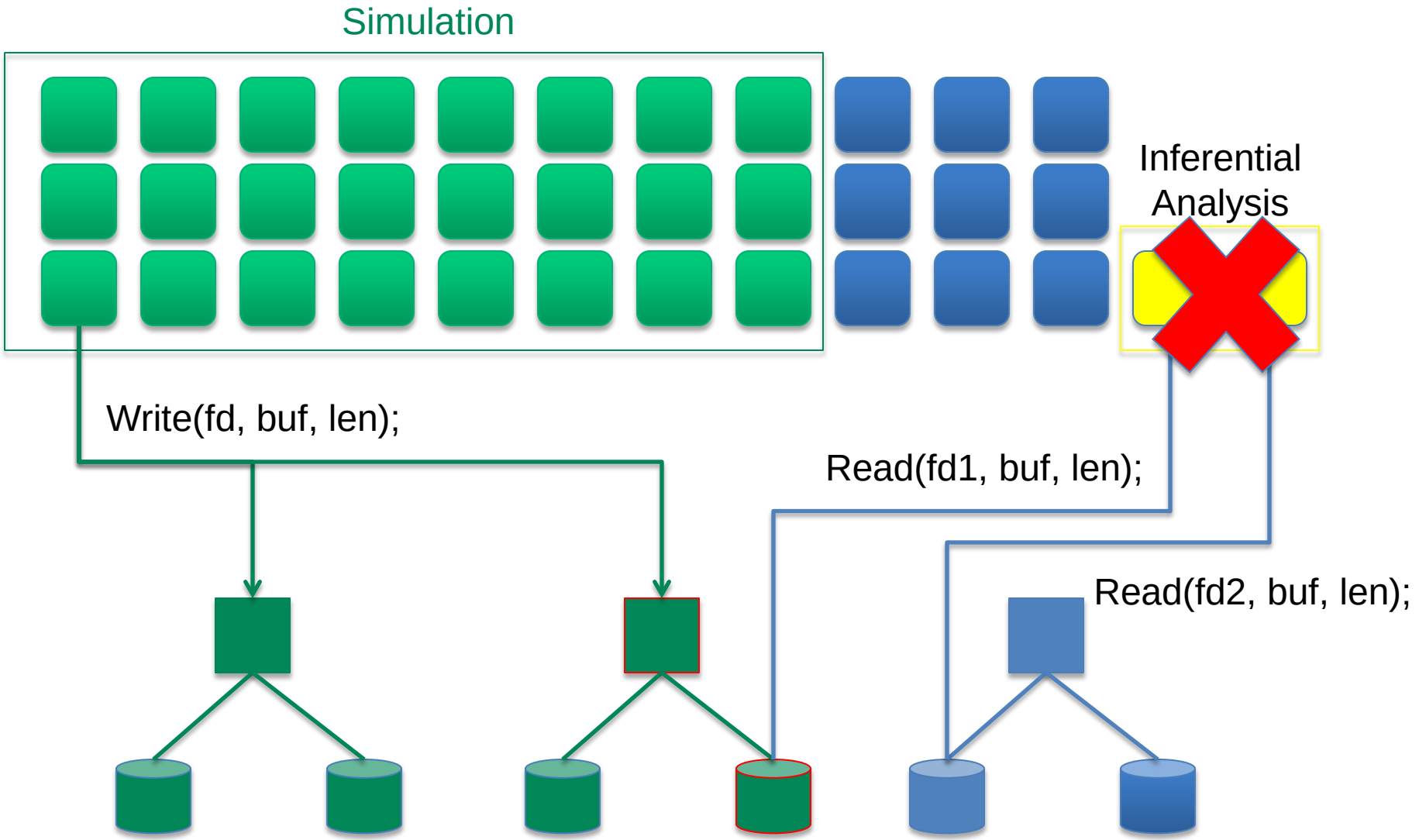
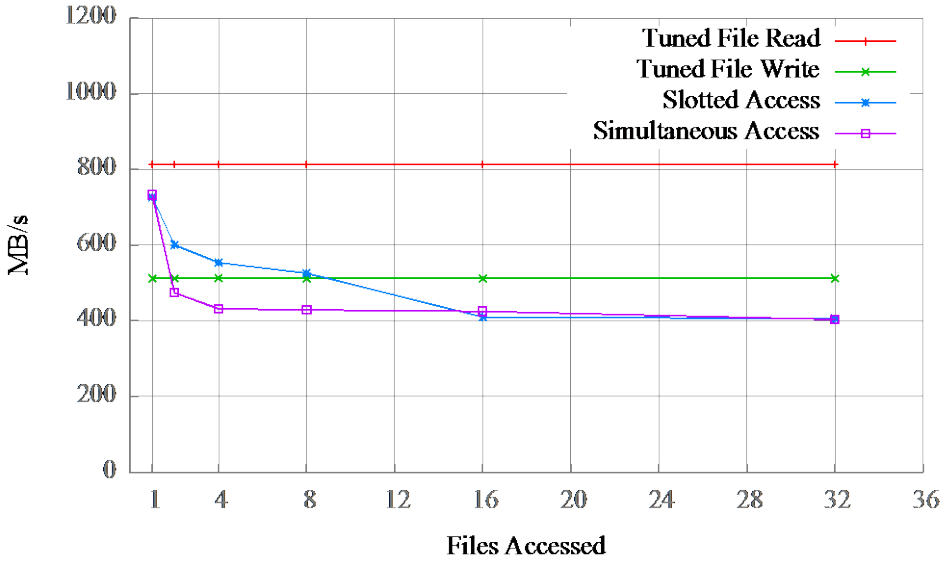
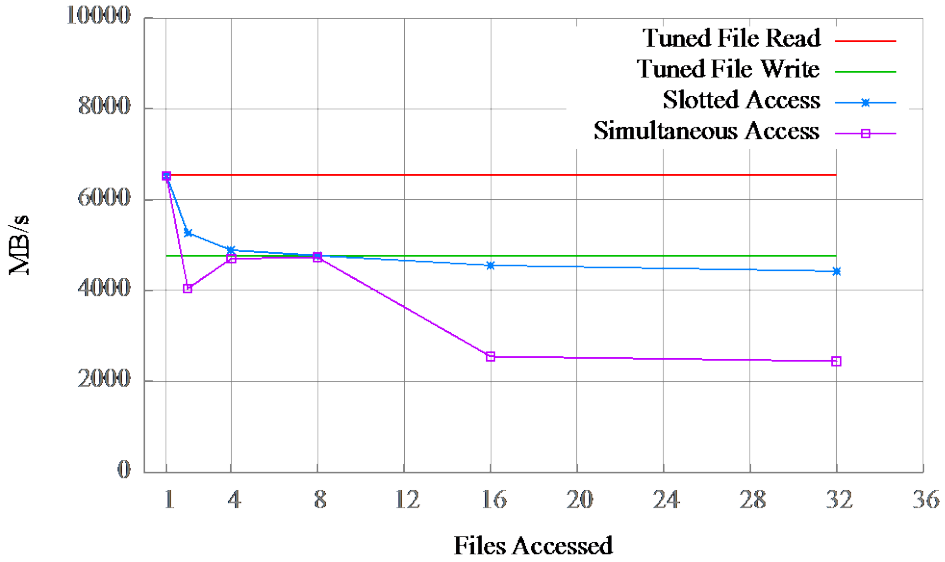


I/O Interference Reality

- Why can't scientific applications just overlap computation with I/O?
  - A time-step based simulation doesn't checkpoint after every time-step, just after some time-steps
  - Next program state depends on previous program state
  - Significant memory pressure
  - Coordination across multiple compute nodes makes these problems worse rather than better
- Doesn't CFQ scheduling make this a non-issue?
  - The storage servers use the same PID
- Alternative solutions like ADIOS circumvent FS services

Read/Write I/O interference



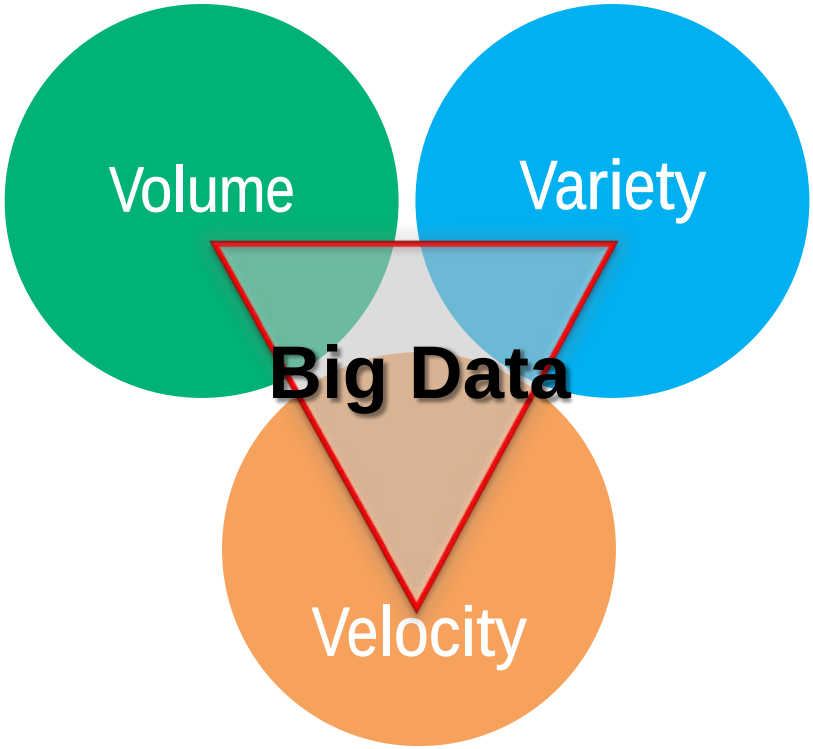


- Low-end storage array
- Simultaneous access falls off immediately

- High-end solid state storage (FusionIO Octal)
- Performance loss due to large queue depths

A Scalable Object Store

- HPC Storage + Analytics
- SOS Goals:
  1. 100% Asynchronous access
  2. Provide storage quality of service (QoS)
  3. Object resilience with multi-tiered storage
  4. In transit object data transformation

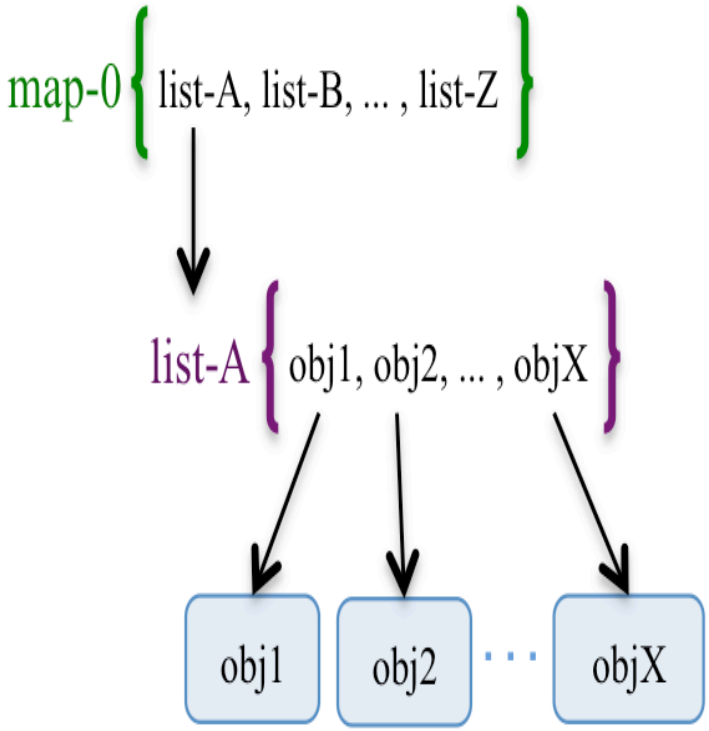


Quality of Service

- Two factors make QoS tractable:
  - SOS I/O is fundamentally async and server-directed
  - Object semantic takes away consistency between two clients writing to same store
- Lot's of existing work on how to do this for a single server with multiple clients
  - No magic, we just take a slotted approach to multiple access (like ALOHA)
  - Don't try to make it perfect, if an IOP runs past the end of the slot, complete it anyway
- Clients request QoS via reservations
  - Similar to network RSVP protocols

SOS Prototype Data Organization Model

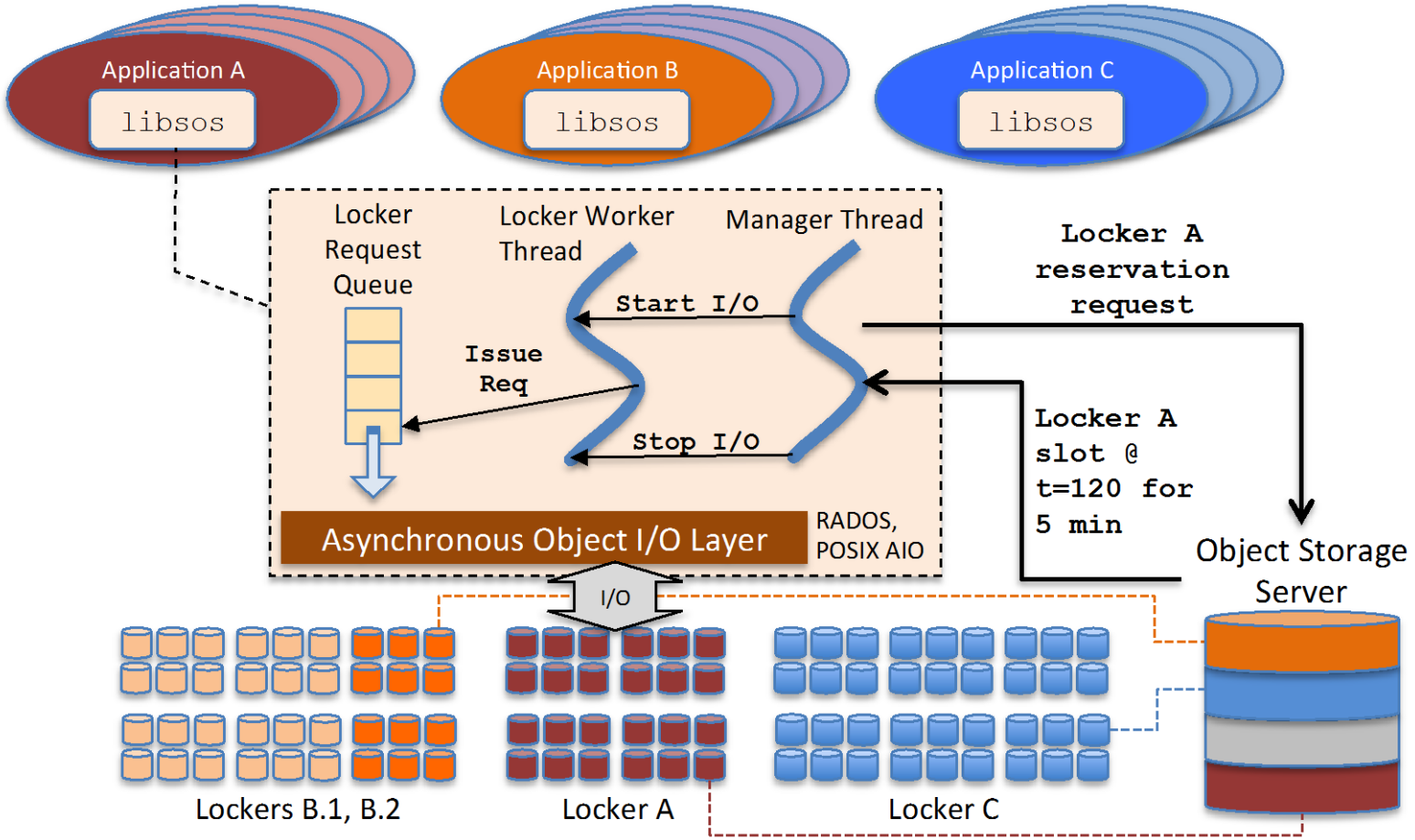
- Objects
  - Named data buffers
- Object Collections
  - Lists – named collection of objects
  - Maps – named collections of lists
- Provides naming hierarchy, that we believe is compatible with use cases



SOS Prototype Storage Organization Model

- Object Lockers
  - A dynamically provisioned allocation of storage resources
  - Provides opaque private namespace
  - Returned via a reservation request
  - Lockers provide the QoS scheme
- Prototype implementation is based on Ceph
  - Lockers provided by RADOS pools
  - Asynchronous Object Placement with CRUSH is weird
  - Leverage the lessons of POSIX AIO and Linux AIO

SOS Prototype



Ongoing work

- Server-directed object placement
  - Ceph uses CRUSH which is client directed placement
  - Exploring organizing locker's out of Chord Rings
- Scalable reservation protocols
  - Currently dedicating a server interval slot to handling reservations
  - Simply dropping reservation requests when a reservation for a new locker cannot be satisfied
  - Reservations acquired in order for existing lockers (to avoid dining philosophers problem)
  - Fault tolerant runtimes are still rare

Future Use Cases

- Scalable Fault Tolerance Backplane (for runtimes)
  - Storage systems are and should continue to be far more reliable than large compute resources
- Visualization and performance traces
  - Tricky because these are user-guided, and performance is dominated by small, unaligned data access
- Key-value support
  - Important to whole classes of Cloud applications
  - E.g. HTTP Session Data

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Thanks!

Questions?

Asynchronous I/O Interfaces

- HPC networks moving steadily toward asynchrony simply to support scale
- Many existing asynchronous I/O API's problematic
- The only exception I am aware of is Linux AIO
  - Has proven very useful in scenarios such as FS scan
  - Effective because it improves disk access performance!
- SOS attempts to build on lessons of Linux AIO
  - HPC networks likely natively async
  - Improve disk performance via server-directed I/O
  - Improve client predictability QoS