SPIDER II

OLCF's next-generation Spider file system

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Open Scalable File Systems, Inc.

EOFS European Open File System

20 Years of Excellence in Computational Science
OLCF Oak Ridge Leadership Computing Facility 1992–2012

U.S. DEPARTMENT OF ENERGY | Office of Science

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Spider at OLCF

- Deployed in 2008
  - 240 GB/s, 10 PB, proudly served more than 26,000 clients
  - 4 MDS, 192 OSS, and 1,344 OSTs
  - Center-wide, shared resource, scratch space for OLCF users/projects
  - Jaguar was the main consumer
    - >18,000 clients, ~2 PFLOPS, 300 TB main memory

Plans to upgrade Jaguar started early on, in-parallel with Spider II plans

Motivations for Spider

- Single shared storage pool
  - For all OLCF resources
- Aggregate performance and scalability
  - For all OLCF resources
- Resilience against system failures
  - internal to the storage system as well as failures of any computational resources
- Allow growth of the storage pool
  - independent of the computational platforms

Spider met all of these requirements!

All valid for next-generation Spider as well!

Titan at OLCF

- Jaguar upgrade
  - Still in acceptance
  - A magnitude higher in compute power compared to Jaguar
    - 200 cabinets, 18,688 nodes, 27 PFLOPs, 18,688 NVIDIA Kepler GPUs
  - Doubled in memory size
    - 600 TB scalar, 710 TB total (including GPUs)
  - Increased I/O requirements
    - Bandwidth and capacity

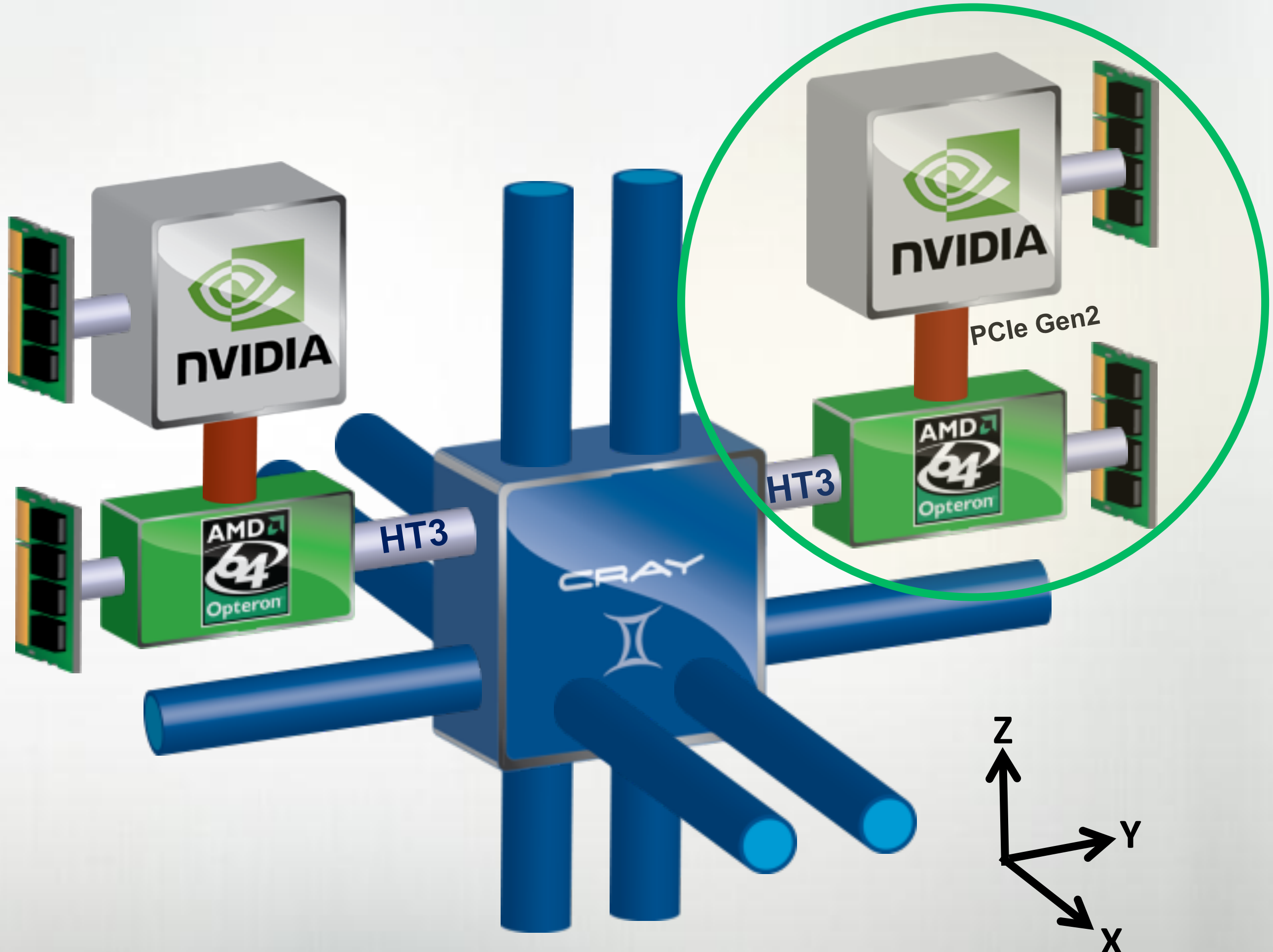
Replacing Spider I was more cost effective

Increased I/O requirements

Increasing maintenance costs

Cray XK7 Compute Node

XK7 Compute Node
AMD Opteron 6274 16 core processor @ 141 GF
Tesla K20x @ 1311 GF
Host Memory 32GB 1600 MHz DDR3
Tesla K20x Memory 6GB GDDR5
Gemini High Speed Interconnect

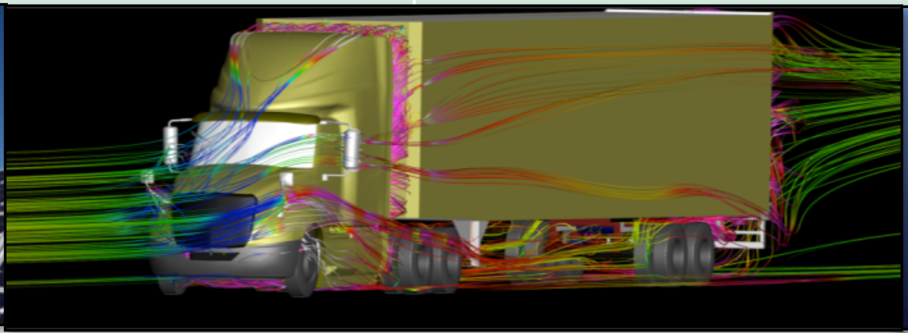
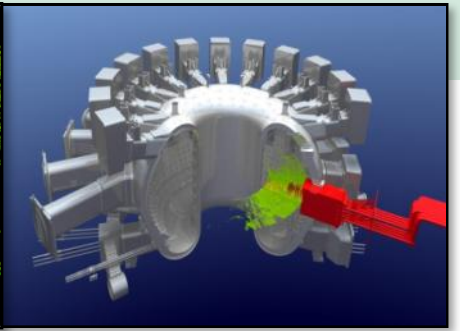


Slide courtesy of Cray, Inc.

Titan System Goals

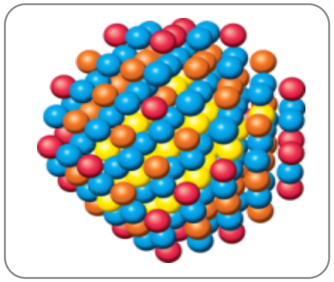
Deliver breakthrough science for DOE, industry, and the nation

Energy	Science & Innovation
Transform the nation's energy system and secure U.S. leadership in clean energy technologies	**Maintain a vibrant U.S. effort in science and engineering**
▪ Renewable Energy ▪ Nuclear Energy ▪ Electricity Grid ▪ Fossil Fuels	▪ Science & Technology ▪ Innovation ▪ Energy Sources, Usage, and Efficiency ▪ Science Education

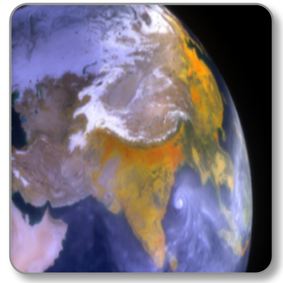




Accomplishing these missions requires the power of Titan

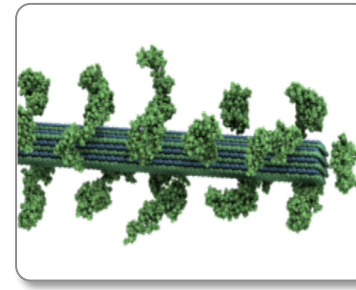
Early Science Applications on Titan



Material Science (WL-LSMS)
Role of material disorder, statistics, and fluctuations in nanoscale materials and systems.

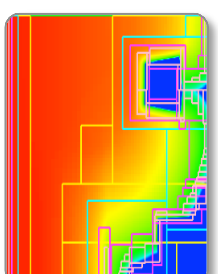


Climate Change (CAM-SE)
Answer questions about specific climate change adaptation and mitigation scenarios; realistically represent features like precipitation patterns/ statistics and tropical storms.

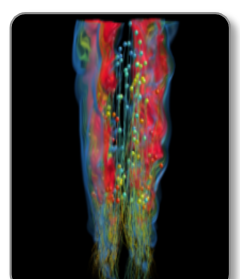


Biofuels (LAMMPS)
A multiple capability molecular dynamics code.

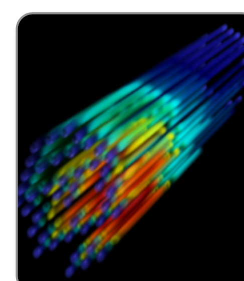
Astrophysics (NRDF)
AMR Radiation transport – critical to astrophysics, laser fusion, combustion, atmospheric dynamics, and medical imaging.



Combustion (S3D)
Combustion simulations to enable the next generation of diesel/bio- fuels to burn more efficiently.



Nuclear Energy (Denovo)
Unprecedented high-fidelity radiation transport calculations that can be used in a variety of nuclear energy and technology applications.



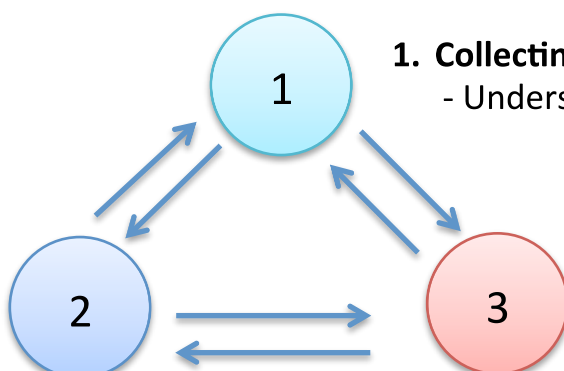
Upgrading Spider

- Efforts started in late 2009
  - Right after Spider was deployed
  - It was a marathon, not a sprint
    - Perhaps decathlon would be a better term

Completed Efforts	On-going or Pending Efforts
Understanding Spider Evaluating storage technologies and solutions Writing and releasing the RFP Evaluation of the responses	Deployment and installation Acceptance Integration Commissioning Production

Understanding Spider – pre RFP

- Learned more about Spider and our production environment
  – *"Lessons Learned in Deploying the World's Largest Scale Lustre File System,"* CUG'10
  – *"Workload characterization of a leadership class storage,"* PDSW'10
  – *"Monitoring tools for large scale systems,"* CUG' 10
  – *"I/O congestion avoidance via routing and object placement,"* CUG'11
- Summarized findings and our comprehensive understanding
  – *"A Next-Generation Parallel File System Environment for the OLCF*, CUG'12



1. Collecting requirements
- Understand I/O demands

2. Design
- Architect and build storage system

3. Validation
Operation, maintenance (performance efficiency, capacity utilization)

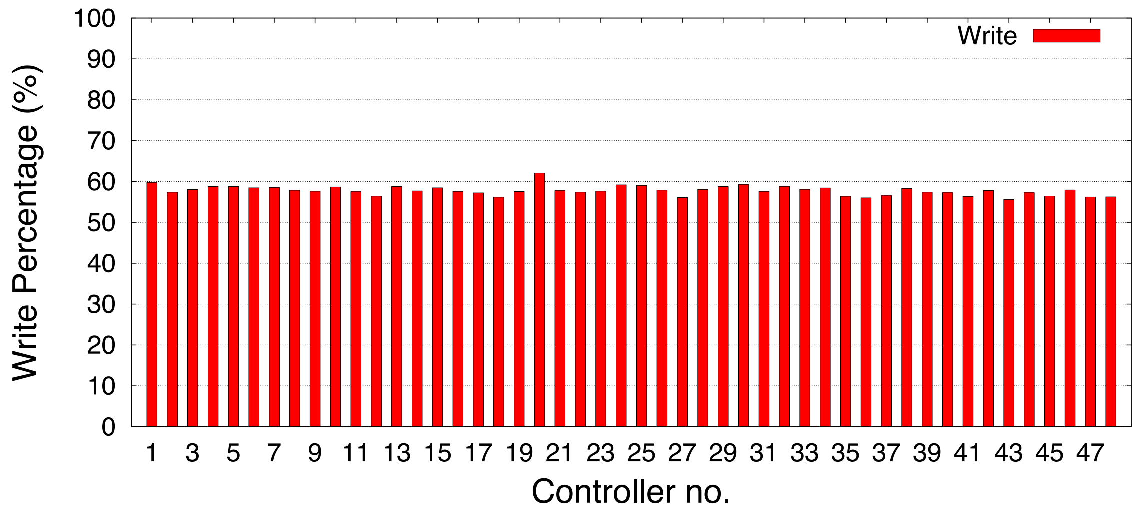
Understanding Spider – pre RFP

Congestion is real and present!

Avoidable up to a certain degree
30% performance increase

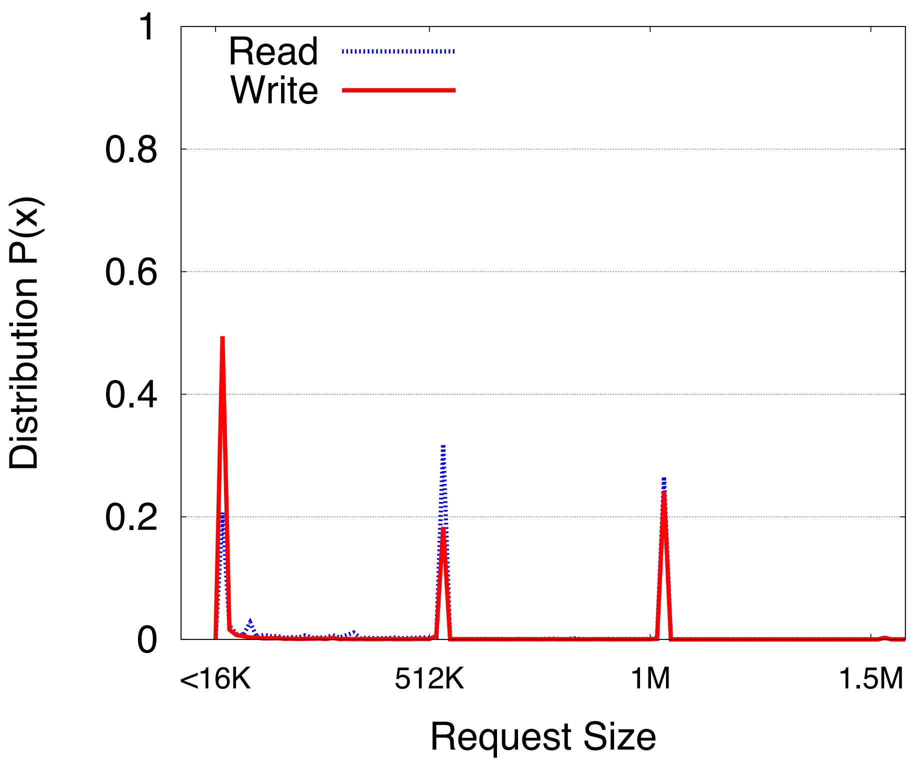
42% read I/O workload!

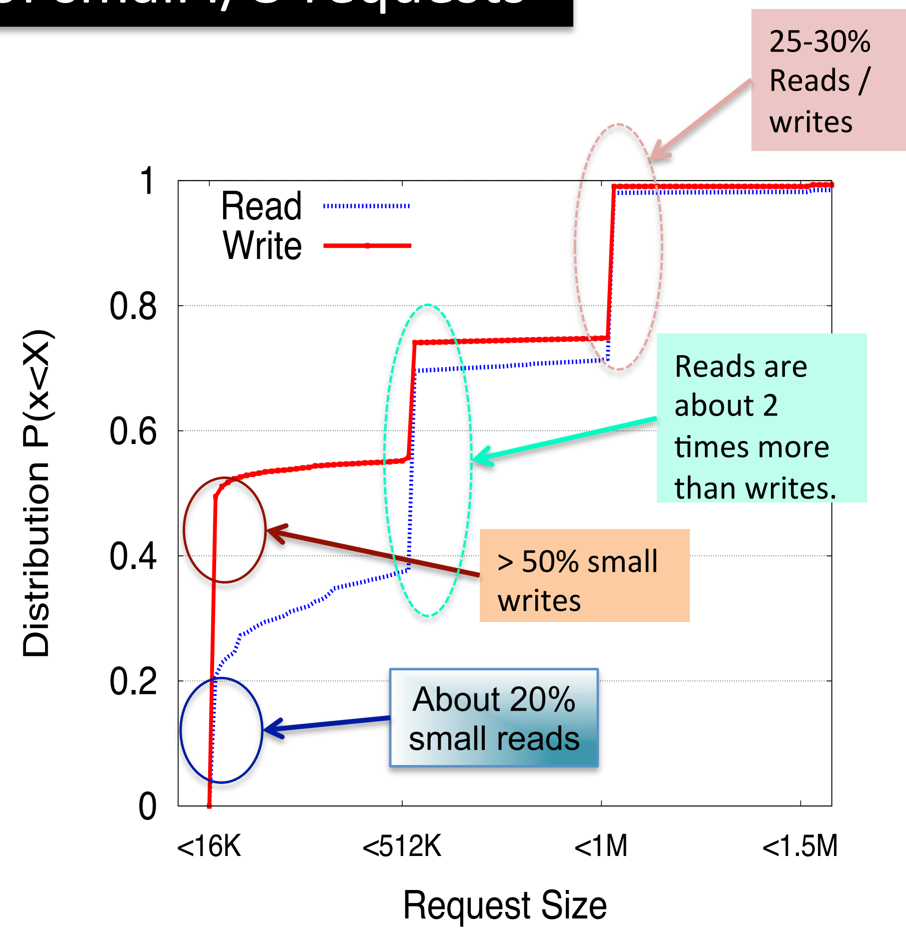
Contrary to our beliefs



Understanding Spider – pre RFP

Substantial amount of small I/O requests





Evaluation Efforts – pre RFP

Evaluation Efforts – pre RFP

- A new benchmark suite developed
  - Block-level
    - Wrapper around fair-lio
    - Based on the *libaio* libraries
  - Lustre-level
    - Wrapper around obdfilter-survey
  - Catalogues and stores results, plots them with gnuplot
  - Released to public in 2010
  - Received positive feedback

Evaluation Efforts – pre RFP

- A new storage evaluation testbed was established
  - Testing solutions before they were GA
  - Evaluated
    - Embedded or integrated solutions
    - Block solutions
    - Host-to-storage network technologies
    - Host-to-compute network technologies

- Visited another site for more experience on a missing technology

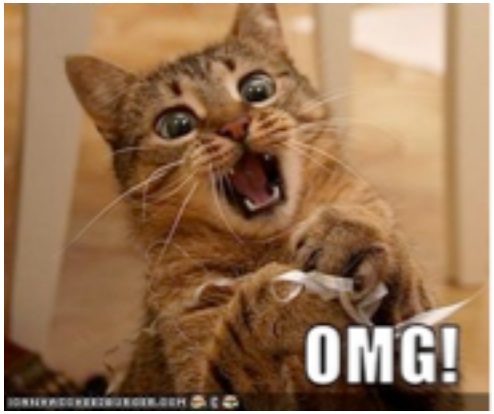
Writing and releasing the RFP

- RFP process started in Fall of 2010
  - Gathering requirements, document writing
- Encountered some setbacks
  - Thailand flooding in July 2011 caused disk prices to spike
  - Had to wait until prices settled down
  - Budget sensitivity and continued disk price elevation near end of FY2012 caused delay into FY2013

RFP released November 2012 and responses were due December 2012

Writing and releasing the RFP

- Requirements
  - Both block-level and Integrated Lustre appliances were allowed
  - 1.2 TB/s block-level performance
    - Sequential writes and reads
  - 1.0 TB/s Lustre-level performance
    - Nice and well aligned writes and reads
  - 240 GB/s block-level random writes and reads
  - Minimum of 18 PB storage (after RAID)
  - SAS or IB FDR host-to-storage connectivity
  - Parity check on read
  - Performance under rebuild, etc



Evaluation of the Responses

- Data Direct Networks' proposal was selected
- Final Negotiated system

Scalable Storage System

36 SFA12K40 Infiniband FDR
10 60-disk enclosures per couplet
560 2 TB NL SAS drives per couplet
20,160 drives
32 PB capacity (after RAID)
> 1 TB/s aggregate performance

Test and Development System

1 SFA12K40 Infiniband FDR
5 60-disk enclosure
280 2 TB NL SAS drives

SPIDER II

THE WORLD'S FASTEST FILE SYSTEM

Facts

32 PB capacity (after RAID)

> 1 TB/s aggregate performance

288 Lustre OSS total

8 OSS per couplet

4 MDS and 2 MGS

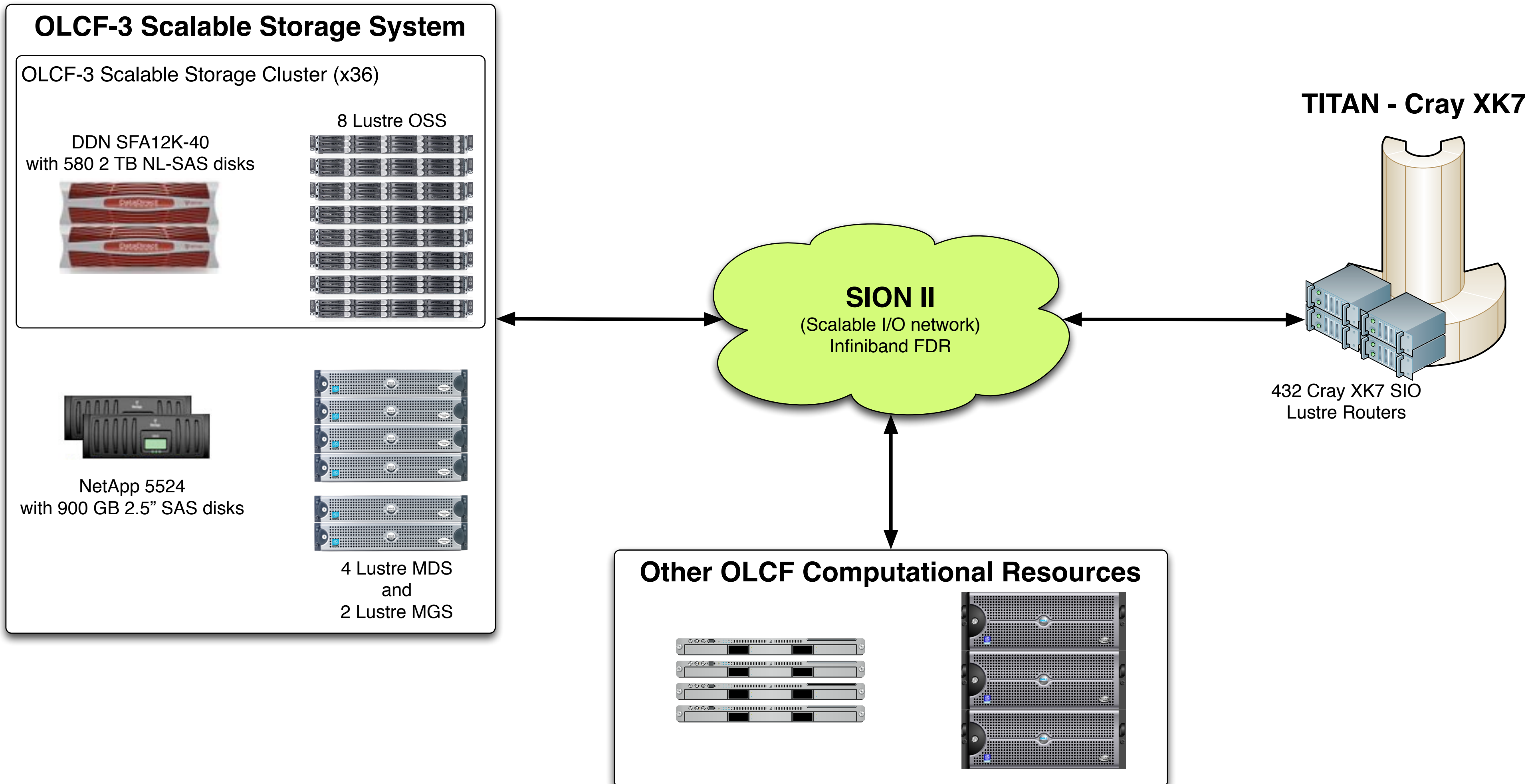
Configured in 4 rows

2x 108-port Core FDR IB switches

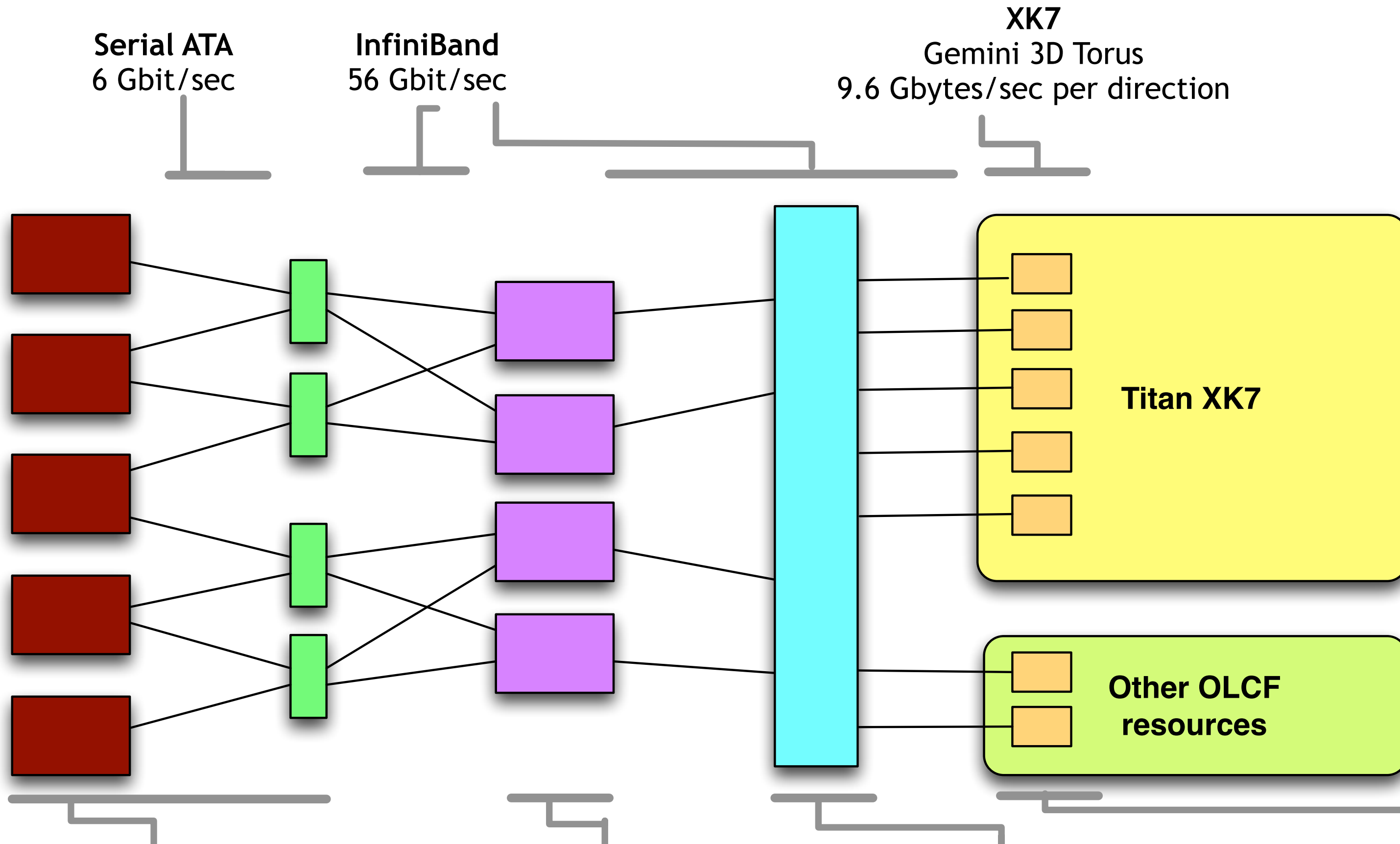
36x 36-port FDR IB switches

432 Lustre Titan LNET routers

Spider II Architecture



Spider II Architecture



Enterprise Storage
controllers and large racks of disks are connected via InfiniBand.

36 DataDirect SFA12K-40 controller pairs with 2 Tbyte NL- SAS drives and 8 InifiniBand FDR connections per pair

Storage Nodes
run parallel file system software and manage incoming FS traffic.

288 Dell PowerConnect 5548 servers with 64 GB of RAM each

SION II Network
provides connectivity between OLCF resources and primarily carries storage traffic.

1600 ports, 56 Gbit/sec InfiniBand switch complex

Lustre Router Nodes
run parallel file system client software and forward I/O operations from HPC clients.

432 XK7 SIO nodes configured as Lustre routers on Titan

What are we delivering to users?

- > 1 TB/s Lustre scratch space
  - Based on Lustre 2.4
    - Latest maintenance branch
    - Includes features we want and require
      - Large stripe count
      - Distributed Namespace (DNE)
      - Metadata performance improvements
      - Imperative recovery (IR)
  - Will not be using DNE to start
    - Planning ahead to allow for this feature in the future

Integration efforts

- Lustre 2.4 testing
  - Small-scale
    - Round the clock testing for stability, regression, and performance on a single cabinet Cray XK7 (Arthur)
    - Home built Cray Lustre 2.4 client as well as servers
    - Early detection and correction of problems and bugs
  - Large-scale
    - Monthly testing of small-scale tested code drops on Titan
    - Did three tests and four more to go
    - Identified some number of problems at scale
    - Partnership with Cray
- IB FDR testing on Cray
  - Cray and Mellanox

Schedule

- System infrastructure delivery
  - Completed
- Block storage delivery
  - Started in late March and will end in early May
- Release an RFP for Lustre Support by end of April
  - Level 1, 2, and 3 support. Contact besancenezwr@ornl.gov.
- Block acceptance
  - Starts after storage and infrastructure are installed
  - To be completed by May 31
- Complete file system integration by late August
- Commission the system by September


Networks
DataDirect Networks

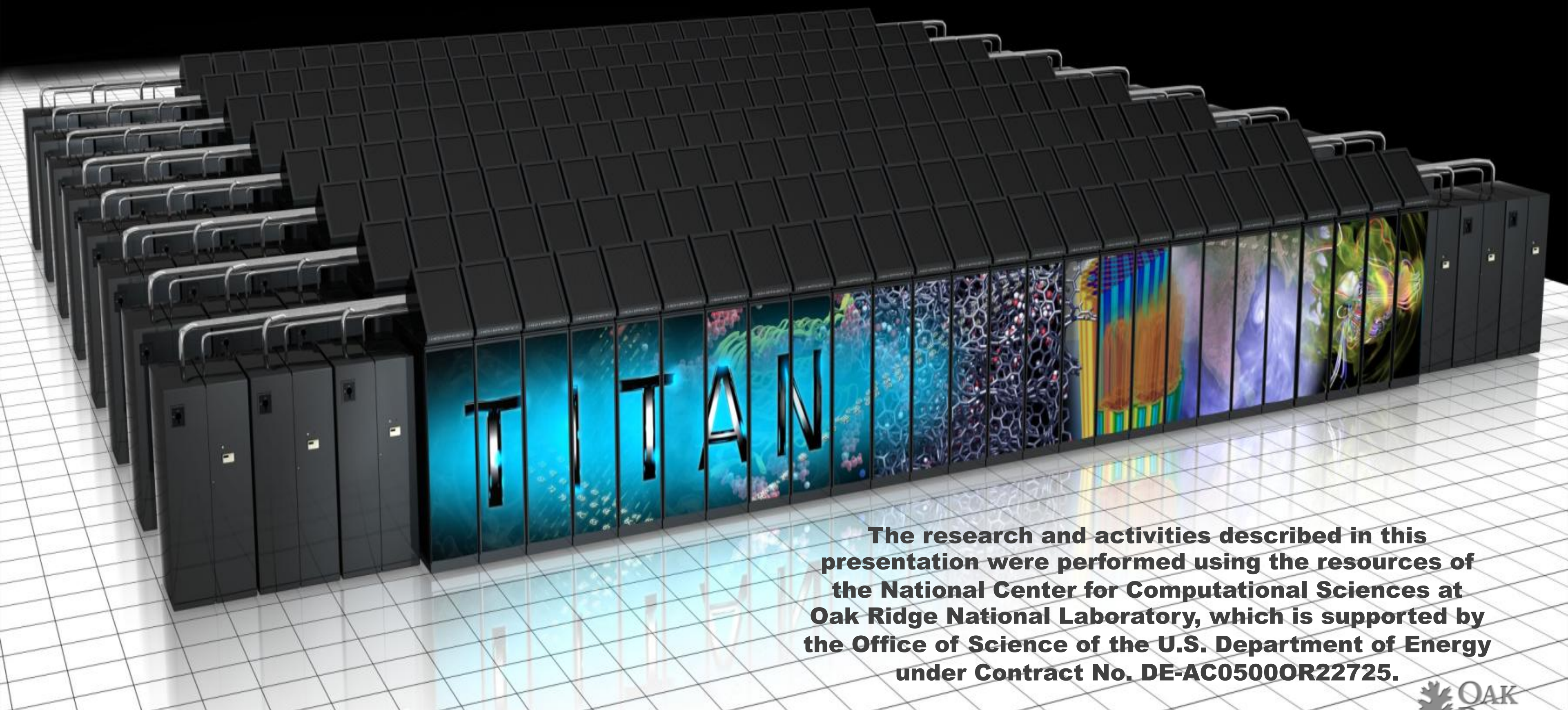

Lustre File System – Spider


DataDirect Networks

Questions?

oralhs@ornl.gov

**Want to join our team?
ORNL is hiring. Contact us at
http://jobs.ornl.gov**



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