Summit Architecture Overview

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ORNL Summit System Overview

System Performance

- Peak of 200 Petaflops (FP_{64}) for modeling & simulation
- Peak of 3.3 ExaOps (FP_{16}) for data analytics and artificial intelligence

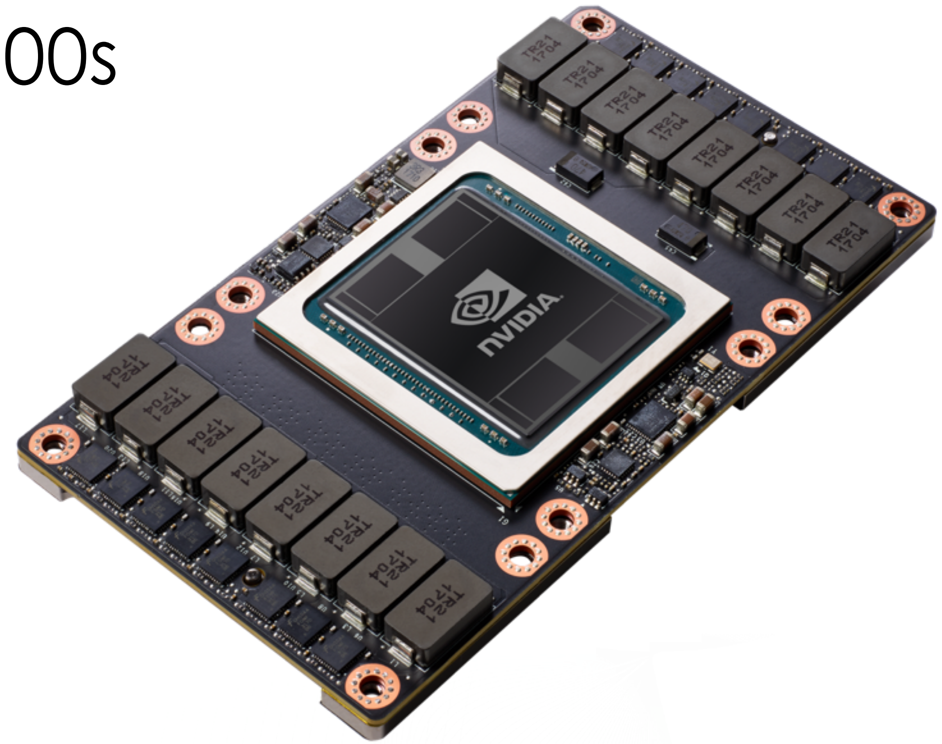
The system includes

- 4,608 nodes
- Dual-port Mellanox EDR InfiniBand network
- 250 PB IBM file system transferring data at 2.5 TB/s

Each node has

- 2 IBM POWER9 processors
- 6 NVIDIA Tesla V100 GPUs
- 608 GB of fast memory
  (96 GB HBM2 + 512 GB DDR4)
- 1.6 TB of NV memory

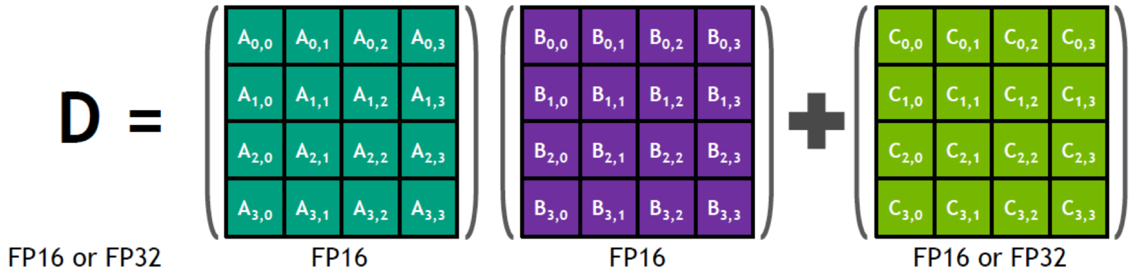
Summit Contains 27,648 NVIDIA Tesla v100s



Each Tesla v100 GPU has:

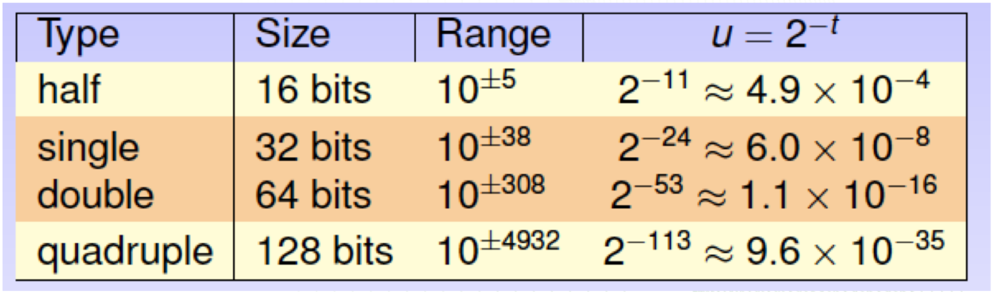
- 150+150 GB/s total BW (NVLink v2.0)
- 5,120 CUDA cores (64 on each of 80 SMs)
- 640 Tensor cores (8 on each of 80 SMs)
- 20MB Registers | 16MB Cache | 16GB HBM2 @ 900 GB/s
- 7.5 DP TFLOPS | 15 SP TFLOPS | 120 FP_{16} TFLOPS

- Tensor cores do mixed precision multiply-add of 4x4



$$D = \begin{pmatrix} A_{0,0} & A_{0,1} & A_{0,2} & A_{0,3} \\ A_{1,0} & A_{1,1} & A_{1,2} & A_{1,3} \\ A_{2,0} & A_{2,1} & A_{2,2} & A_{2,3} \\ A_{3,0} & A_{3,1} & A_{3,2} & A_{3,3} \end{pmatrix} \begin{pmatrix} B_{0,0} & B_{0,1} & B_{0,2} & B_{0,3} \\ B_{1,0} & B_{1,1} & B_{1,2} & B_{1,3} \\ B_{2,0} & B_{2,1} & B_{2,2} & B_{2,3} \\ B_{3,0} & B_{3,1} & B_{3,2} & B_{3,3} \end{pmatrix} + \begin{pmatrix} C_{0,0} & C_{0,1} & C_{0,2} & C_{0,3} \\ C_{1,0} & C_{1,1} & C_{1,2} & C_{1,3} \\ C_{2,0} & C_{2,1} & C_{2,2} & C_{2,3} \\ C_{3,0} & C_{3,1} & C_{3,2} & C_{3,3} \end{pmatrix}$$

$$D = AB + C$$



Type	Size	Range	$u = 2^{-t}$
half	16 bits	$10^{\pm 5}$	$2^{-11} \approx 4.9 \times 10^{-4}$
single	32 bits	$10^{\pm 38}$	$2^{-24} \approx 6.0 \times 10^{-8}$
double	64 bits	$10^{\pm 308}$	$2^{-53} \approx 1.1 \times 10^{-16}$
quadruple	128 bits	$10^{\pm 4932}$	$2^{-113} \approx 9.6 \times 10^{-35}$

- The M&S community must figure how out to better utilize mixed / reduced precisions
- Eg: Possible to achieve 4x FP64 peak for 64bit LU on V100 with iterative mixed precision (Dongarra et al.)

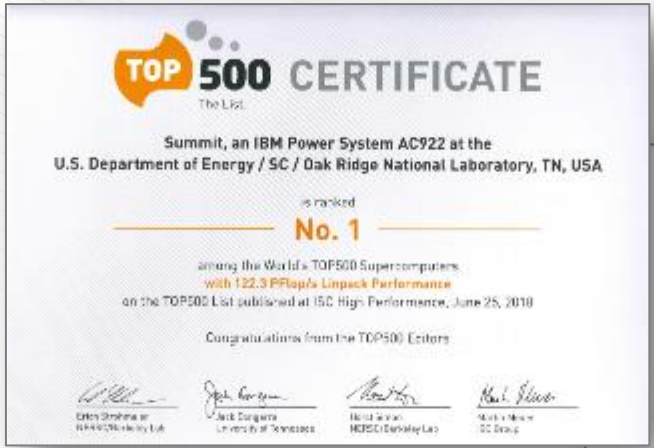
Supercomputer Specialization vs ORNL Summit

- As supercomputers got larger and larger, we expected them to be more specialized and limited to just a small number of applications that can exploit their growing scale

- Summit's architecture seems to have stumbled into a sweet spot that has broad capability across:
  - Traditional HPC modeling and simulation
  - High performance data analytics
  - Artificial Intelligence

In 2018 Summit Demonstrated Its Balanced Design

Achieves #1 on TOP500, #1 on HPCG, #1 Green500, and #1 on I/O 500



TOP 500 CERTIFICATE

The List

Summit, an IBM Power System AC922 at the
U.S. Department of Energy / SC / Oak Ridge National Laboratory, TN, USA

is ranked

No. 1

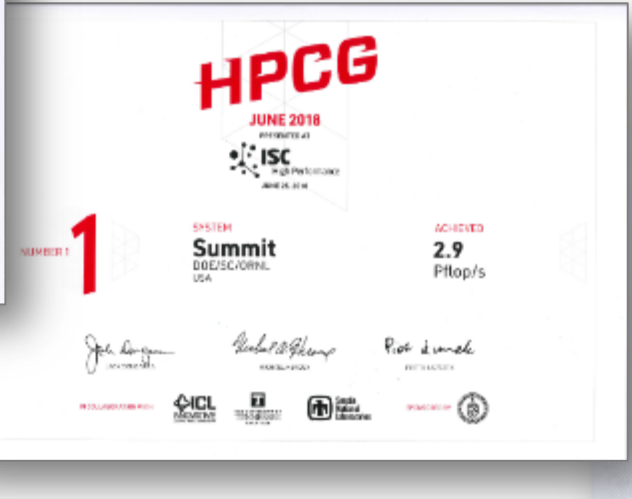
among the World's TOP500 Supercomputers
with 122.3 PFlop/s Linpack Performance
on the TOP500 List published at ISC High Performance, June 25, 2018

Congratulations from the TOP500 Editors

Erich Strohmaier, NERSC/Berkeley Lab — Jack Dongarra, University of Tennessee — Horst Simon, NERSC/Berkeley Lab — Martin Meuer, ISC Group

122 PF HPL
#1 raw performance

144 PF in Nov 2018



HPCG

JUNE 2018

ISC High Performance

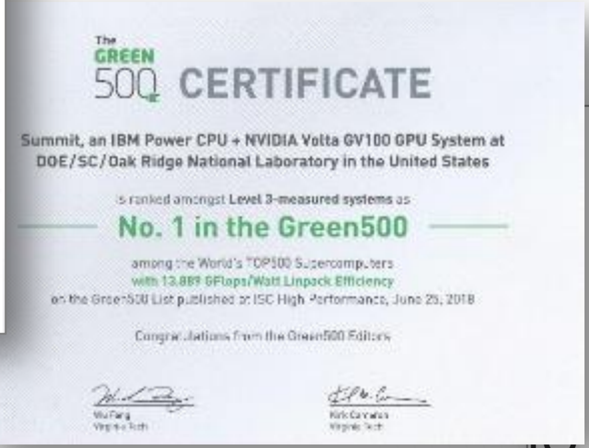
NUMBER 1

SYSTEM
Summit
DOE/SC/ORNL
USA

ACHIEVED
2.9
Pflop/s

ICL

2.9 PF HPCG
#1 fast data movement



The GREEN 500 CERTIFICATE

Summit, an IBM Power CPU + NVIDIA Volta GV100 GPU System at
DOE/SC/Oak Ridge National Laboratory in the United States

is ranked amongst Level 3-measured systems as

No. 1 in the Green500

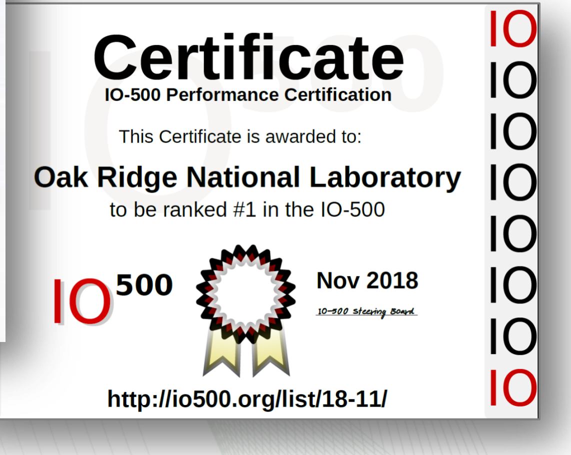
among the World's TOP500 Supercomputers
with 13.889 GFlops/Watt Linpack Efficiency
on the Green500 List published at ISC High Performance, June 25, 2018

Congratulations from the Green500 Editors

Wu Feng, Virginia Tech — Kirk Cameron, Virginia Tech

13.889 GF/W
#1 energy efficiency

14.668 GF/W Nov 2018



Certificate

IO-500 Performance Certification

This Certificate is awarded to:

Oak Ridge National Laboratory

to be ranked #1 in the IO-500

IO500

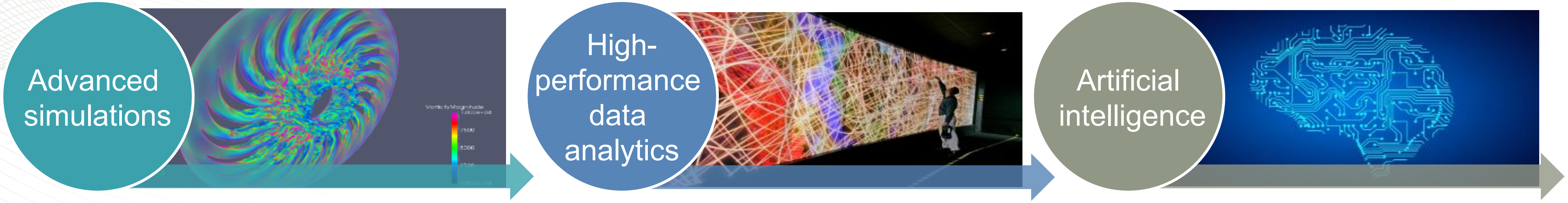
Nov 2018

IO-500 Steering Board

http://io500.org/list/18-11/

#1 HPC storage performance

Summit Excels Across Simulation, Analytics, AI



- Data analytics – CoMet bioinformatics application for comparative genomics. Used to find sets of genes that are related to a trait or disease in a population. Exploits cuBLAS and Volta tensor cores to solve this problem 5 orders of magnitude faster than previous state-of-art code.
  - **Has achieved 2.36 ExaOps** mixed precision (FP_{16}-FP_{32}) on Summit
- Deep Learning – global climate simulations use a half-precision version of the DeepLabv3+ neural network to learn to detecting extreme weather patterns in the output
  - **Has achieved a sustained throughput of 1.0 ExaOps (FP_{16})** on Summit
- Nonlinear dynamic low-order unstructured finite-element solver accelerated using mixed precision (FP_{16} thru FP_{64}) and AI generated preconditioner. Answer in FP_{64}
  - **Has achieved 25.3 fold speedup** on Japan earthquake – city structures simulation
- **Half-dozen Early Science codes are reporting >25x speedup on Summit vs Titan**

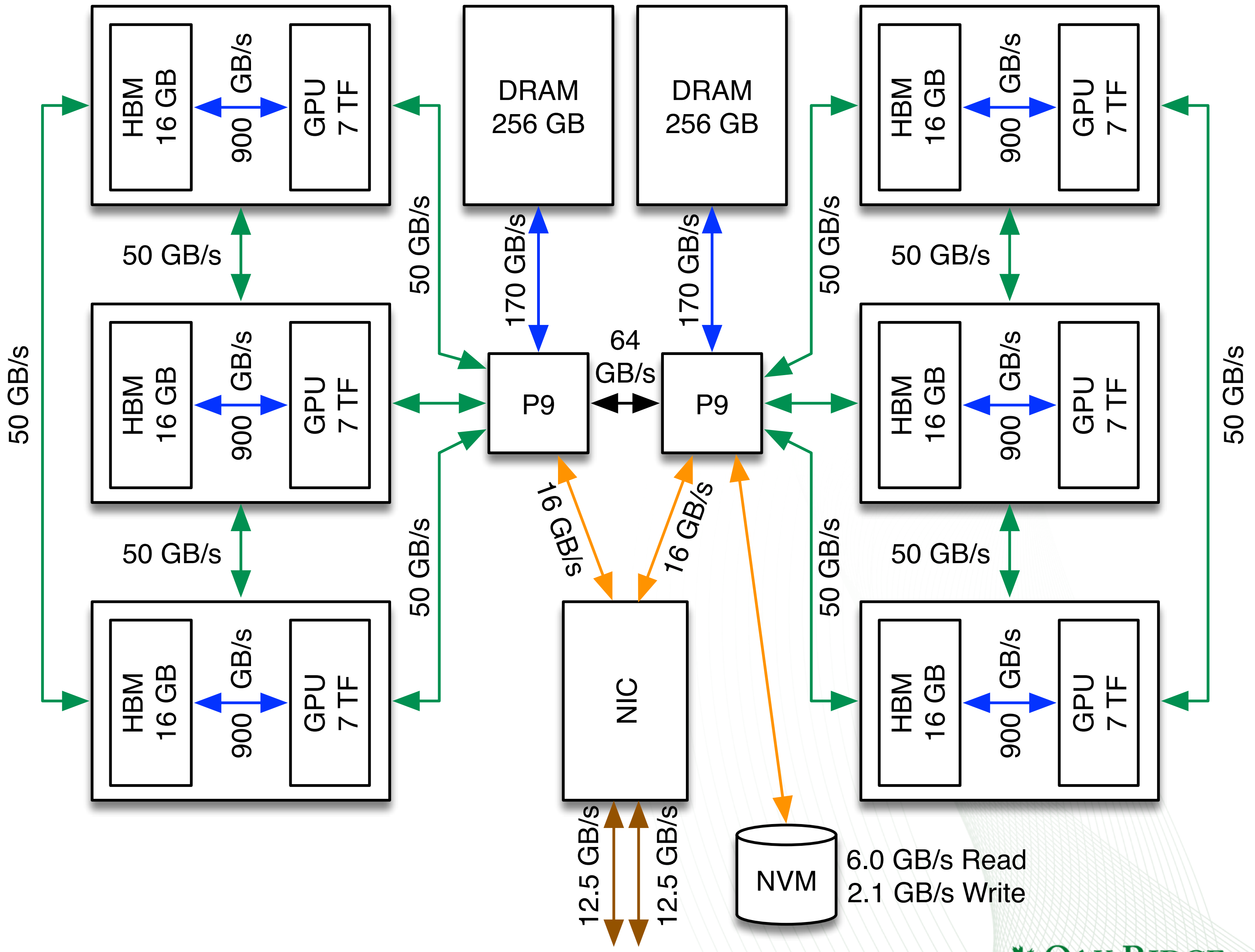
How is Summit Architecture different from Titan? ORNL’s leadership supercomputer

- Many fewer nodes
- Much more powerful nodes
- Much more memory per node and higher memory bandwidth
- Much higher bandwidth between CPUs and GPUs
- Faster interconnect
- Much larger and faster file system
- 7x more performance for only slightly more power (Summit’s 8.8 MW vs Titan’s 8.2)

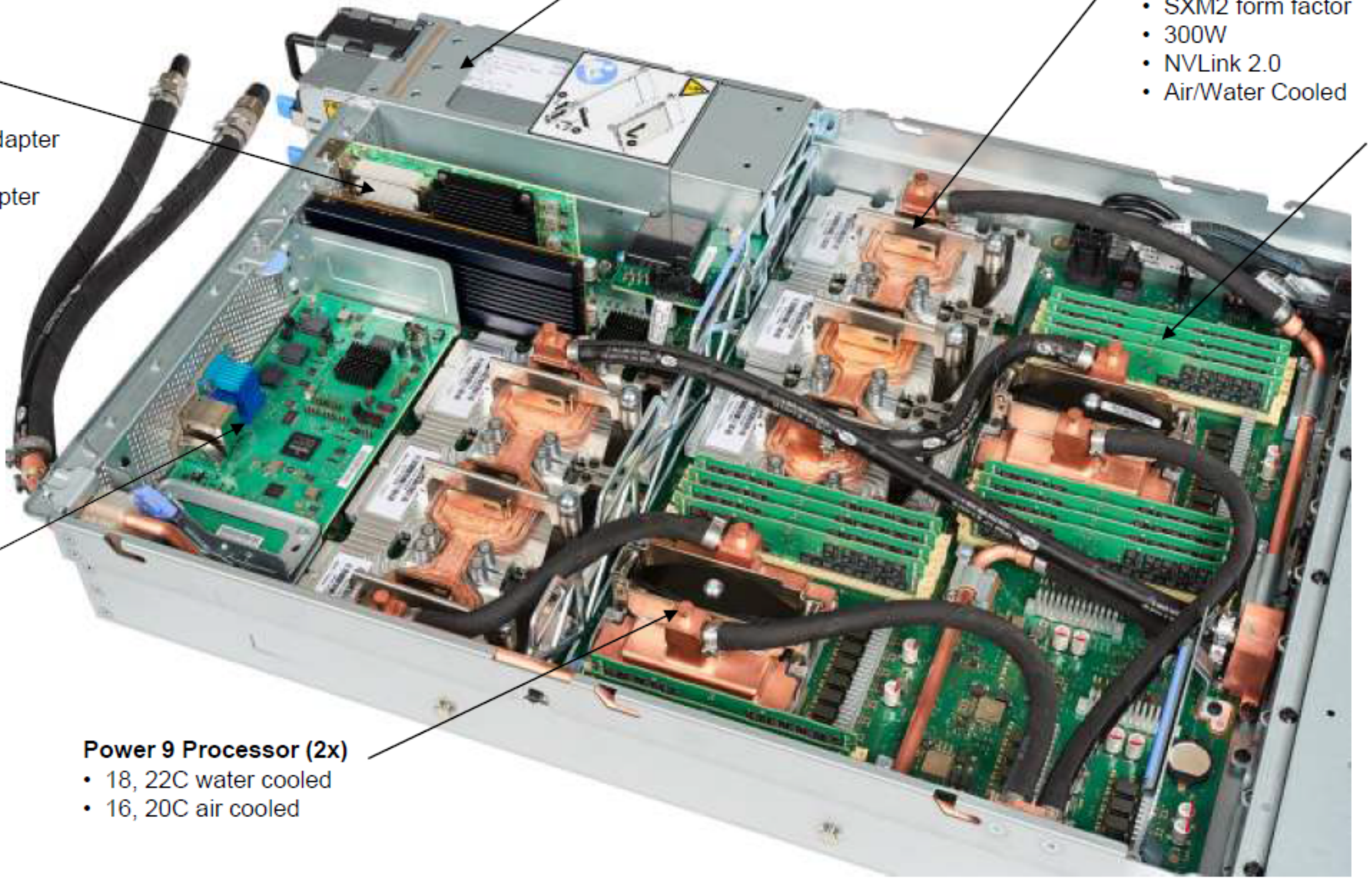
Feature	Titan	Summit
Peak FLOPS	27 PF	200 PF
Max possible Power	9 MW	13 MW
Number of Nodes	18,688	4,608
Node performance	1.4 TF	42 TF
Memory per Node	32 GB DDR3 + 6 GB GDDR5	512 GB DDR4 + 96 GB HBM2
NV memory per Node	0	1.6 TB
Total System Memory	0.7 PB	2.8 PB + 7.4 PB NVM
System Interconnect	Gemini (6.4 GB/s)	Dual Port EDR-IB (25 GB/s)
Interconnect Topology	3D Torus	Non-blocking Fat Tree
Bi-Section Bandwidth	15.6 TB/s	115.2 TB/s
Processors on node	1 AMD Opteron™ 1 NVIDIA Kepler™	2 IBM POWER9™ 6 NVIDIA Volta™
File System	32 PB, 1 TB/s, Lustre®	250 PB, 2.5 TB/s, GPFS™

Summit Node Schematic

- Coherent memory across entire node
- NVLink v2 fully interconnects three GPUs and one CPU on each side of node
- PCIe Gen 4 connects NVM and NIC
- Single shared NIC with dual EDR ports



Summit Board (1 node) showing the Water Cooling



Power Supplies (2x)
- 2200W
- 200VAC, 277VAC, 400VDC input

NVidia Volta GPU
- 3 per socket
- SXM2 form factor
- 300W
- NVLink 2.0
- Air/Water Cooled

PCIe slot (4x)
- Gen4 PCIe
- 2, x16 HHHL Adapter
- 1, Shared slot
- 1 x8 HHHL Adapter

Memory DIMM's (16x)
- 8 DDR4 IS DIMMs per socket
- 8, 16, 32,64, 128GB DIMMs

BMC Card
- IPMI
- 1 Gb Ethernet
- VGA
- 1 USB 3.0

Power 9 Processor (2x)
- 18, 22C water cooled
- 16, 20C air cooled

Questions?

Summit in Annex Bldg
Titan here
OAK RIDGE
National Laboratory