



Ushering in a New Era

Argonne National Laboratory's
Aurora System

April 2015



ANL Selects Intel for World's Biggest Supercomputer

2-system CORAL award extends IA leadership in extreme scale HPC



Cori
NERSC‡
>30PF

April '14

Trinity
NNSA†
>40PF

July '14

Aurora
Argonne National Laboratory
>180PF

April '15

+

Theta
Argonne National Laboratory
>8.5PF

>\$200M

‡ Cray* XC* Series at National Energy Research Scientific Computing Center (NERSC).
† Cray XC Series at National Nuclear Security Administration (NNSA).

The Most Advanced Supercomputer Ever Built

An Intel-led collaboration with ANL and Cray to accelerate discovery & innovation



Prime Contractor



Subcontractor

>180 PFLOPS

(option to increase up to 450 PF)

>50,000 nodes

13MW

2018 *delivery*

18X higher
performance[†]

>6X more energy
efficient[†]

Source: Argonne National Laboratory and Intel.

[†]Comparison of theoretical peak double precision FLOPS and power consumption to ANL's largest current system, MIRA (10PFs and 4.8MW)



Aurora | *Science From Day One!*

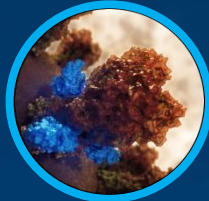
Extreme performance for a broad range of compute and data-centric workloads

Transportation



Aerodynamics

Biological Science



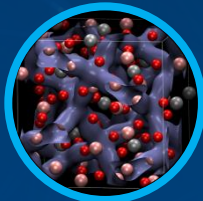
Biofuels / Disease Control

Renewable Energy



Wind Turbine Design / Placement

Materials Science



Batteries / Solar Panels

Computer Science



Co-array
Fortran

New Programming Models

Training

Argonne Training
Program on Extreme-
Scale Computing

Public Access

US Industry
and International

Focus Areas

Aurora | Built on a Powerful Foundation

Breakthrough technologies that deliver massive benefits

Compute

Interconnect

File System

3rd Generation
Intel® Xeon Phi™



>17X performance[†]

FLOPS per node

>12X memory bandwidth[†]

>30PB/s aggregate
in-package memory bandwidth

**Integrated Intel® Omni-Path
Architecture**

Processor code name: Knights Hill

2nd Generation
Intel® Omni-Path
Architecture

>20X faster[†]

>500 TB/s bi-section bandwidth

>2.5 PB/s aggregate node link
bandwidth

Intel® Lustre*
Software

>3X faster[†]

>1 TB/s file system throughput

>5X capacity[†]

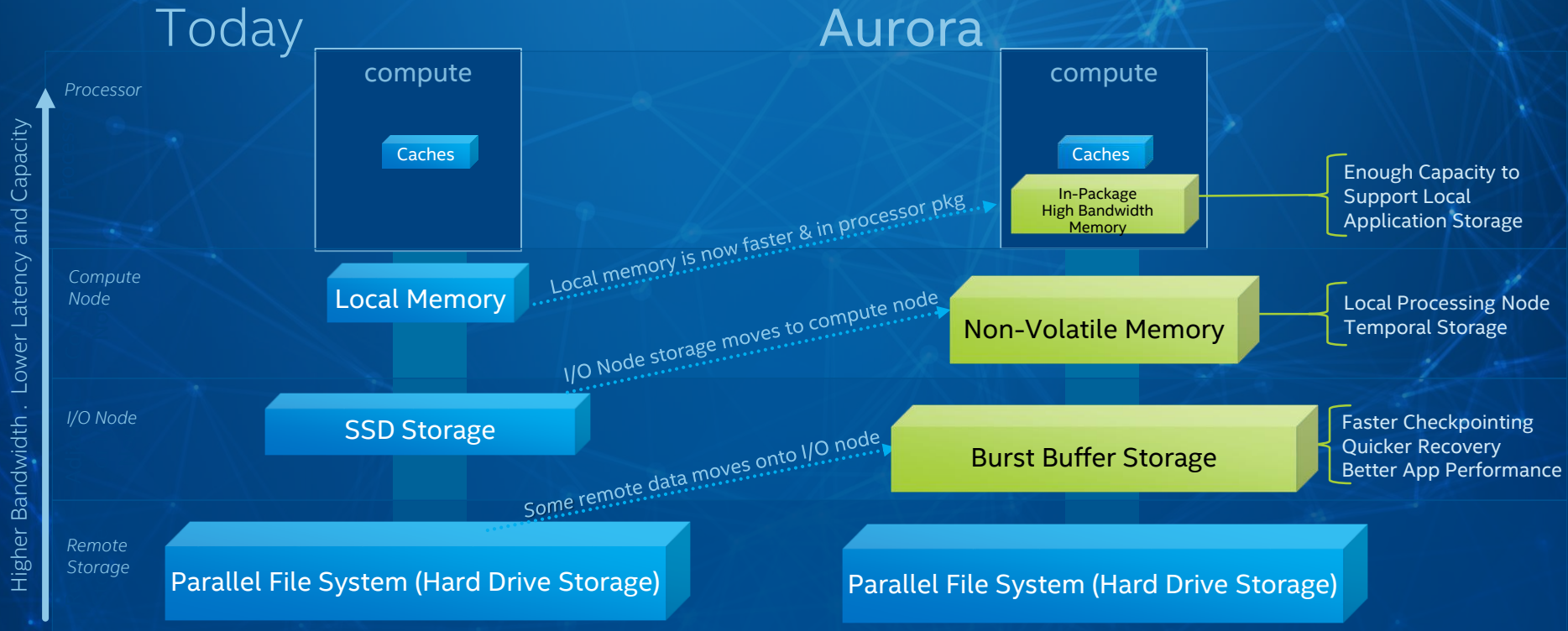
>150TB file system capacity

Source: Argonne National Laboratory and Intel.

[†]Comparison to ANL's largest current system, MIRA. See the Aurora Fact Sheet for further details.

Aurora | Uses New Intel Memory-Storage Hierarchy

Keeping data closer to compute → better data-intensive app performance and energy efficiency



Cray: A Strategic Subcontracting Role

Working with Intel to create a state of the art system



Cray assists Intel by providing:

- **Next-generation “Shasta” supercomputer**
using new technologies from Intel and Cray
- **Scalable software stack**
with new capabilities from Intel and Cray
- **Proven system manufacturing capability**
- **On-site system support**

“Cray is honored and proud to be a part of this partnership with Argonne and Intel to build and deliver one of the world’s most innovative supercomputers”

– Peter Ungaro

President and Chief Executive
Officer, Cray

Compute

Store

Analyze

Implications Beyond Aurora...*HPC is Entering New Era*

Current and future Intel innovations aim at overcoming architectural challenges



Breaking Down "The Walls"

.....

Memory | I/O | Storage
Energy Efficient Performance
Space | Resiliency |
Unoptimized Software



Fast and Efficient Data Mobility

.....

Rapidly Growing
Big Data Analytics



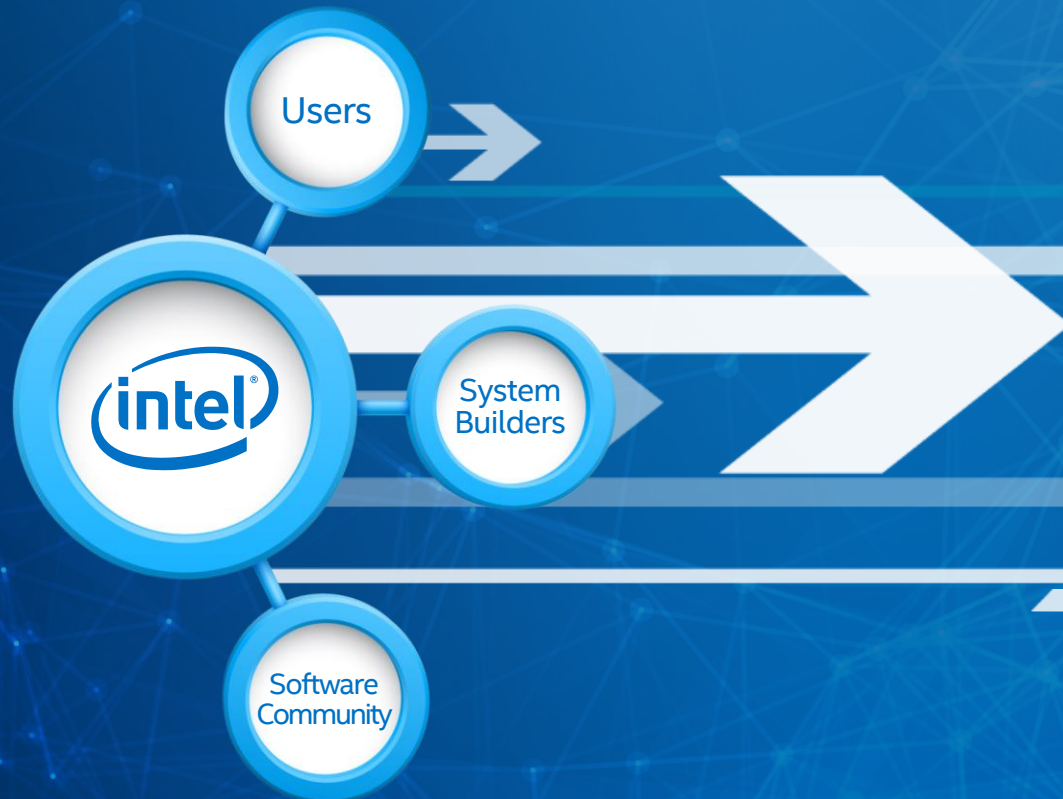
Extending HPC's Reach

.....

Democratization at Every Scale
Cloud Access | Exploration of New
Parallel Programming Models

Intel-led Collaboration: Unprecedented Breakthroughs

Brings innovations, holistic designs, and the means to deliver the full benefits to users



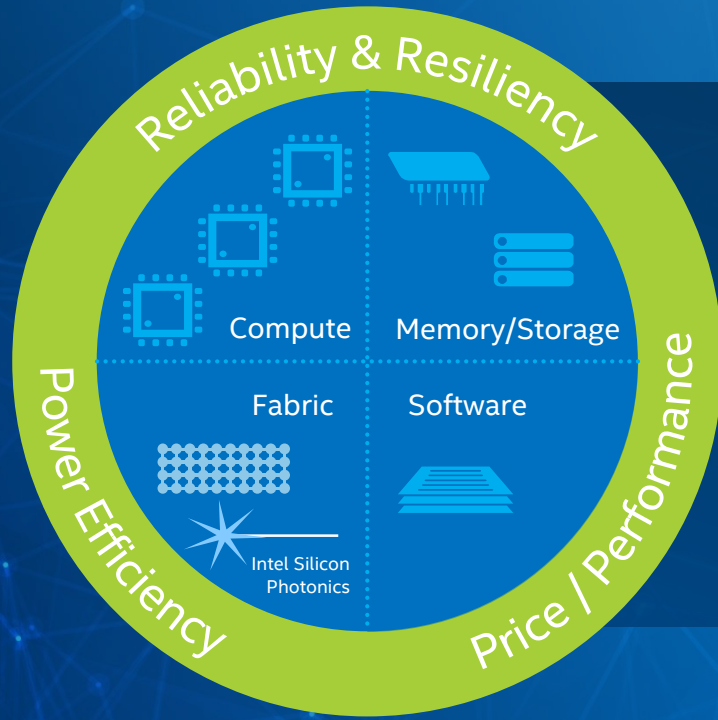
Expanding portfolio of game changing **technologies** in a **scalable system design framework**

Co-design approach that optimizes for overall workload performance, efficiency and reliability

Thriving, open, enabled, and innovating **ecosystem**

Intel's HPC Scalable System Framework

A design foundation enabling wide range of highly workload-optimized solutions



Aurora

Small clusters through Supercomputers

Compute and Data-Centric Computing

Standards-Based Programmability

Intel® Xeon® Processors
Intel® Xeon Phi™ Coprocessors
Intel® Xeon Phi™ Processors

Intel® True Scale Fabric
Intel® Omni-Path Architecture
Intel® Ethernet

Intel® SSDs
Intel® Lustre-based Solutions
Intel® Silicon Photonics Technology

Intel® Software Tools
Intel® Cluster Ready Program

Aurora.....

It's one more landmark.

It's the next one we have to reach.

But the journey does not stop there.



Legal Disclaimers

All information provided here is subject to change without notice. Contact your Intel representative to obtain the latest Intel product specifications and roadmaps.

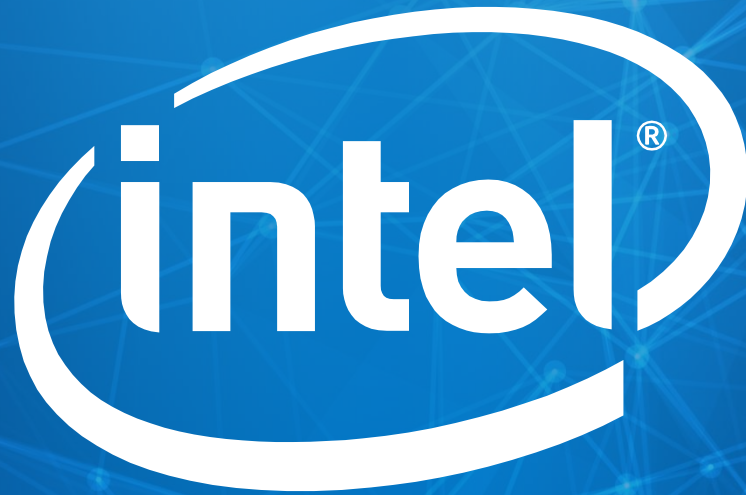
Results have been estimated or simulated using internal Intel analysis or architecture simulation or modeling, and provided to you for informational purposes. Any differences in your system hardware, software or configuration may affect your actual performance.

Intel technologies' features and benefits depend on system configuration and may require enabled hardware, software or service activation. Performance varies depending on system configuration. No computer system can be absolutely secure. Check with your system manufacturer or retailer or learn more at <https://www-ssl.intel.com/content/www/us/en/high-performance-computing/path-to-aurora.html>.

Intel, the Intel logo, Xeon, Intel Xeon Phi and Intel Inside are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States or other countries.

*Other names and brands may be claimed as the property of others.

© 2015 Intel Corporation



Aurora FactSheet

System Feature	AURORA	MIRA (Argonne)
Peak System Performance	180 - 450 PetaFLOP/s	10 PetaFLOP/s
Processor	Future Generation Intel® Xeon Phi™ Processor (Code name: Knights Hill)	IBM* PowerPC* A2 1600 MHz processor
Number of Nodes	>50,000	49,152
Compute Platform	Intel system based on Cray* Shasta next generation supercomputing platform	IBM Blue Gene/Q*
Aggregate High Bandwidth On-Package Memory, local Memory and Persistent Memory	>7,000 Terabytes	768 Terabytes
Aggregate High Bandwidth On-Package Memory Bandwidth	>30 Petabytes/s	2.5 Petabytes/s
System Interconnect	2 nd Generation Intel® Omni-Path Architecture with silicon photonics	IBM 5D torus interconnect with VCSEL photonics
Interconnect Aggregate Node Link Bandwidth	>2.5 Petabytes/s	2 Petabytes/s
Interconnect Bisection Bandwidth	>500 Terabytes/s	24 Terabytes/s
Interconnect Interface	Integrated	Integrated
Burst Buffer Storage	Intel® SSDs, using both 1 st and 2 nd Generation Intel® Omni-Path Architecture	None
File System	Intel® Lustre* File System	IBM GPFS* File System
File System Capacity	>150 Petabytes	26 Petabytes
File System Throughput	>1 Terabyte/s	300 Gigabyte/s
Intel Architecture (Intel® 64) Compatibility	Yes	No
Peak Power Consumption	13 Megawatts	4.8 Megawatts
FLOP/s Per Watt	>13 GigaFLOP/s per watt	>2 GigaFLOP/s per watt
Delivery Timeline	2018	2012
Facility Area for Compute Clusters	~3,000 sq. ft.	~1,536 sq. ft.

*Other names and brands may be claimed as the property of others

Aurora's High Performance Software Stack

System and Infrastructure: focused on scalability and reliability

- Low-jitter, high scalability Linux environment
- Integrated RAS and system management, with centralized system database
- Lustre* & distributed file system with efficient user-space I/O offload
- Resource management: Cobalt

Communication: optimized for high performance and scalability

- Multiple MPI options: MPICH3, Intel® MPI, Cray MPI

Standards-based Development Environment:

- Compilers: Intel, Cray, and GNU
- Languages: C, C++, Fortran, Coarray Fortran, UPC, Chapel
- Programming Models: MPI, OpenMP*, SHMEM

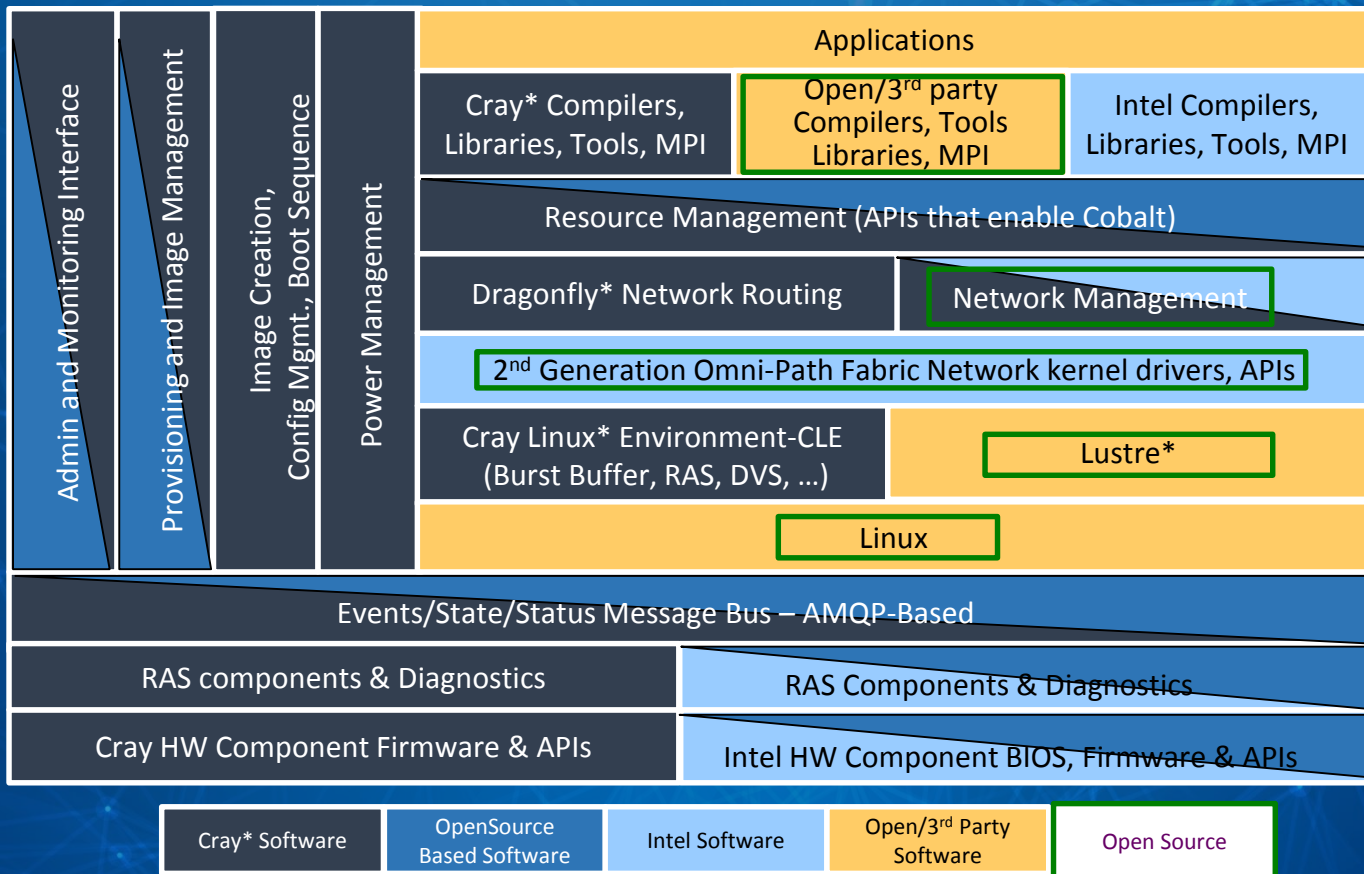
Performance libraries:

- Intel® Math Kernel Library
- Cray Scientific & Math Libraries
- BLAS, ScaLAPACK, FFTW, PETSc, Trilinos

Application analysis tools:

- Intel® Parallel Studio XE
- Cray Performance Analysis Suite
- GDB, Open|SpeedShop, TAU, HPCToolkit, VampirTrace, and Darshan

Aurora's High Performance Software Stack



Theta System Fact Sheet

System Feature	Theta Details
Peak System Performance	>8.5 PetaFLOP/s
Compute Node CPU	Next Generation Intel® Xeon Phi™ processors (Code name: Knights Landing) https://software.intel.com/en-us/articles/what-disclosures-has-intel-made-about-knights-landing
Compute Node Count	>2,500
Compute Platform	Intel system based on Cray* XC* supercomputing platform
Compute Node Peak Performance	>3 TeraFLOP/s per compute node
Cores Per Node	>60 cores with four hardware threads per core
High Bandwidth On-Package Memory	Up to 16 Gigabytes per compute node
High Bandwidth On-Package Memory Bandwidth	projected to be 5X the bandwidth of DDR4 DRAM memory, >400 Gigabytes/sec
DDR4 Memory	192 Gigabytes using 6 channels per compute node
Lustre* File System	10 Petabytes
Lustre* File System throughput	210 Gigabytes/s
System Interconnect	Cray Aries* high speed Dragonfly* topology interconnect
Peak Power Consumption	1.7 Megawatts
Delivery Timeline	Mid-2016
Programming Environments	Intel, Cray, and GNU
Programming models	MPI + OpenMP

Legal Disclaimers

All information provided here is subject to change without notice. Contact your Intel representative to obtain the latest Intel product specifications and roadmaps.

Results have been estimated or simulated using internal Intel analysis or architecture simulation or modeling, and provided to you for informational purposes. Any differences in your system hardware, software or configuration may affect your actual performance.

Intel technologies' features and benefits depend on system configuration and may require enabled hardware, software or service activation. Performance varies depending on system configuration. No computer system can be absolutely secure. Check with your system manufacturer or retailer or learn more at <https://www-ssl.intel.com/content/www/us/en/high-performance-computing/path-to-aurora.html>.

Intel, the Intel logo, Xeon, Intel Xeon Phi and Intel Inside are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States or other countries.

*Other names and brands may be claimed as the property of others.

© 2015 Intel Corporation