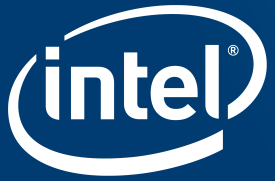
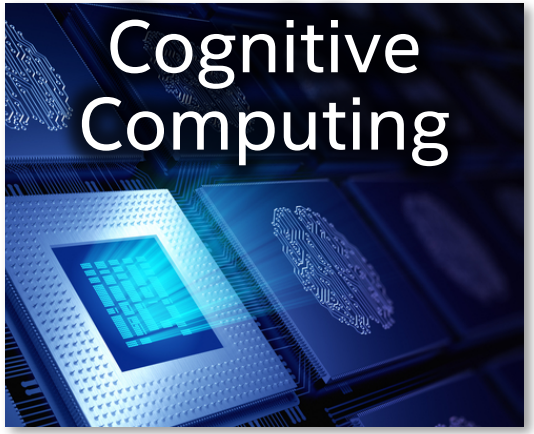


High Performance, High Fidelity, or Lower Cost Visualization – Pick ~~ONE~~ THREE!

Jim Jeffers
Principal Engineer, Manager
SW Defined Visualization
Intel Corporation

HPC is Foundational to Insight



Advancing Science

And Our Understanding of the Universe

High ROI: $515

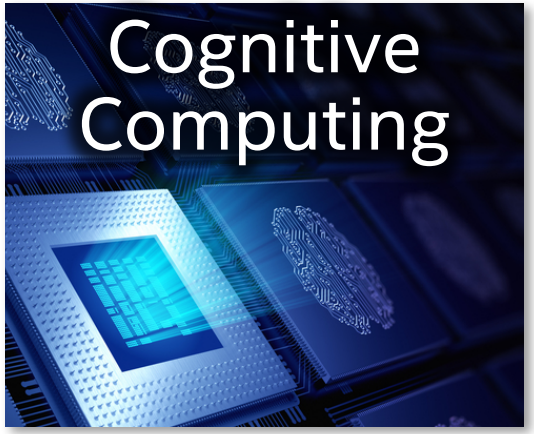
Average Return Per $1 of HPC Investment[1]

Machine Learning

Joins Computational Learning Theory with HPC

[1]Source: IDC HPC and ROI Study Update (September 2015)

HPC is Foundational to Insight



Visualization is often the key!

And Our Understanding of the Universe

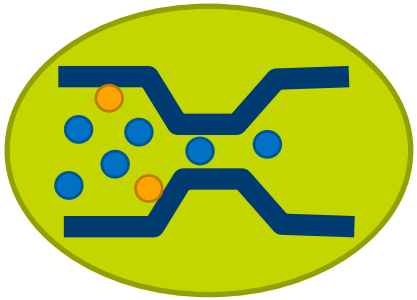
Average Return Per $1 of HPC Investment[1]

Joins Computational Learning Theory with HPC

[1]Source: IDC HPC and ROI Study Update (September 2015)

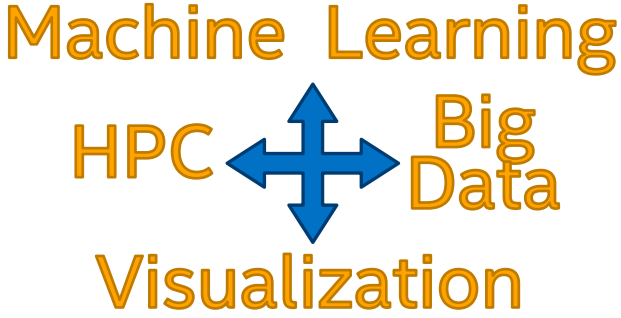
Growing Challenges in HPC

System Bottlenecks
"The Walls"



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

Divergent Workloads



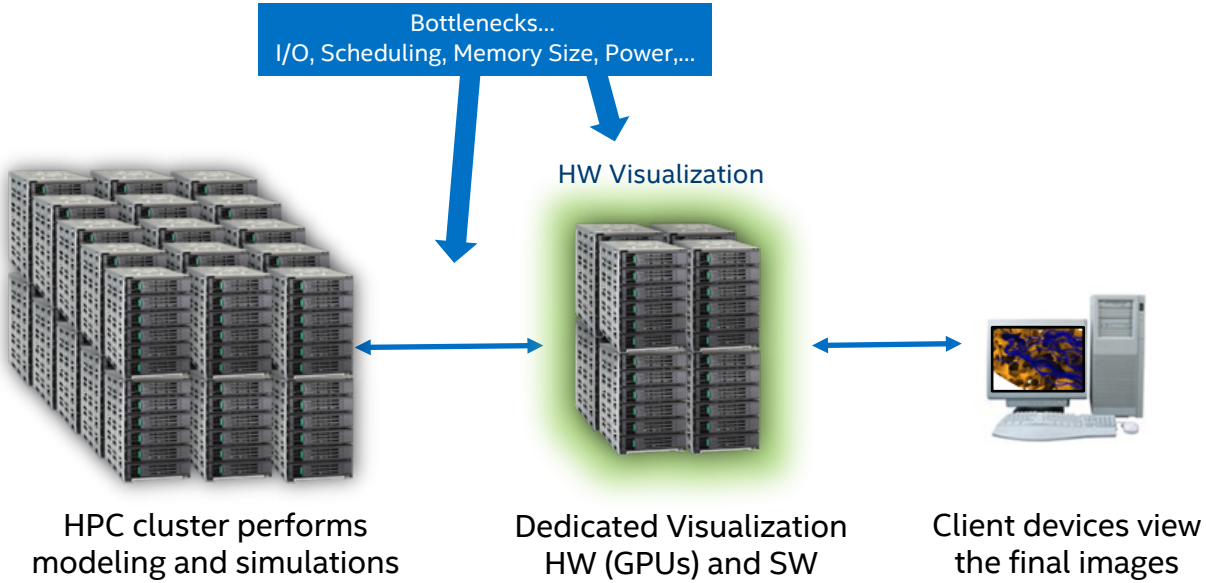
Resources Split Among Modeling and Simulation | Big Data Analytics | Machine Learning | Visualization

Barriers to Extending Usage

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

Challenges for '*Traditional*' Large Scale Visualization

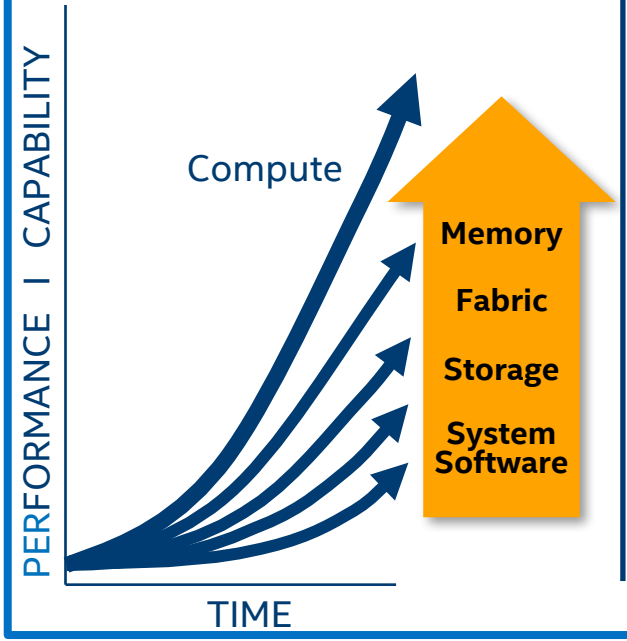
Using Dedicated hardware and specialized software



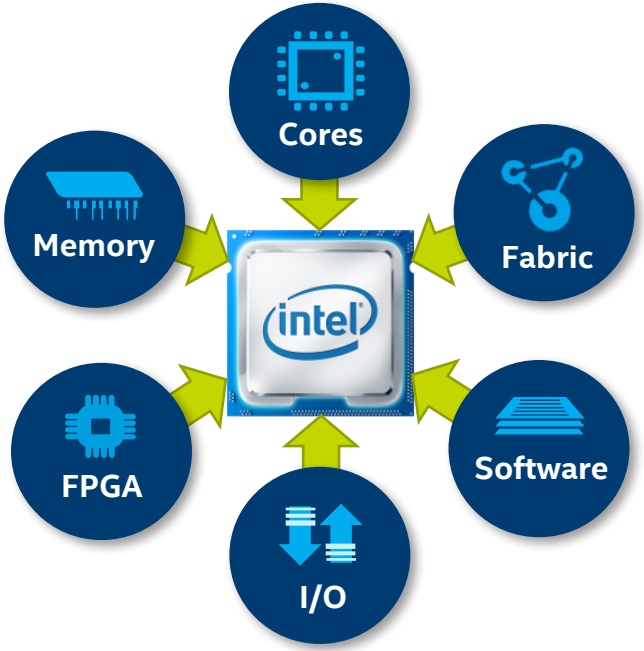
A Holistic Architectural Approach is Required

System

Innovative Technologies



Tight Integration



Software

Modernized Code

Intel® Scalable System Framework

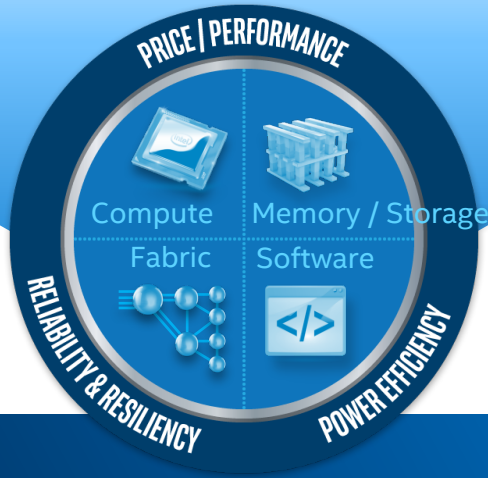
Modeling & Simulation

HPC Data Analytics

Machine Learning

Visualization

Many Workloads – one Framework

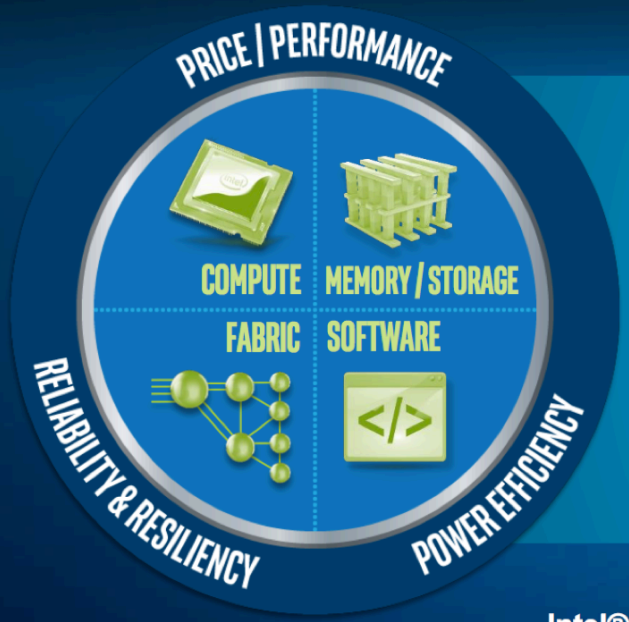


A Flexible Framework for Today & Tomorrow

Enabling Breakthrough System Performance

Intel® Scalable System Framework

A Holistic Solution for All HPC Needs



Small Clusters Through Peta and Exascale

Compute and Data-Centric Computing

Standards-Based Programmability

IA and HPC Ecosystem Enabling

On-Premise and Cloud-Based

Intel® Xeon® Processors
Intel® Xeon Phi™ Processors
Intel® FPGAs and Server Solutions

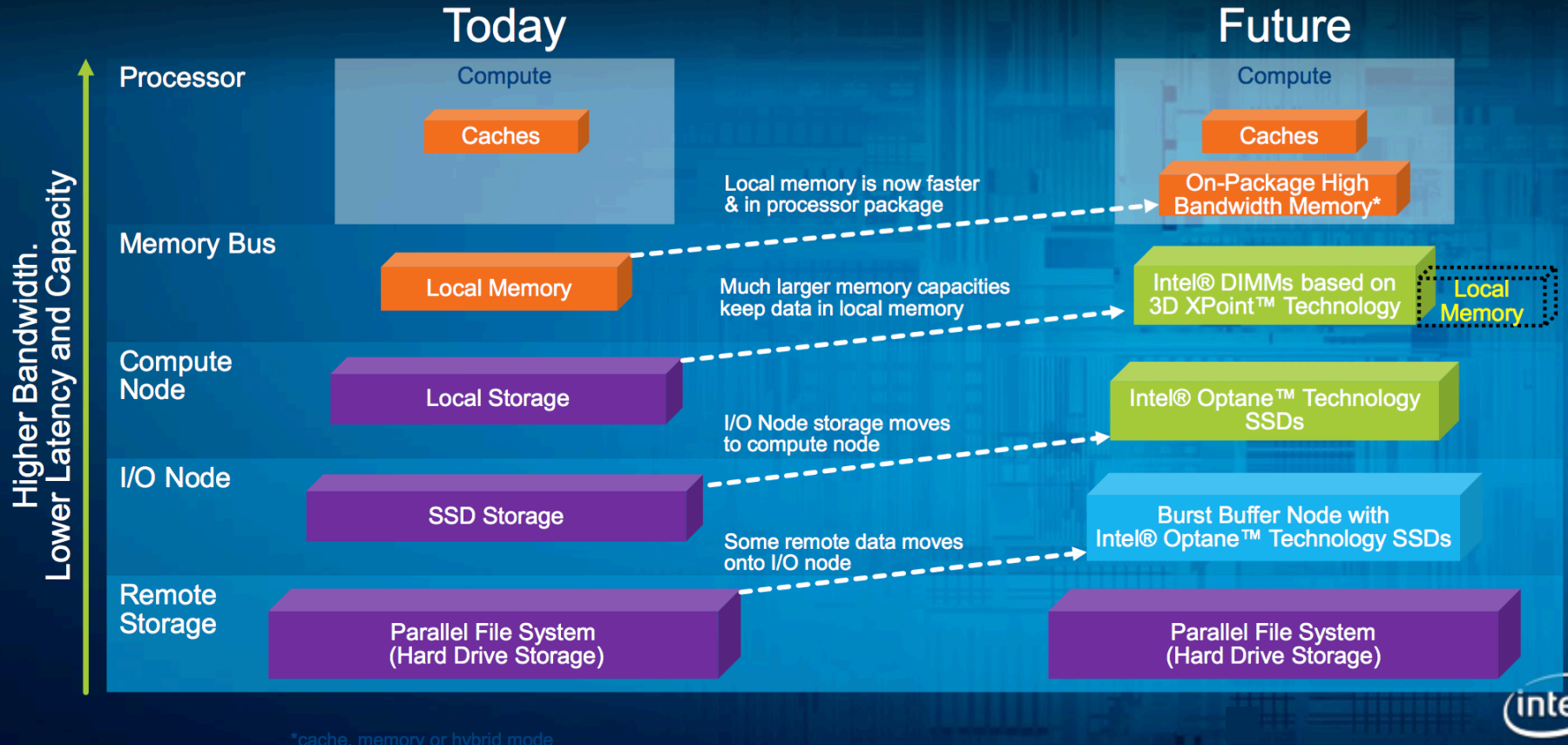
Intel® Solutions for Lustre*
Intel® Optane™ Technology
3D XPoint™ Technology
Intel® SSDs

Intel® Omni-Path Architecture
Intel® Silicon Photonics
Intel® Ethernet

Intel® HPC Orchestrator
Intel® Software Tools
Intel® Cluster Ready Program
Intel Supported SDVis

Tighter System-Level Integration

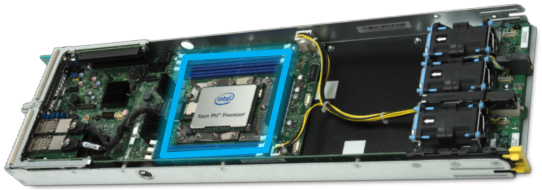
Innovative Memory-Storage Hierarchy



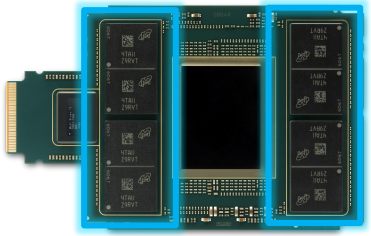
*cache, memory or hybrid mode

Intel® Xeon Phi™ Processors

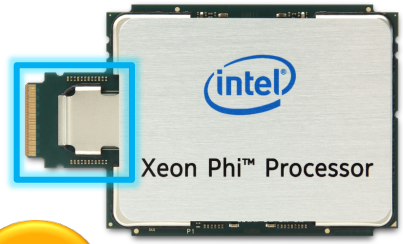
Your path to deeper insight (64, 68, 72 cores – AVX-512 SIMD)



1st **Bootable, Host CPU for Highly-Parallel Workloads***



1st **Integrated Memory***



1st **Integrated Fabric***

Leadership Performance[1] vs. GPU Accel

- Up to **5x** Performance[1]
- Up to **8x** Performance/Watt[1]
- Up to **9x** Performance/USD$[1]

...with all the benefits of a CPU

- ✓ Run x86 Workloads
- ✓ Programmability
- ✓ Power Efficient
- ✓ No PCIe* Bottleneck
- ✓ Large Memory Footprint
- ✓ Scalability & Future-Ready

* Claims of 1st integrated fabric; bootable, host CPU for highly-parallel workloads; and integrated memory refer to Intel ® Xeon® processors.
1. For comparison and configuration details see slide 12. Results based on Intel estimates.

Intel® Xeon Phi™ Processor Configurations

Results based on Intel estimates. Configurations:

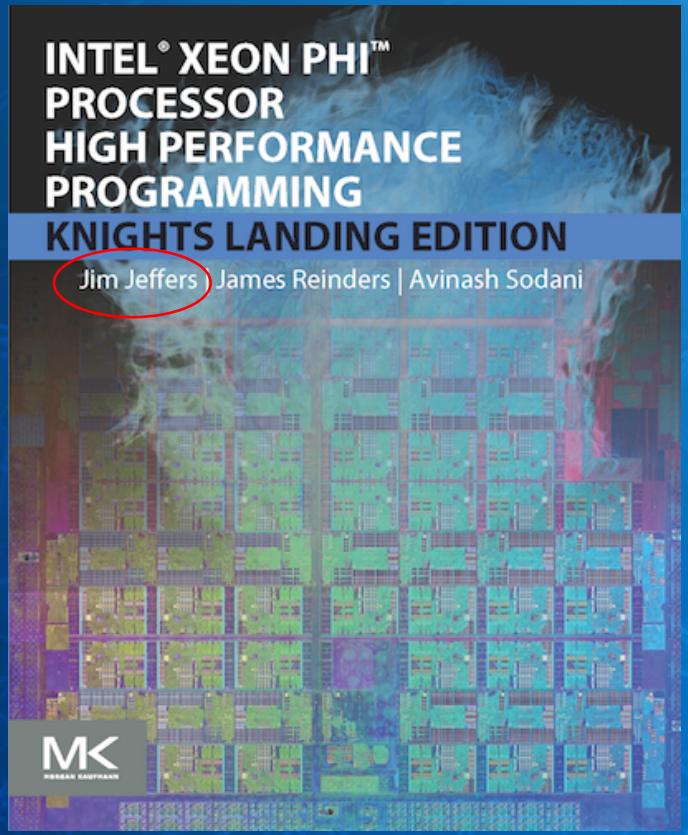
1. Intel measured results as of June 2016. Up to 5x more timesteps per second, 8x higher performance per watt and 9x better performance per dollar claims based on LAMMPS* Course-Grain Water Simulation using Stillinger- Weber* potential comparison of the following:

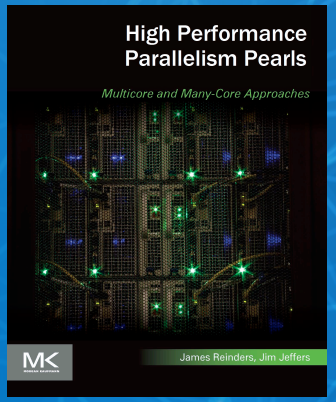
   BASELINE CONFIGURATION: Dual Socket Intel® Xeon® processor E5-2697 v4 (45 M Cache, 2.3 GHz, 18 Cores) with Intel® Hyper-Threading and Turbo Boost Technologies enabled, 128 GB DDR4-2400 MHz memory, Red Hat Enterprise Linux* 6.7 (Santiago), Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe* x16, Intel® Server Board S2600WT2R, BMC 1.33.9832, FRU/SDR Package 1.09, 1.0 TB SATA drive WD1003FZEX-00MK2A0 System Disk + one NVIDIA Tesla* K80 GPUs, NVIDIA CUDA* 7.5.17 (Driver: 352.39), ECC enabled, persistence mode enabled. Number of MPI tasks on host varied to give best performance. CUDA MPS* used where possible. Mean Benchmark System Power Consumption: 683W. Estimated list price including host: $13,750 source http://www.colfax-intl.com/ND/Servers/CX1350s-XK6.aspx.

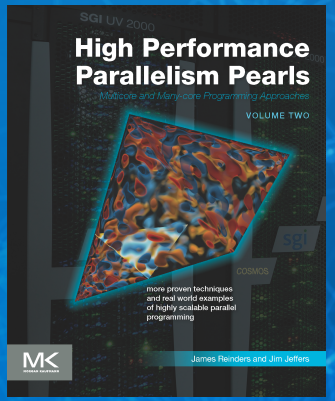
   NEW CONFIGURATION: One node Intel Xeon Phi processor 7250 (16 GB, 1.4 GHz, 68 Cores) in Intel® Server System LADMP2312KXXX41, 96GB DDR4-2400 MHz, quad cluster mode, MCDRAM flat memory mode, Red Hat Enterprise Linux* 6.7 (Santiago) running Intel® Compiler 16.0.2, Intel® MPI 5.1.2.150, Optimization Flags: "-O2 -fp-model fast=2 -no-prec-div -qoverride-limits", Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, 1.0 TB SATA drive WD1003FZEX-00MK2A0 System Disk. Mean Benchmark System Power Consumption: 378W. Estimated list price: $7300 source Intel Recommended Customer Pricing (RCP).

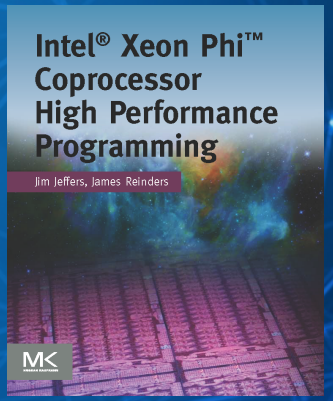
Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks

Shameless Plug!







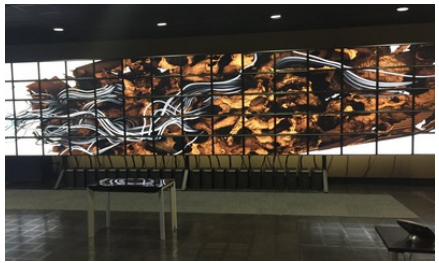


*Other names and brands may be claimed as the property of others.

So What About Visualization?

Our Vision: Scalable, Flexible Vis Rendering that Runs Anywhere!

Standalone Laptops or Workstations



Big Memory Nodes or Rendering Focused Clusters

Large Compute+Vis clusters with
Local or Remote Clients

How?

Intel® SSF and Intel-Supported Software Defined Visualization (SDVis)!

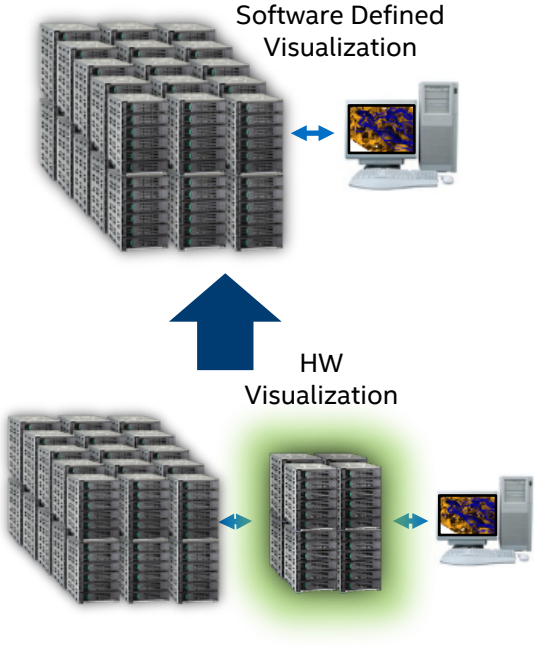
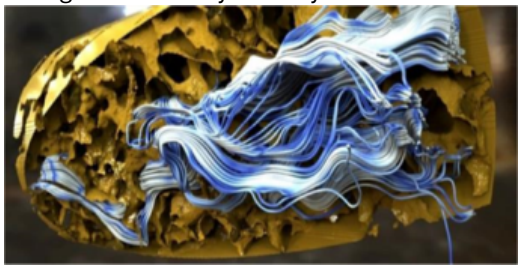
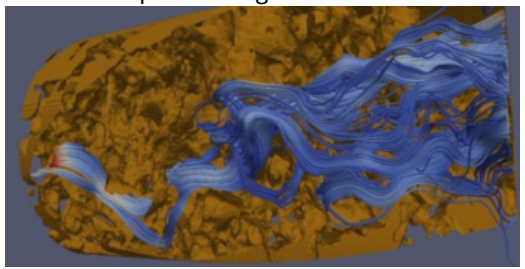


Image Rendered by OSPRay



Standard OpenGL Image



Embree

- CPU Optimized Ray Tracing Algorithms
- 'Tool kit' for Building Ray Tracings Apps
- Broadly Adopted by 3rd Party ISVs
- More at http://embree.github.io

OSPRay

- Rendering Engine Based on Embree
- API Designed to Ease Creation of Visualization Software
- More at http://ospray.org

OpenSWR

- High Performance CPU Vis Rasterization
- Fully Integrated into MESA v12.0+
- Supports ParaView, Visit, VTK, EnSight, VL3
- More at http://mesa3d.org

Addressing Large-scale, High Performance, and High Fidelity Visualization with SDVis

Gain deeper understanding of data impacting science & discovery

High fidelity, more realistic images even as data sets become increasingly larger, and more complex; no need to compromise data resolution

Solve computing + modeling problem together (in-situ vis)

Essential SW development suite that makes concurrent simulation and visualization efficient – users can work interactively and get results quicker

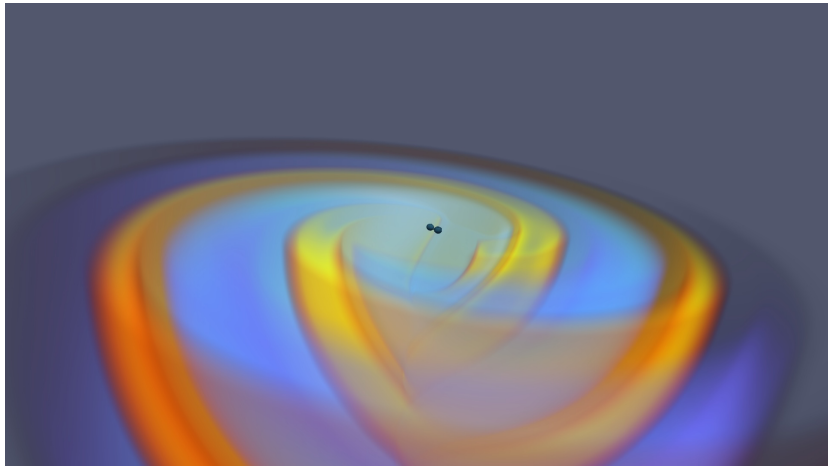
One system

Use same system for both simulation and visualization, avoid data transfer delays and memory size constraints – faster insights for solving toughest problems

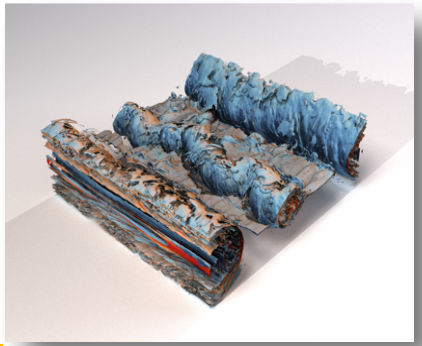
Benefits of SDVis

- Open-sourced technology delivering vivid visualization of complex, enormous data sets
- Innovative software libraries for visualizing results with *high performance* by unlocking the parallelism already in your system
- *High-fidelity* images for gaining deeper insights in science and industry, faster
- Software Only solution *lowers costs* – no card cost, no card maintenance, lower power bills

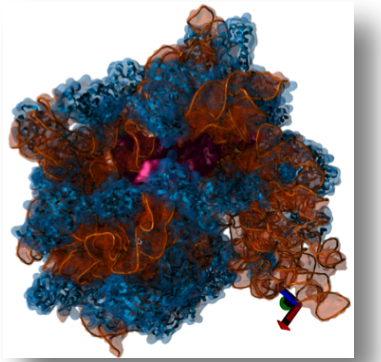
Your Work. No Compromises.



Gravational Waves : GR-Chombo AMR Data, Stephen Hawking CTC, UCambridge; Queens College, London; visualization, Carson Brownlee, Intel, ParaView)



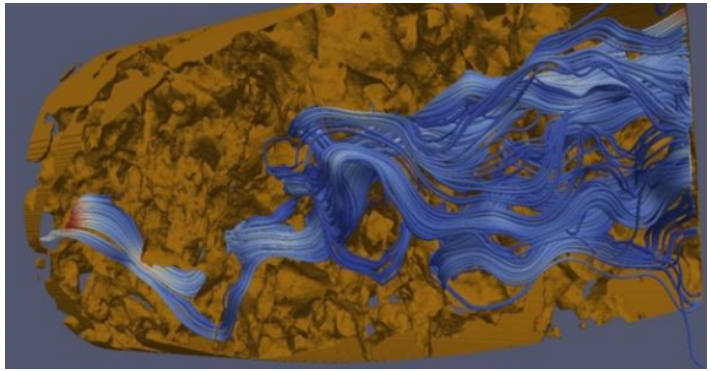
Magnetic Reconnection Model, Courtesy Bill Duaghton(LANL) and Berc Geveci(Kitware)

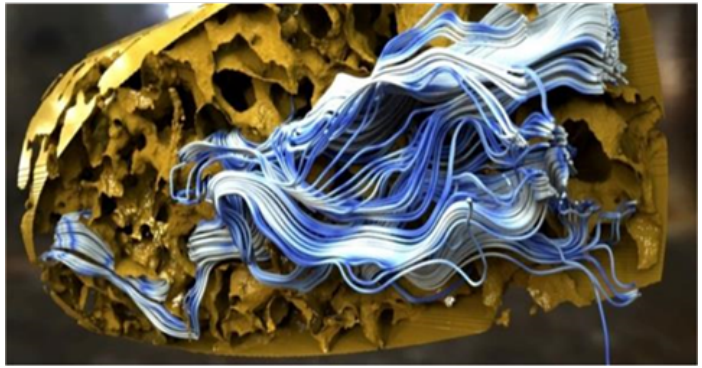


Ribosome: Data: Max-Planck Institute for Biophysical Chemistry

Hi-Fidelity Visualization with...

- ... scalable image quality
- ... scalable model size
- ... scalable in rendering cost





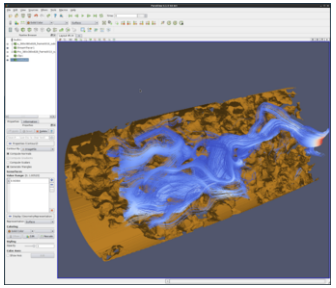
Data set provided by Florida International University

OpenSWR Software Rasterizer

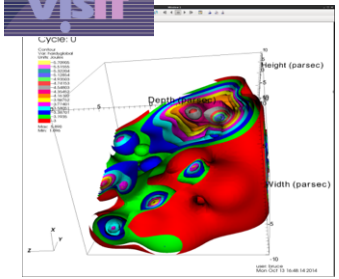
(www.mesa3d.org
www.openswr.org)

- High performance open source software implementation of OpenGL* rasterizer
  - Fully multi-threaded and vectorized for Intel® processors
  - Can access full system memory - highest resolution data
  - Leverages community development effort (MESA)
- Drop in replacement for OpenGL library
- Available since July'16 in Mesa v12.0+ targeting features and performance for leading SciVis Apps

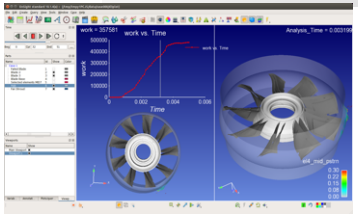
ParaView



VISIT



CEI EnSight Extreme Visualization Software



Argonne NATIONAL LABORATORY VL3

Ray Tracing Foundation: Embree Ray Tracing Kernel Library

Provides highly optimized and scalable ray tracing kernels

- Acceleration structure build and ray traversal
- Single Ray, Ray Packets(4,8,16), Ray Streams(N)

Targets up to photorealistic professional and scientific rendering applications

Highest ray tracing performance on CPUs

- 1.5–6× speedup reported by users

Support for latest CPUs / ISAs

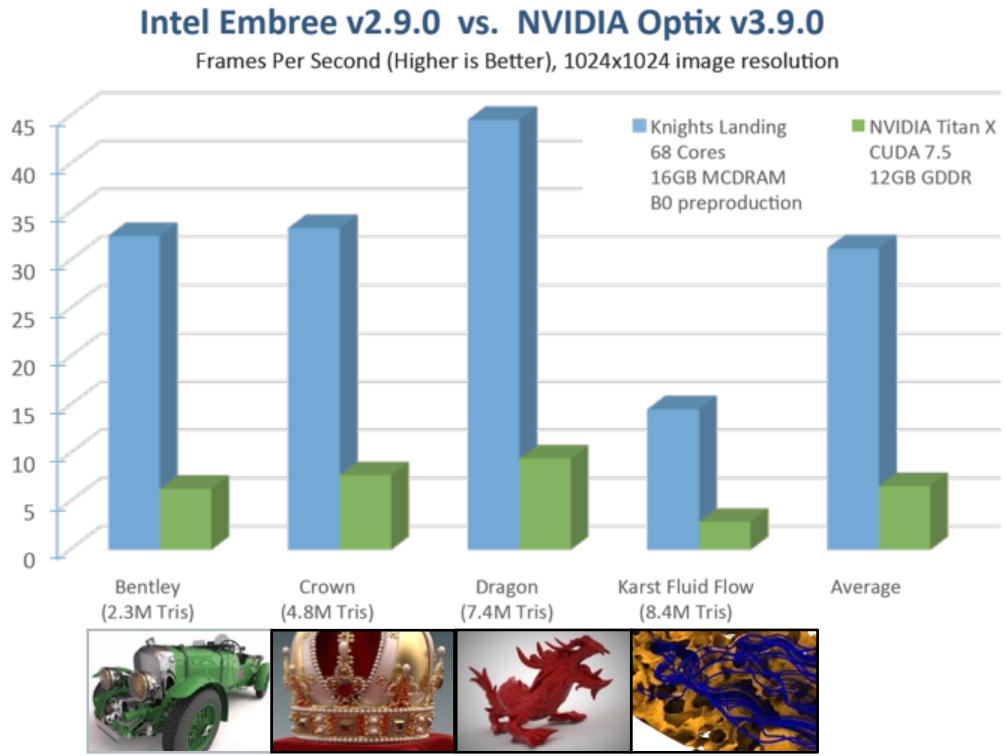
- Intel® Xeon Phi™ Processor (codenamed *Knights Landing*) – AVX-512

API for easy integration into applications

Free and open source under Apache 2.0 license

- http://embree.github.com

High Performance:
Embree (Knights Landing) v. NVIDIA* OptiX* (Titan X)



Embree 2.9.0, Intel® SPMD Program Compiler (Intel® SPC) 1.9.0
Intel C/C++ Compiler 16.0.1
Intel® Xeon Phi™ Processor Preproduction

NVIDIA* OptiX* 3.9.0, CUDA* 7.5
Intel Xeon E5-2699 2x18 cores, 2.3 Ghz
NVIDIA Titan X (Maxwell)

Source: Used with permission from the book "Intel® Xeon Phi™ Processor – Knights Landing Edition" – Jeffers, Reinders, Sodani, Morgan Kaufman (2016)

OSPRay: A Ray-Tracing based Rendering Engine for *High-Fidelity* Visualization

- Build on top of Embree; Launched June 2016
- Scalable Visualization targeted features
  - Surfaces (both polygonal and non-polygonal)
  - Volumes, and volume rendering
  - *High-Fidelity* rendering/shading methods
  - Scalable Cluster Wide Rendering
- Packed it up in an 'easy-to-use' rendering library for visualization
  - Same "spirit" as OpenGL, but different API

OSPRay: A Ray-Tracing based Rendering Engine for High-Fidelity Visualization

"Deep Dive" OSPRay talk

by *Ingo Wald, Intel SDVIs Tech Lead and Architect*

Aaron Knoll, Vis Researcher, SCI @ Univ. of Utah

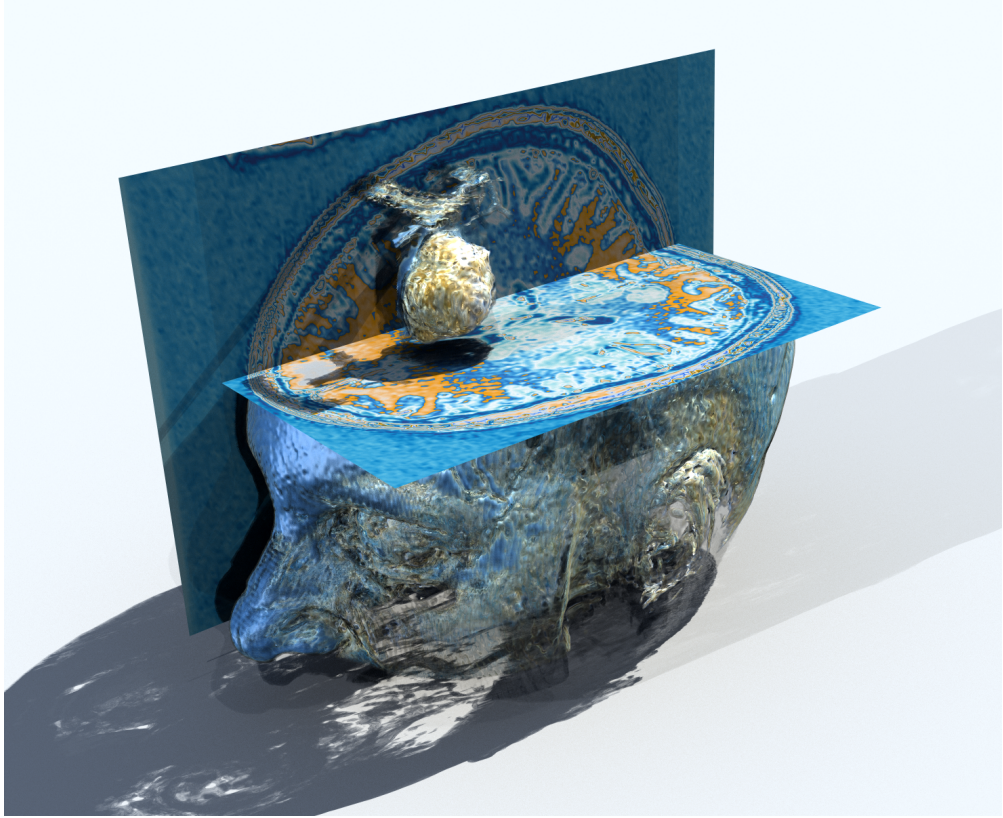
Thursday 8:30 AM – Key 1+2+5 – SciVis Rendering Papers

Some SDVis Examples

SC'16 Sneak Peak – ParaView v5.2 with integrated OSPRay and OpenSWR

- Brain Tumor monitoring and treatment
- 3D interactive @ 10-20fps
- Intel® Xeon Phi™ processor cluster
- Ambient occlusion plus shadows
- Stop by the Intel SC'16 booth to see it live!

- Data courtesy Kitware. Visualization, Carson Brownlee, Intel



NASA – Custom OSPRay App

- Rendered on Pleiades supercomputer attached Vis wall cluster

dataset: parachute; simulation: Dr M. Barad, NASA Ames; visualization: Tim Sandstrom, NASA Ames

Stephen Hawking Centre for Theoretical Cosmology – ParaView / VTK with OSPRay

- 600 GB Memory Footprint
- 36 TB Simulation Data Set
- 4 Intel® Xeon Phi™ 7230 Processors
- 1 Intel® Xeon® E5 v4 Dual Socket node
- Intel® Omni-Path Fabric
- ~10 fps

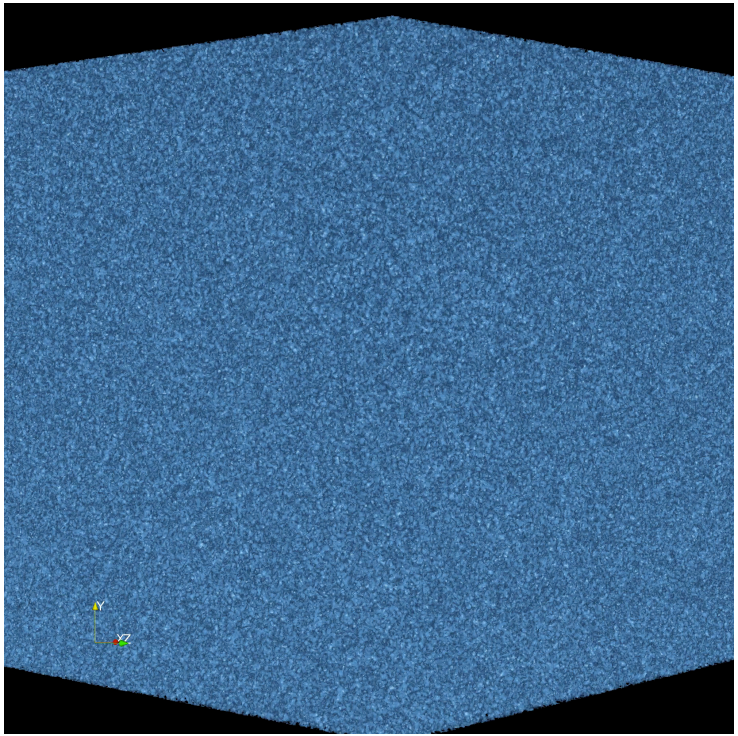
Gravational Waves : GR-Chombo AMR Data, Stephen Hawking CTC, UCambridge; Queens College, London; visualization, Carson Brownlee, Intel)

Stephen Hawking Centre for Theoretical Cosmology – ‘Walls’ in situ with OSPRay Rendering

- 10 TB Memory Footprint
- SGI UV-300 16TB SMP
- >1000 Shared memory Intel® Xeon® E5 v3 processors
- ~15 fps

- Domain Wall formation in the universe from Big Bang to today (13.8 billion years)

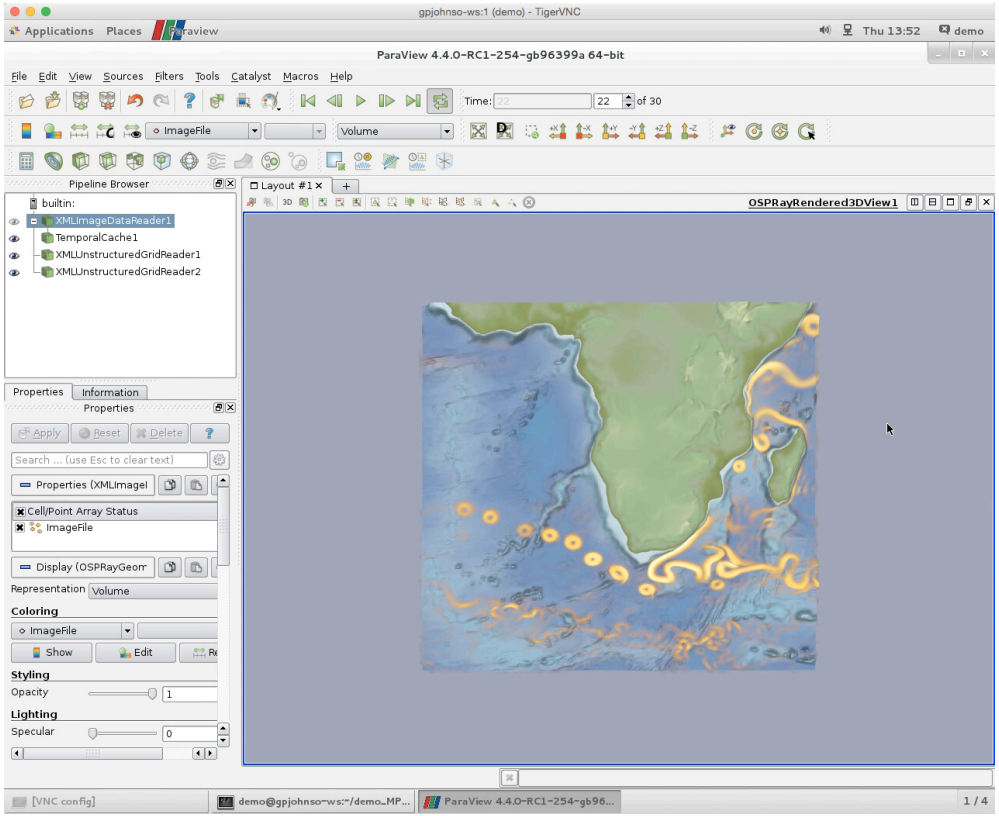
- Simulation code by Shellard et al, Visualizaiton by Johannes Gunther (Intel)



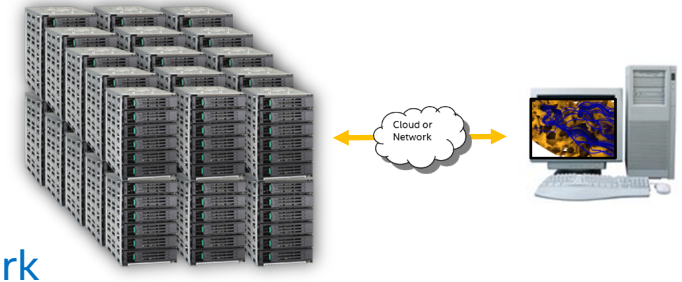
Los Alamos National Lab and Texas Advanced Computing Center – Ocean Climate

- ParaView v5.0 w/OSPRay and OpenSWR
- 1.2 TB Memory Footprint
- 8 node Intel® Xeon Phi™ processor pre-prod cluster
- Intel® Omni-Path Fabric
- ~15-20 fps

- Data: MPAS-Ocean/ACME, U.S. Dept. of Energy, Visualization:TACC,, UT-CAT



Summary



Intel® Scalable System Framework:

- A Holistic, Integrated, System Focused Framework
- Addresses ever-growing HPC challenges for data size, flexibility, reliability and maintainability

Software Defined Visualization:

- OpenSWR, OSPRay and Embree rendering libraries using CPUs and main memory
- Integrating into prominent Vis tools, ParaView*, VisIt, EnSight*, VMD, Brayns, ….
- All freely available (Open Source), developed and maintained by Intel

Performance, Fidelity and Lower Cost -> *Pick All Three!*

Want to work with SW Defined Visualization?

Post-doc and Grad Student opportunities at:

- Texas Advanced Computing Center – contact: Paul Navratil
- SCI @ University of Utah – contact: Chris Johnson

Going to SC'16 in Salt Lake?

- Come to the Intel HPC Developer Conference
- SW Defined Visualization Track (Sat. 11/12 PM – Sun 11/13)
- https://hpcdevcon.intel.com/register/devcon.aspx
- Contact: james.L.jeffers@intel.com

THANK YOU!

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